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Zrenjanin, Republic of Serbia

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Industrial Engineering and Environmental Protection

IIZS conference

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IX International Conference – Industrial Engineering And Environmental Protection (IIZS 2019)

Zrenjanin, 3rd-4th October 2019.

University of Novi Sad
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INTRODUCTION

Departments of Mechanical engineering, Department of Industrial engineering in exploitation of oil and gas and Department of Environmental protection of Technical Faculty "Mihajlo Pupin", Zrenjanin, has organized the IX International Conference «Industrial Engineering and Environmental Protection – IIZS 2019».

The theme of scientific conference «IIZS 2019», covers the fields of Industrial engineering and Environmental protection, which are defined in the program of the conference, such as: Mechanical engineering, Energetics and process technique, Designing and maintenance, Oil and gas engineering, Health and environmental protection, Environmental management, Occupational safety.

The main goals of the conference are: innovation and expansion of knowledge engineers in industry and environmental protection; support to researchers in presenting the actual results of research projects, establishing new contacts with leading national and international institutions and universities; popularization of the faculty and its leading role in our society and the immediate environment, in order to attract quality young population for studying at our faculty, cooperation with other organizations, public companies and industry; initiative for collecting ideas in solving specific practical problems; interconnection and business contacts; introducing professional and business organizations with results of scientific and technical research; presentation of scientific knowledge and exchange of experiences in the field of industrial engineering.

We would like to express our gratitude to the partners of the conference – „Aurel Vlaicu" University of Arad, Faculty of engineering, Arad, Romania; University «St. Kliment Ohridski«, Technical faculty, Bitola, Macedonia; University Politehnica Timisoara, Faculty of engineering, Hunedoara, Romania; University of East Sarajevo, Faculty of mechanical engineering East Sarajevo, B&H, Republic of Srpska; University of Giresun, Faculty of engineering, Giresun, Turkey.

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Additionally, we wish to thank all the authors of papers and participants of the Conference IIZS 2019 in hope that we will continue our cooperation successfully in the future and that each new year will bring better ideas and solutions in these interesting topics.

President of the Organizing Committee
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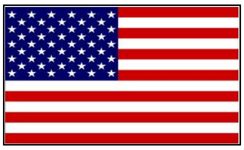
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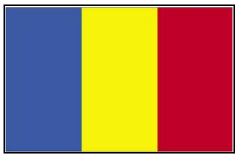
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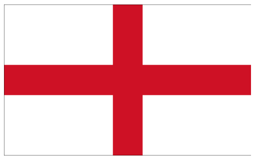
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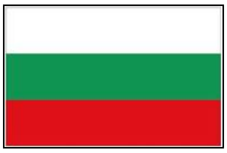
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CONTENTS

PLENARY SESSION

PORTRAIT OF THE INTERREG IPA PROJECT BETWEEN CROATIA AND SERBIA, SENS WETLANDS

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Abstract: The main objective of the SeNs Wetlands Project is to enforce integrated cross-border analytical monitoring of key physicochemical parameters and existing risks, as well as protection of the green environment and biodiversity. The research is performed in cooperation of Faculty of technical sciences, University of Novi Sad, Institute for Nature Conservation of Vojvodina Province, Serbia, Faculty of Electrical Engineering, Computer Science and Information Technology, University of Osijek, and Public Institution for Management of Protected Natural Values of Vukovar-Srijem County, Croatia within the Interreg IPA CBC Croatia-Serbia Project „Active SEnsor monitoring Network and environmental evaluation for protection and wiSe use of WETLANDS and other surface waters“, with acronym SeNs Wetlands, financed by EU realized through 5 work packages in the period of 3 years. The Lake Zobnatica, Serbia and the Wetlands of Tompojevci, Croatia, protected natural areas, are surrounded by agricultural land, and are selected as representative areaels for the research field of the Project SENS Wetlands. Wetlands are aquatic open or semi-closed with complex and diverse biodiversity that are highly sensitive and vulnerable aquatic bodies, due to the agricultural exploitation and communal pollution. The results of pollution analysis provide bases for development of guidelines specified for the growth and maintenance of a protective green belt around the Lake and the Wetlands, which are proven to minimize or eliminate pollutants. The key physicochemical parameters that were followed are pH, air and water temperature, electroconductivity, dissolved oxygen, chemical oxygen demand (COD), biological oxygen demand (BOD_5), total organic carbon (TOC), anions - nitrites ($NO^{2-}_{(aq)}$) and nitrates ($NO^{3-}_{(aq)}$), orthophosphates ($PO_4{}^{3-}{}_{(aq)}$) and ammonium nitrogen cation ($NH_4{}^{+}$-$N_{(aq)}$), total nitrogen and phosphorus, sulphates ($SO_4{}^{2-}{}_{(aq)}$), chlorides ($Cl^{-}{}_{(aq)}$), fluorides ($F^{-}{}_{(aq)}$), total chlorine and cations of metals (nickel (Ni^{2+}(aq)), iron ($Fe^{2/3+}$(aq)), zinc (Zn^{2+} (aq)), chromium (Cr^{6+}(aq)), copper ($Cu^{2+}{}_{(aq)}$).

Key words: SeNs Wetlands, Interreg Project, key physicochemical parameters, sensors, protective green belt

INTRODUCTION

The key objective and goals of the SeNs Wetlands Project are to implement integrated cross-border monitoring for key physicochemical parameters and existing risks, as well as the protection of protected aquatic areas and biodiversity [1]. The Project will be carried out by implementation of integrated continuous monitoring system for the purpose of cross-border data collection and evaluation. The expected changes are improvement of the knowledge level and existing data, development of guidelines for surface and groundwater and biodiversity protection, use of modern sensor methods. The results will be the Guidebook, for the establishment and maintaining vegetated green strips along the banks of surface waters in agriculture landscapes of Pannonia Region. The optimal structure of multifunctional bank vegetation belt can be defined by the analysis of merged data. The main target groups are Municipalities and Local Authority, Local Community, Public Utilities, Private and Governmental Institutions, Environmental and civil NGOs and University and Research Institutes.

The Project sites are within hydrological systems of watercourses recognized as ecological corridors, as the wetland in Croatia has a direct influence on the water of the Natura 2000 site, and the site in Serbia is proposed for the Nature Park. Water pollution from agricultural sources is a common problem of both Serbia and Croatia. The water quality is one of the drivers of biodiversity loss in wetlands. Buffer/filter function of the bankside vegetation have not been recognized widely, field data from the Pannonian region are scarce and mostly gained by indirect methods. The continuous monitoring by sensors located in measurement wells will produce data about the quantity and seasonal dynamics of the most important pollutants responsible for the eutrophication. Direct beneficiaries of the Project will be the local municipalities and/or water authorities, and the general public. Indirect benefits will be accessible data for all stakeholders. The Project SeNs Wetlands emerged from the necessity of applying an extra effort in the process of protection of wetlands and habitats which represent the most sensitive and endangered ecological systems. Wetlands are areas of diverse biodiversity that are becoming more sensitive and vulnerable by modernization and exploitation, mainly due to exponential growth of agricultural activities.

Impaired and degraded ecosystems have reduced tolerance and adaptability to environmental condition variations. The optimal revitalization of ecosystem require high inter and transdisciplinary, cross-border activities. The Project addresses one of the major cross-border challenges of the Pannonia Region and the bordering agricultural landscapes characterized by the high percent of arable land and increased pressures on the natural systems. Water pollution from agricultural sources is a common cross-border problem, caused by cultivation reaching the edge of water. Although the natural habitats are heavily fragmented, a significant number of existing and planned Natura 2000 sites are in the region. Project sites are within hydrological systems of watercourses (Bosut in Croatia, Krivaja in Serbia) recognized as ecological corridors. The wetland in Croatia have a direct effect on the water quality of the Natura 2000 site located downstream, and the project site in Serbia is proposed for the protection as Nature Park. The key goals of the SeNs Wetlands Project are monitoring of water quality, nurturing and maintaining flora (green belt) and fauna, education on purpose of vegetation in the wetland ecosystem and positive effects on the sustainable development of the area. The dissemination of the Project results will provide data to research facilities, water authorities, local community and the general public. The pollution analysis will provide bases for development of guidelines and the Guidebook specified for the growth and maintenance of a protective green belt that is proven to minimize or eliminate contaminants.

Laboratory analysis and in-situ measurement of physicochemical parameters of groundwater wells, run-off and surface water samples from 18 locations in Serbia, and 14 in Croatia. Data obtained in laboratory conditions and *in-situ* by developed FOS are valuated and discussed in order to obtain the realistic presentation of the ecological network pollution and possibility to recommend remarks to reduce water pollution. In this part of the Project life only the results for the measured physicochemical parameters are shown according to the work package Implementation.

All the key physicochemical parameters (in Serbia and Croatia) will be the result of collaboration of the Project Partners. The analytical determination of key physicochemical parameters is performed in Accredited Laboratory for environmental and occupational monitoring, Department of Environmental Engineering and Occupational Safety, Faculty of Technical sciences, University of Novi Sad. These types of research have been performed for the first time in Serbia and Croatia within the Interreg IPA CBC Croatia-Serbia Project „Active SEnsor monitoring Network and environmental evaluation for protection and wiSe use of WETLANDS and other surface waters“ AF_HR-RS135_SeNs_Wetlands financed by European Union.

MATERIALS, METHODS AND SAMPLING SITES

The contamination properties and sources of wetlands with the reference to the industrial, agricultural and domestic sources are poorly researched and still highly unknown, particularly in Western Balkan countries. Sensitive water bodies, the Lake Zobnatica and the Wetlands of Tompojevci, are surrounded by agricultural land, and Lake Zobnatica, as a countryside touristic destination, has a vast number of leisure activities (Figure 1).

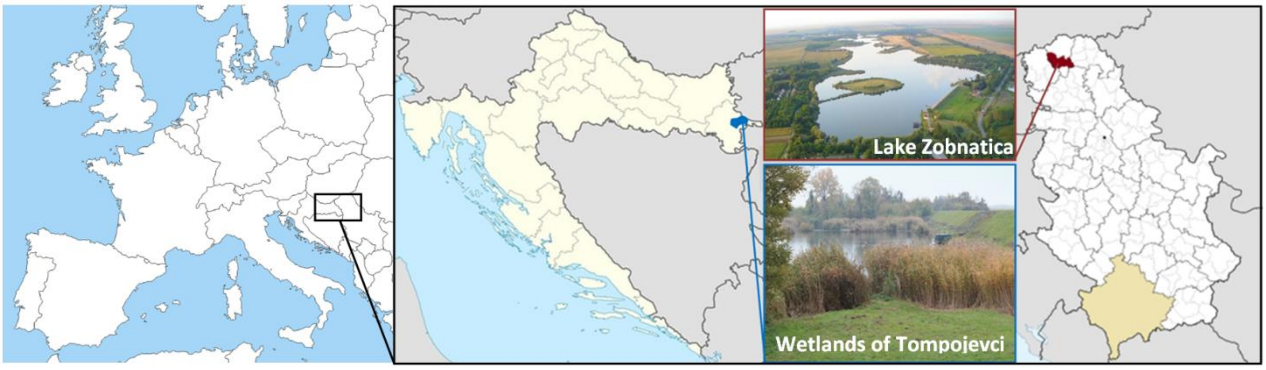

Figure 1. The wetlands of Tompojevci and the Lake of Zobnatica

The seasonal sampling for quantitative and qualitative analysis of the selected physicochemical parameters of water by analytical laboratory methods and fibre optic sensors (FOS) were conducted. The key physicochemical parameters pH, electroconductivity, dissolved oxygen, COD, BOD_5, TOC, anions - $NO_2^-{}_{(aq)}$ and $NO_3^-{}_{(aq)}$, $PO_4^{3-}{}_{(aq)}$ and NH_4^+-N $_{(aq)}$, total nitrogen and phosphorus, $SO_4^{2-}{}_{(aq)}$, $Cl^-{}_{(aq)}$, $F^-{}_{(aq)}$, Cl_2, and cations of metals ($Ni^{2+}{}_{(aq)}$, $Fe^{2/3+}{}_{(aq)}$, $Zn^{2+}{}_{(aq)}$, $Cr^{6+}{}_{(aq)}$, $Cu^{2+}{}_{(aq)}$) are performed in Accredited Laboratory. Laboratory analyses of physicochemical parameters of run-off, groundwater wells and surface water samples from 18 locations in Serbia, and 14 in Croatia are performed. Key physicochemical parameters were selected for determination by FOS device. Laboratory equipment based on FOS will be developed and calibrated to monitor the quality of the studied water bodies. Analysed physicochemical parameters in water by FOS device are: NO_2^- and NO_3^-, NH_4-N, Cl_2, PO_4^-, SO_4^{2-}, $Cl^-{}_{(aq)}$, $F^-{}_{(aq)}$, Ni^{2+}, Fe^{3+}, Zn^{2+}, Cr^{6+}, Cu^{2+}.

Preliminary screening and sampling of Lake Zobnatica surface water, in the vicinity of Bačka Topola, Vojvodina, Serbia, were conducted on 17th November of 2017, and 28th May of 2018. Sampling campaigns of ground water, surface water and run-off water in the vicinity of Lake Zobnatica were conducted on 2nd July 2018 and 30th August 2018, after the piezometers (labelled B1 to B9) and collectors were positioned, constructed and installed. During the sampling campaigns there was no precipitation and the air temperatures were 28°C and 35°C. Ground water was collected from piezometers B1 to B9. Sampling sites B1, B8 and B9 are located in agricultural area, B2, and B3 are near the Lake. Forest and grass are between B1, B2 and B3 sampling sites, and B4 – B7 are in green belt area.

Preliminary screening and sampling of surface water in protected area of Wetlands of Tompojevci, Croatia, were conducted on 24th January of 2018, and 24th April of 2018. Sampling campaign of ground water and surface water in Wetlands of Tompojevci was conducted on 7th September of 2018, after the piezometers (labelled P1 to P6) were positioned, constructed and installed. During the sampling campaign there was no precipitation and the air temperature was 28°C.

Sampling procedure is shown in Figure 2.

Figure 2. Sampling champagnes on representative localities of Lake Zobnatica and wetland Tompojevci

The classification of surface water quality prescribed by Regulation on emission limit values of polluting substances in surface and groundwater and deadlines for their achievement (Official Gazette of the RS 50/2012) is shown in Table 1 and Table 2.

Table 1. The limit values of physic-chemical parameters for classification of water quality, Regulation on emission limit values of polluting substances in surface and groundwater and deadlines for their achievement (Official Gazette of the RS 50/2012).

Parameter	Class I	Class II	Class III	Class IV	Class V
pH	6.5-8.5	6.5-8.5	6.5-8.5	6.5-8.5	<6.5 or >8.5
EC	<1000 / BLQ	1000	1500	3000	>3000
DO	- / BLQ	- / BLQ	5	4	<4
PO_4^{3-}	- / BLQ	-	0.2	0.5	>0.5
NO_2^-	0.01 / BLQ	0.03	0.12	0.3	0.3
NO_3^-	- / BLQ	-	6	15	>15
NH_4^+-N	- / BLQ	-	0.6	1.5	>1.5
$SO_4^{2-}{}_{(aq)}$	50 / BLQ	100	200	300	>300
$Cl^-{}_{(aq)}$	50 / BLQ	-	150	250	>250
Cl_{tot}	0.005	0.005	-	-	-
TOC	- / BLQ	-	15	50	>50
COD	10 / BLQ	15	30	125	>125
BOD_5	- / BLQ	-	7	25	>25
Cr_{tot}	25 / BLQ	50	100	250	>250
$Cu^{2+}{}_{(aq)}$	5/22/40/112*	5/22/40/112*	500	1000	>1000
$Zn^{2+}{}_{(aq)}$	30/200/300/500*	300/700/1000/2000*	2000	5000	>5000
$Fe^{2/3+}{}_{(aq)}$	200	500	1000	2000	>2000
Phenols	<1	1	20	50	>50

Table 2. The maximum allowable values of physicochemical parameters for class I and II quality of water for lakes below 200 m of sea level (Official Gazette of the RS 50/2012)

Parameter of surface water	Maximum allowable values for class I	Maximum allowable values for class II
pH	6.5-8.5	6.5-8.5
DO	8.52	7
TOC	2	6
BOD_5	2	5
NH_4^+-N	0.1	0.3
NO_3^-	1	3
PO_4^{3-}	0.02	0.1
P_{tot}	0.05	0.2
Cl^-	50	100

RESULTS AND DISCUSSION

SeNs Wetlands Project apostrophizes the major cross-border challenge of the Pannonia Region and the bordering agricultural land characterized by the increased pressures on the natural systems. Water pollution from agricultural sources is a common cross-border problem. The poor water quality is the cause of the minimization of biodiversity and often makes surface waters inadequate for irrigation. Surface and ground water pollution from agricultural sources is a persistent and demanding cross-border problem.

The selected result of key physicochemical parameters for 2018 and 2019, shown as maximum and minimum measured concentration levels (Table 3).

Table 3. Results of physicochemical parameters in the vicinity of the Lake Zobnatica and Wetlends of Tompojevci

The Lake Zobnatica						
Parameter	**SWmin**	**SWmax**	**ROmin**	**ROmax**	**GWmin**	**GWmax**
pH	**7.08**	**9.66**	7.08	**9.43**	6.95	**9.09**
EC	926	*1165*	134	678	477	*1446*
DO	*5.14*	11.05	**0.80**	10.35	**0.80**	7.53
NO_3^-	0.001	*0.188*	<0.002	**0.92**	0.001	**0.80**
NO_2^-	0.008	0.01	<0.01	**3.50**	0.008	**3.42**
NH_4^+-N	0.01	0.14	<0.01	*3*	<0.01	*2.5*
TN	<1	2.54	<1	**73.26**	<1	**76.23**
$PO_4^{3-}{}_{(aq)}$	<0.01	**1.263**	0.089	**4.494**	<0.01	**8.042**
Cl_{tot}	**0.01**	**0.14**	<0.01	**1.66**	**0.01**	**0.16**
$Cl^-_{(aq)}$	3.4	82.9	1.7	47.7	<0.01	*144.1*
$F^-_{(aq)}$	0.13	2.29	<0.02	0.51	0.03	2.56
Cr^{6+}	<0.01	0.015	<0.001	0.675	<0.01	0.039
$SO_4^{2-}{}_{(aq)}$	43	98	1	99	0	94
$Ni^{2+}_{(aq)}$	<0.006	0.003	<0.006	0.18	<0.006	0.021
$Fe^{2/3+}_{(aq)}$	<0.02	0.50	<0.02	3.78	<0.02	0.38
$Zn^{2+}_{(aq)}$	0.07	0.28	<0.01	1.4	0.06	0.54
$Cu^{2+}_{(aq)}$	<1	10	<1	82	2	35
TOC	*11.14*	*22.54*	*6.906*	*42.85*	3.385	*46.441*
COD	*21.2*	**52.3**	*12.2*	**78.6**	1.01	**346**
BOD_5	1.21	*7.31*	0.36	3	0.3	3.26
Wetalands Tompojevci						
Parameter	**SWmin**	**SWmax**	**ROmin**	**ROmax**	**GWmin**	**GWmax**
pH	7.19	8.07	7.02	7.73	6.96	**12.80**
EC	308	948	173	502	298	*1218*
DO	**3.77**	*5.62*	**0.68**	*5.86*	**1.59**	9
NO_3^-	0.001	0.008	0.009	**0.235**	0.003	**0.291**
NO_2^-	< 0.01	0.03	0.04	1.11	0.01	*1.83*
NH_4^+-N	0.01	*1.29*	0.04	**3**	< 0.01	**3.88**
TN	<1	*4*	<1	**275.68**	<1	**46.99**
$PO_4^{3-}{}_{(aq)}$	<0.01	**9.403**	< 0.01	**10.875**	<0.01	**10.886**
Cl_{tot}	**0.01**	**0.14**	-	-	**0.01**	**0.41**
$Cl^-_{(aq)}$	6.2	37.2	0.2	80.5	2.3	45
$F^-_{(aq)}$	<0.02	0.40	<0.02	2.97	<0.02	1.24
Cr^{6+}	0.003	0.037	<0.01	0.097	0.004	0.636
$SO_4^{2-}{}_{(aq)}$	1	63	1	27	1	98
$Ni^{2+}_{(aq)}$	<0.006	0.019	<0.006	0.072	<0.006	0.033
$Fe^{2/3+}_{(aq)}$	0.03	1.16	<0.02	0.84	0.01	0.99
$Zn^{2+}_{(aq)}$	0.09	0.66	0.27	2.73	0.01	1.04
$Cu^{2+}_{(aq)}$	1	12	1	*132*	1	50
TOC	*6.7*	*20.7*	*9.8*	**79.90**	2.53	**141.48**
COD	*18.5*	**56.2**	*17.8*	**180**	0.137	**170**
BOD_5	0.12	*2.66*	-	-	0.1	2.58
Table and sample legend	**SW**-surface water		**RO**-run-off		**GW**-ground water	
	Normal font – values within the limits for class I		*Italic font – values over the limits for class II*		**Bold font – values over the limits for class V**	

The planned biodiversity survey enables the comparison of the buffer capacity and habitat quality of the bank vegetation.

According to the results and maximal allowable values Wetlands of Tompojevci belongs to the class V water quality (orthophosphates and dissolved oxygen), with high trophic state and bad eco-status. The results of preliminary screening analyses in Wetlands of Tompojevci indicated pollution and need for detailed monitoring of surface water as well as ground water and run-off water. The preliminary results and maximal allowable values show that the Lake Zobnatica can be classified as class IV at best, as poor ecological status and utilization for irrigation and industrial use (process and cooling water) [2, 3].

Following the development and progress of the Project the parameters shown of the most importance to the analytical study of the wetlands in Tompojevci and Lake Zobnatica are pH, dissolved oxygen, conductivity, orthophosphates, nitrates, nitrites and total nitrogen. The sensors of FOS system are in the process of development expected to be set on locations, but the preliminary results are abundant and enable the development of insights and conclusions.

All obtained results of sampled ground and surface water, indicate significant pollution, leading to the conclusion that the surrounding agricultural land has high impact onto the sensitive water bodies Wetlands of Tompojevci, Croatia and the Lake Zobnatica, Serbia.

CONCLUSIONS

The SeNS Wetlands Project main objective is development of integrated cross-border monitoring for protection of environment and biodiversity, which will provide the first and the new cross-border data correlation and evaluation. Specific objectives of the Project are development and implementation of active sensor monitoring system which will provide cross-border database; analysis of physicochemical parameters in water by standard analytical and new fibre optic sensor methods; definition of guidelines for enhancing the ecosystem services of bank side vegetation in the agricultural landscapes in Pannonia region and adjacent areas; collection of data about the interests of local communities and other stakeholders in the sustainable use of the multifunctional vegetation strips. The SeNS Wetlands Project main outputs are Development of wireless water quality measurement stations and monitoring network system for Data Acquisition, Processing and Presentation (DAPP); New fiber optic sensor (FOS) for monitoring of environmental water quality; Examination of environmental water quality inside the structural elements of the ecological network and measurement wells; Guidelines for the establishment of multifunctional bank side vegetation strips and plan for the establishment of multifunctional vegetation strip.

Highly inter and multidisciplinary area of environmental protection has a significant segment of transdisciplinarity, cross-border and inter regional character. The significance of the obtained results is also the possibility to disseminate knowledge, experiences to wider areas of similar geological, climatic and physical-chemical characteristics.

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REFERENCES

[1] Internal report and material of the Interreg IPA CBC Croatia-Serbia Project „Active SEnsor monitoring Network and environmental evaluation for protection and wiSe use of WETLANDS and other surface waters“ AF_HR-RS135_SeNs_Wetlands

[2] Sremački, M., Obrovski, B., Mihajlović, I., Petrović, M.,Vojinović Miloradov, M., Kicošev, V., Dragićević, P., Radić, J., Kvalitet površinske vode zaštićenih akvatičnih sistema u Srbiji i Hrvatskoj,Voda i sanitarna tehnika, 5,550-555, 2018

[3] Regulation on emission limit values of polluting substances in surface and groundwater and deadlines for their achievement (Official Gazette of the RS 50/2012)

[4] http://senswetlands.ferit.hr

[5] VojinovićMiloradov, M., Sremački, M., Mihajlović, I., Petrović, M., Obrovski, B., Sabadoši, K., Kicošev, V., Keser, T., Dragićević, P., Radić, J.: SeNs Wetlands Project: Overview of the

interreg IPA Project between Croatia and Serbia, International Conference Ecological Truth and Environmental Research, 291-297, ISBN 978-86-6305-097-6, Bor,18-21 Jun, 2019

[6] Sremački, M., Obrovski, B., Petrović, M., Mihajlović, I., Vojinović Miloradov, M., Radić, J.: Environmental evaluation of groundwater quality in the protected area of Lake Zobnatica, International Conference Ecological Truth and Environmental Research, 280-285, ISBN 978-86-6305-097-6,Bor, 18-21 Jun, 2019

[7] Obrovski, B., Bajić, J., Mihajlović, I., Vojinović-Miloradov, M., Batinić, B., Živanov, M.: Colorimetric fiber optic probe for measurement of chemical parameters in surface water, Sensors and Actuators B: Chemical, 228, 168-173, ISSN: 0925-4005, 2016

CONCEPTS OF ENVIRONMENTAL (BIO) ENGINEERING IN ENVIRONMENTAL HEALTH

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Abstract: Most of the people in the world today have an immediate and intuitive sense of the urgent need to build a sustainable future. Environmental engineering is the branch of (bio) engineering that is concerned with protecting people from the effects of adverse environmental effects, such as pollution, and improving environmental quality. Environmental (bio) engineers work to improve recycling, waste disposal, public health, and water and air pollution control. Environmental health (bio) engineering can be considered as sanitary (bio) engineering brought to meet the needs of the future of the World. Sanitary (bio) engineering is essentially disease-oriented: it may be defined as the use of (bio) engineering principles and (bio) engineering devices for public health purposes. Environmental health (bio) engineering, is the application of (bio) engineering fundaments to the control, modification or adaptation of the physical, chemical or biological characteristics of the environment in the interest of the health, comfort and social activities of people. It requires the control (quantity and quality) of the basic necessities and waste by-products, whether solid, liquid or gaseous. These by-products, if uncontrolled and allowed to accumulate, lead to widespread disease and physical damage, and could literally make human existence impossible. The fundamental concept of sustainable development is depending on the social, the economic and the environmental dimensions. For development to be sustainable, all the 3 dimensions need to be addressed in a balanced and integrated way, to reach present and future needs. Many health problems will continue to be exacerbated by pollution, noise, crowding, inadequate water and sanitation, improper waste disposal, chemical contamination, poisonings and physical hazards associated with the growth of densely populated cities. Education for sustainable development is an emerging but dynamic concepts that encompass a new vision of education that seeks to empower people of all ages to assume responsibility for creating a sustainable future. Today, the prospects for future health depend to an increasing extent on the processes of globalisation and on the emergence of global environmental changes occurring in response to the great weight of humankind's economic activity. The globalization of trade, travel and culture is likely to have both positive and negative impacts on health. Increased trade in services and products harmful to health and the environment, travel and mass migration of people constitute additional global threats to health. A healthy population is essential for economic development. The modern engineering education should be reformed to include the spheres of economy, science and education. Finally, we have to accelerate progress towards universal health coverage and the sustainable development goals by ensuring equitable access to a skilled and motivated health worker within a performing health system.
Key words: (bio) engineering, education, environment, health, sustainable development

INTRODUCTION

There is increasing evidence that the integrity of the environment is under substantial pressure. The science of Environmental Health has always been concerned with the study of the human - environment interface, and now even more than ever, practitioners are needed who understand this link and the strategies available to control and minimize the risks associated with environmental health hazards. The practice of environmental (bio) engineering dates back to the dawn of civilization. Ever since groups of people began living in semi-permanent settlements, they have had to deal with the challenges of providing clean water and disposing of solid waste and sewage. With the growth of cities and the advent of large-scale farming and manufacturing, people have also had to worry about air quality and soil contamination. So, the topics covered include: an introduction to environmental health, ecosystems and sustainability; environmental health issues (e.g. air pollution, water and sanitation, waste and contaminated land, communicable diseases and food safety, physical agents, disaster management); and environmental health settings including the built environment.
Makienko and Panamaryova [1] mentioned that about 40% of the students used the term "innovative technology" in their responses, but could not explain the meaning of innovative technology, innovative organization and the innovative university. Perhaps the reason for this is that the term is widely used today as a slogan in the various spheres of the whole World reality: mass media, speeches of

politicians, economists and analysts in the field of education, and etc., but the desire to give a rigorous definition of the term "innovation" is present only in the academic community.

SCOPE OF ENVIRONMENTAL HEALTH

The term environmental health covers at least: water supply engineering, sewage treatment, solid waste disposal, the control of disease vectors, air pollution control, water pollution control, radiation protection, environmental biology, industrial hygiene, industrial toxicology, urban noise control, the prevention of road accidents, town planning, architecture, the peaceful uses of outer space, and preventive, occupational, aerospace medicine, etc. Most of these subjects are concerned with physical, chemical, or biological environmental agents and not the social environment as exemplified by culture and by social, economic, political and administrative institutions.

Environmental health monitoring and surveillance

Environmental health monitoring and surveillance include two classes of activity, each applied to two different types of phenomenon. Systematic collection of data by standardized procedures can be carried out either for examination at convenient times or under convenient circumstances or as a basis for action; these two activities, conveniently distinguished as monitoring and surveillance, are often confused with each other and opportunities for the use of the same techniques to solve different environmental health problems are overlooked.
Surveillance and monitoring is one fundamental class of activities, often having elements common to many programmes. Environmental management is an activity which the health authorities share with many other governmental agencies. Either the environmental agents affecting human health, such as heat, viruses, polluted water, insanitary food, or photochemically polluted air, or the indices of their effects on human health, such as mortality, morbidity, chronic illness, accelerated aging, the impairment of function, sensory irritation, or other damage to health, can be monitored or kept under surveillance. Environmental epidemiology is the systematic study of the health effects of defined environmental factors on defined populations-makes exacting demands on monitoring and surveillance systems, but the results obtained are of great importance in environmental health evaluation.

Environmental hazards and quality evaluation

The qualitative and quantitative study of the effects of various environmental factors on human health on the biosphere involves environmental physiology, laboratory and clinical toxicology, and environmental epidemiology. The impacts are less likely to appear as rates for disease entities, but rather as measurable deviations from health and biotas, such as accidental injuries, skin irritation or inflammation, cough or headache, altered immunity or respiratory or neurological function, community or job dissatisfaction, changed blood constituents, or abnormal substances in the blood or urine. A systematic study of environmental hazards must therefore develop measurable criteria of health.
Environmental health (bio) engineering can be considered as sanitary (bio) engineering brought to meet the needs of the future of the World. Sanitary (bio) engineering is essentially disease-oriented: it may be defined as the use of (bio) engineering principles and (bio) engineering devices for public health purposes. Environmental health (bio) engineering, is the application of (bio) engineering fundaments to the control, modification or adaptation of the physical, chemical or biological characteristics of the environment in the interest of the health, comfort and social activities of people. It requires the control (quantity and quality) of the basic necessities and waste by-products, whether solid, liquid or gaseous. These by-products, if uncontrolled and allowed to accumulate, lead to widespread disease and physical damage, and could literally make human existence impossible.
The practice of environmental health, (bio)engineering is based on the systems and/or resources approach which realized that in dealing with the environment humans are dealing essentially with water, air and soil systems, and that these represent resources which must be conserved and used in the best interests of humans. This means that the (bio) engineers can no longer be concerned solely with public water supply, waste water disposal, air pollution or solid wastes, etc. In dealing with water they

must recognize that it is not used solely for public water supply purposes; its uses in agriculture, medicine and industry, for recreational and transportation purposes, and for power generation are important, and aesthetic aspects cannot be neglected. Thus public water supply must be developed as a logical part of a broad water resources plan and the engineer involved must be responsible for ensuring that such a plan is developed.

Air resources are not unlimited and must be used rationally. Air pollution over worldwide areas is a matter of direct interest not only to those concerned with aesthetics and morbidity, but to the (bio) engineer, who must be responsible for the beneficial use and conservation of global air resources. In dealing with solid waste disposal, (bio) engineers are directly involved in questions of land use and indirectly in those of air and water pollution. Housing is another major problem; although somewhat neglected, its importance is being increasingly recognized as people throughout the world rebel against the unsatisfactory conditions existing in most urban areas.

Difference between Environmental (Bio) Engineering and Environmental Management?

Environmental (bio)engineering is a branch of engineering and it deals with biology, botany, chemistry, climatology, ecology, ecological fisheries, environmental law, forest sciences, geo-sciences, soil science, information science, public affairs, public health, toxicology, zoology and etc. to develop the solution to the environmental problems such as public health, waste disposal, water/air pollution control, and recycling waste at local and global level to improve overall quality of environment. In addition, the environmental (bio) engineering contributes towards preventive measures to sustain the environment. They help government or team manager to improve the policies or resolve the issues by providing the valuable technical inputs.

Environmental Management is a broader term that adds economic and finances to understand the viability and profitability of the project before proposing the same to the senior management. Apart from that include environmental (bio) engineering and management to improve existing policies or create new policies and implement them. The environmental management is managing the environmental related project and guide the engineering team to implement it. At global level they help creating awareness, policies, and process related to global warming, water/air pollution, waste management.

Manager is to manage the team as team-lead with help of technological/technical strategy, business strategy, and organizational strategy to guide and with help of man-management to monitor the team, the progress and quality of the work to ensure high quality delivery on time. It deals with technology, people and resources needed for implementing the entire project.

Environmental Management: offers research and opinions on use and conservation of natural resources, protection of habitats and control of hazards, spanning the field of Environmental Management Services without regard to traditional disciplinary boundaries.

Figure 1. Environmental Management

Environmental Management presents the work of academic researchers and professionals outside universities, including those in business, government, research establishments, and public interest groups, presenting a wide spectrum of viewpoints and approaches.

CONCEPTS OF ENVIRONMENTAL HEALTH

What are environmental (bio) engineers responsibilities?

Environmental (bio) engineers typically are the project designers leading to environmental protection, such as water reclamation facilities, air pollution control systems, and operations that convert waste to energy, soil protection, etc. Obtain, update, and maintain plans, permits, and standard operating procedures.

What is environmental (bio) engineering management?

Environmental (bio) engineers devise solutions for waste water management, water and air pollution control, recycling, waste disposal, and public health. They evaluate hazardous-waste management systems to evaluate the severity of such hazards, advice on treatment and containment, and develop regulations to prevent mishaps.

What is the importance of environmental (bio) engineering?

One of the most important responsibilities of environmental (bio) engineering is to prevent the release of harmful chemical and biological contaminants into the air, water and soil.

What are the branches of environmental (bio) engineering?

The main areas of environmental (bio) engineering include air pollution control, industrial hygiene, radiation protection, hazardous waste management, toxic materials control, recycling, water supply, wastewater management, storm water management, solid waste disposal, and public health and land management.

What are the 4 types of environmental hazards?

Four categories: physical, chemical, biological, and cultural.

- Physical hazards are physical processes that occur naturally in the environment.
- Chemical hazards can be both natural and human-made chemicals in the environment.

What are the five components of environmental science?

These five components are: atmospheric sciences, environmental chemistry, forestry and agricultural science, geosciences, and oceanography and marine sciences.

What are examples of environmental problems?

The environmental problems like global warming, acid rain, air pollution, urban sprawl, waste disposal, ozone layer depletion, water pollution, climate change and many more affect every human, animal and nation on this planet.

What are the environmental factors that affect health?

- Exposure to hazardous substances in the air, water, soil, and food.
- Natural and technological disasters.
- Climate change.

- Occupational hazards.
- The built environment.

CHANGING CONCEPTS OF ENVIRONMENTAL HEALTH

The most important principle of modern environmental health is that no advance in technology is without its risk of environmental degradation or hazard.

Modern environmental health problems

The modern experts in environmental health must be capable of working on problems of air, water, soil, housing, or work place, etc., and of improving the situation in one place without making it worse elsewhere. He must see the environment as a whole, not as a series of disconnected parts. They must be appreciate and understand not only human disease but human health too. Environmental health calls for both the abatement of nuisances and their prevention. Nevertheless, it is practically certain that those trained in environmental health (bio) engineering in the next ten years will spend much of their professional lives in the field of environmental health planning, concerned with the prevention of environmental hazards and of environmental degradation. The experts in environmental health must be able to say with authority and on a reasonable basis where power plants or cities should or should not be located; how much of a fertile basin can be used for commercial and residential purposes; what type of waste disposal facilities a new industry, factory or crop will require; what type of engine can be used as the prime mover in a transportation system; which domestic materials are suitable for a house and which must be imported. In less developed areas, the environmental health experts must understand the sequence of development in the provision of water supplies, the disposal of liquid and solid wastes, the provision of wholesome food and adequate food storage facilities, the prevention of occupational diseases and industrial injuries, the abatement of air and water pollution, the prevention of soil pollution etc. The evaluation of environmental health hazards and their abatement, or the prevention of hazards and of environmental degradation, is the two basic activities in environmental health.

PROBLEM-SOLVING AND (BIO) ENGINEERING DESIGN

Problems of systems

Engineering and bioengineering have always involved problems of systems and of components; what have changed dramatically is the scale of the systems (e.g., in air traffic control, urban sewage and waste disposal, electric power systems, information storage, retrieval, etc.). The systems approaches to problems have had a marked effect on the way problems are tackled. For example, unusual groupings of humans are proving essential in tackling problems effectively in bioengineering and environmental engineering. There is no standard academic curriculum that will not guarantee insight into any given problem, nor is an unusual background necessarily a bar to the possession of insight. In engineering today, rigid professional classification is unacceptable if it impedes a free attack on problem-solving.
Problem-solving in engineering and bioengineering involves the selection of materials, the synthesis of components and the structuring of systems in such a manner as to yield an effective result in terms of some combination of technological, economic, political, social, and aesthetic criteria. The selection of one among a set of possible solutions has always been a fundamental task of the engineering profession.

THE USE OF SYSTEMS ANALYSIS IN ENVIRONMENTAL (BIO) ENGINEERING

Four necessary steps for decision-making:

1. Construct a model that satisfies the conditions of the available mathematical and computational techniques, and that at the same time adequately represents the important features of system performance. This step involves one of the traditional goals of the natural sciences: **description**.

2. Define a criterion function, or "measure of merit", that enables all of the possible designs or plans to be arranged in order of preference. This must be expressed formally and quantitatively as a function of the system variables and parameters. The principal purpose of this **objective** function is to reduce the indeterminacy of the model. Stated differently, the objective function is used to eliminate all the less desirable, but technically possible, systems designs. As opposed to the descriptive role of traditional natural sciences, this step lends emphasis to the prescriptive role of modern systems analysis.
3. Obtain empirical estimates of the parameters of the model for the given situation. Almost inevitably this will involve the use of conventional or advanced statistical techniques.
4. Solve the model, using mathematical and computational techniques to select values of decision or design variables that maximize-or, more generally, optimize-the objective function. In this process modern computing facilities are increasingly necessary

Optimization of an objective function for purposes of selecting best designs or making best decisions is a relatively new concept, but invoking of optimality principles for purposes of prediction bas long been of theoretical importance, particularly in the physical sciences.
Besides the objective function, there are usually a number of technical and other requirements. These may be either constraints or objectives, as defined below:

1. Constraint: A requirement is a constraint if:
   a. it is never to be violated at any cost, however high; or
   b. there is no gain or advantage in over fulfilling it.
2. Objective: A requirement is an objective if it can be violated, though at sorne cost or penalty, or if there is an advantage in over fulfilling it.

TRENDS IN ENVIRONMENTAL HEALTH (BIO) ENGINEERING EDUCATION

A new kind of (bio) engineer is needed to meet the complex environmental problems of the future. The civil and sanitary (bio)engineers who pioneered such innovations as water-borne sewerage, municipal water treatment and distribution, sewage treatment, vector control, and air pollution abatement, must gradually give way to the environmental health engineer, prepared to treat these problems in a new and different context. The environmental health (bio) engineer, must deal with the environment as a system, controlling, modifying, or adapting it in the interest of the well-being of mankind.
New concept, environmental design, is developing, which recognizes the interrelationships between the work of (bio) engineers, architects, landscape architects, and planners who have the ultimate responsibility for the form, shape, and character of our urban environment. In considering environmental health (bio) engineering from the resources point of view, increasing use must be made of systems analysis. This involves new methods of assessing, controlling and designing systems.
In planning educational programmes to produce the new environmental health (bio) engineer, capable of understanding and dealing with the complexities of environmental control, there must be adequate recognition of recent trends in education. Accordingly, a part of any educational process should be to develop the ability to:

(1) perceive problems and solve them;
(2) understand people, to communicate with them, and to deal with them as individuals and in groups;
(3) organize;
(4) concentrate; and
(5) memorize.

In addition to education in the humanities and social sciences, all engineers should have a fundamental background in mathematics, including statistics and computer technology; physics, including modern physics; chemistry; the engineering sciences, which include fluid mechanics; solid mechanics; materials; thermodynamics; and electrical science. All environmental health (bio) engineers should study systems analysis; epidemiology; biology, including physiology; biochemistry; and management, including policy, law, administration, and finance. Not all educational institutions will be in a position to prepare (bio) engineering specialists in all fields of environmental health.

Contribution of education to sustainable development over the past decade, since the UNs Conference on Environment and Development held in Rio de Janeiro in 1992. The task of Conference was based on the International Work Programme on Education, Public Awareness and Sustainability of the Commission on Sustainable Development. It was mentioned that reorienting education towards sustainable development requires a new vision for education. Education, including formal education, public awareness and training should be recognized as a process by which human beings and societies can reach their fullest potential. So, education is critical to social and economic development and has a profound impact on population health. Principle I of the Rio Declaration on Environment and Development states that "Human beings are at the centre of concerns for sustainable development. They are entitled to a healthy and productive life in harmony with nature" and to achieve this vision, we have to follow:

- Ensure that basic education and functional literacy for all is achieved,
- Make environmental and development education available to people of all ages,
- Integrate environmental and development concepts, including those of population, into all educational programmes, with analyses of the causes of the major problems, and
- Involve schoolchildren in local and regional studies on environmental health, including safe drinking water, sanitation, food and the environmental and economic impacts of resource use.

It is important to consider the impact of health on education and the conditions that occur throughout the life course that can impact both health and education. The health benefits of education accrue at the level of individual; the community and the larger social or cultural context.

Good-quality basic education for all is an agreed strategy and an essential prerequisite for further skills development. Moreover, a wide distribution of education across society is a better indicator of future economic growth than a high average level. However, education has been identified as an important determinant of economic growth. Higher levels of educational attainment lead to a more skilled and productive workforce, producing more efficiently a higher standard of goods and services, which in turn forms the basis for faster economic growth and rising living standards.

Innovation and technological change are powerful drivers of economic growth. Innovation and technology translate into investment in fixed capital and in workforce and entrepreneurial skills which in turn lead to higher productivity.

The goal is to form the educational method which will allow students to get a BSc degree in technologies to understand that the engineer influences the world by manufactured products. As a result of applying the project educational method in the philosophy course, students have received necessary social cultural skills: realizing the anthropocentricity of the engineering profession and engineer's responsibility towards society, understanding basic tendencies of social development and forming the strategic view on reality.

Education is a strategic resource for building resilient and sustainable societies [2], because it plays a central role in changing the lifestyle and minds of people in relation to specific themes. It may lead to the right type of actions, attitudes and behaviour, creating conditions for active and aware citizenship that will lead to sustainable and inclusive growth [3].

Sustainability requires methodological innovations. Universities should develop curricular and extracurricular activities, teaching and research as well as environment-friendly educational structures [4].

The strategy of providing the future environmental engineers that must realise the dependence of professional activity on calls of the times, the state policy, human needs and at the same time understand that technologies change different life aspects both of the human and all biosphere.

Priorities here include the increasing access to: education and training; improving the quality of apprenticeships; making training in public institutions more relevant to workplace needs by strengthening coordination and partnerships with the private sector; and combining institution-based education and training with enterprise-based learning.

The highly concentrated topics are: development, energy, planning and design, engineering and technology, climate change. The most frequent topics are: sustainable development, sustainable energy, sustainable management development planning, sustainable design, international development, chemical engineering.

Education can accelerate progress towards the achievement of each of the proposed sustainable development goals for 2030 and beyond in a multiplicity of ways. Education opens up new work opportunities and sources of social mobility. The effects of education are significant across many development sectors. Education deserves to be a prominent cornerstone in the post-2017 development framework. The political and financial commitments to education by countries and donors need to be secured and renewed. There is a pressing need for closer collaboration across sectors to enable these synergies to take shape and take root.

The hypothesis of the changing in the modern environmental engineering education is competence which a graduate with a BSc or MSc degree in environmental technology must possess.

The professional competence for this modern education includes both specific knowledge and skills determined by professional activity. It indicates a need for a system of advanced training of specialists paying attention to the professional qualifications and to accept new technologies and draws attention to the new methodology of engineering activities: creative thinking and finding new ways to solve problems. So, the main new aim of the modern engineering profession requires above all creative activity aimed at solving the problems of society. For this, the new method of comparative analysis from the theoretical and experimental investigations is needed in this area.

The further development of the technology near future: It was necessary to specify the social functions of the engineer. This issue was focused on finding out whether the students perceived the impact of engineering activity results for the development of various sectors of the economy, changes in the structure of society, the transformation of the spiritual and physiological components of the human being.

Nowadays higher modern engineering education should focus on the Professional Education. Students were offered the following issues: mechanisms of technology influence on the environment; the technology effects on the human or society; factors that affect the development of technology (economic, political, geopolitical, etc.).

Formation of this principle requires the students to understand technology at the professional level and on the other hand, probable and known effects of the use of technology. The students have showed positive dynamics in realizing the anthropocentricity of engineering profession and engineering responsibility to society. But in most cases the responsibility is recognized in the traditional sense: product quality and impacts on the ecosystem. It is necessary to continue the study of topics related to the personal responsibility of the engineer to the team and understanding of the concept of sustainable development. There is a positive tendency in the formation of deliberate vision of the future students. But we should also note a serious contradiction – realizing the impact on the surrounding world and understanding of the future.

Following Commission on Sustainable Development appointed UNESCO [2] as a task management, there seven objectives of the Work Programme were to:

- clarify and communicate the concept and key messages of education for sustainable development
- review national education policies and reorient formal educational systems
- incorporate education into national strategic and action plans for sustainable development
- educate to promote sustainable consumption and production patterns in all countries
- promote investments in education
- identify and share innovative practices
- raise public awareness.

Some key points about education for sustainable development for future are illustrated here:

- Education for sustainable development is an emerging but dynamic concept that encompasses a new vision of education that seeks to empower people of all ages to assume responsibility for creating a sustainable future
- Basic education provides the foundation for all future education and is a contribution to sustainable development in its own right.

- There is a need to refocus many existing education policies, programmes and practices so that they build the concepts, skills, motivation and commitment needed for sustainable development.
- Education is the key to rural transformation and is essential to ensuring the economic, cultural and ecological vitality of rural areas and communities.
- Lifelong learning, including adult and community education, appropriate technical and vocational education, higher education and teacher education are all vital ingredients of capacity building for a sustainable future.

Education not only provides scientific and technical skills, it provides the motivation, justification, and social support for pursuing and applying them. For this reason, society must be deeply concerned that much of current education falls far short of what is required. Improving the quality and coverage of education and reorienting its goals to recognize the importance of sustainable development must be among society's highest priorities.

Declaration on Science agreed by nearly 2000 scientists at the World Conference on Science (In June 1999, the first global conference on science and society in Budapest, Hungary), organized by UNESCO and the International Council for Science: ICSU) focuses on 'Science and Technology should be resolutely directed towards prospects for better employment, improving competitiveness and social justice. Convened by UNESCO and the ICSU, the conference called for sustainability to be both the goal of scientific endeavour and a guide to processes for new approaches to scientific research.

ENVIRONMENTAL SUSTAINABILITY

Environment includes the physical, biological, social, and cultural factors that can influence health, either directly or through their impact on essential life-supporting ecosystems. The environment and these life-supporting ecosystems are affected by many natural forces, but mostly they are influenced by human activities. Environmental sustainability depends on such elements, as biotic and abiotic factors with natural and anthropogenic origin [5].

Global environmental threats to health include climate change, depletion of the ozone layer, reduction of biodiversity, degradation of ecosystems and the spread of persistent organic pollutants. The 3 main determinants of human disruption of the environment are population size, the level of material wealth and consumption, and the types of technology. Therefore, and for this reason the environmental engineering education and environmental engineers are needed to recognize the direct or indirect influences and activities of human in the air, water and soil environments.

Climate change is a major driver of technological change and innovation in the search for measures and policies to mitigate or help adjust to its effects. Sustainable development and the integration of environmental protection into economic and social development objectives are among the most challenging issues on the national and international policy agenda. The goal of cutting carbon emissions poses significant challenges to the world of work.

Green jobs have a high projected level of growth between now and 2024, especially in lower income countries. This is determined by two processes: the development of the green industry and of the green economy sector and the demand for new "green skills" in traditional sectors.

The notion of "green jobs" has become an emblem of a more sustainable economy and society. Jobs in all economic sectors are subject to "greening", but six sectors have particular salience in this respect: energy supply, especially of renewable energy; construction; transportation; basic industry; agriculture; and forestry.

Since the industrial revolution, urbanisation and industrialisation, together with economic development, have led to increases in energy consumption and waste production. Exposure to environmental pollution remains a major source of hazard not only for our health but also for our planet. In 2012, WHO estimated that exposures to polluted soil, water, and air contributed to an estimated 8·9 million deaths worldwide. Of these deaths, 94% (8·4 million) were in low-and-middle-income countries. Different pollutants are linked in children to non-communicable diseases (such as asthma), cognitive disorders, and perinatal defects, and, among adults, to heart disease, stroke, and cancer. However, although environmental pollution is reaching disturbing proportions worldwide, it remains a neglected problem in national policies and on international development agendas.

EDUCATION OF (BIO) ENGINEERS IN EPIDEMIOLOGY AND PUBLIC HEALTH

The role of environmental health (bio) engineering is particularly important in the control of water-, food- and arthropod-borne infections, zoonoses, and worm infestations. The preventive measures used by modern medicine in the control of these infections embrace all the fields of environmental health (bio) engineering. Water- and food-borne enteric infections caused by the members of the *Salmonella* family, cholera, diseases caused by enteroviruses, malaria, schistosomiasis, and plague are examples of infections in which the control of the vector and animal reservoirs is largely in hands of the environmental health (bio) engineer. The control of such diseases calls for close collaboration between the physician, the epidemiologist, the environmental health bioengineer, and their assistants. Successful collaboration depends on a variety of factors; the physician need not know much about bioengineering or control measures, but must understand them. The environmental health (bio) engineer, must be able to understand and communicate with the various medical and paramedical specialists (epidemiologists, microbiologists, entomologists, etc.).

HEALTH AND SUSTAINABLE DEVELOPMENT

Usually, good health facilitates development, and the development promotes improved health. However, improved health may be a prerequisite for development, some behavioural determinants of health. Equally, development which is economically desirable e.g. in agriculture and industry, may have harmful consequences for health and the environment.

'Health' and 'sustainable development' are complex entities. "Making Health Central to Sustainable Development that planning the Health Agenda for the World Summit on Sustainable Development" held in Oslo, Norway, from 29 November to 1 December 2001. It represents a point of departure, rather than a definitive account of all issues relevant to health and sustainable development. The main concept of sustainable development is an elusive one, and its relationship with health highly complex, variable and subject to a large number of interacting factors which influence the relationship (Figure 2).

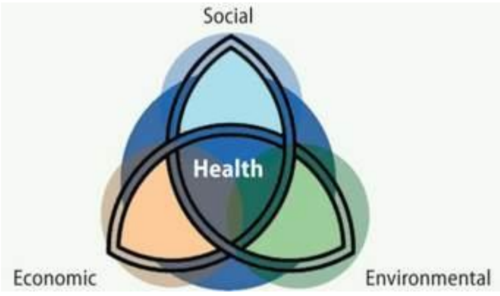

Figure 2. The relation between the health and socio-environmental issues

The fundamental to the concept of sustainable development is depending on three pillars: the social dimension, the economic dimension and the environmental dimension. For development to be sustainable, all 3 dimensions need to be addressed in a balanced and integrated way, to reach present as well as future needs. These 3 dimensions should be seen as mutually enforcing, interdependent entities of sustainability.

Health and sustainable development policies and programmes depend on convenient access to information about a large variety of hazards, ranging from biological hazards in food and water, to chemical hazards such as pesticides, to the different physical and social factors. This is necessary so that health authorities can effectively discharge their responsibility to protect public health. But it also serves to clarify the extent to which health hazards are attributable to environmental and social conditions and/or to the activities and policies of sectors other than health.

Good health facilitates development, and development often promotes improved health. Improved health may be a prerequisite for development, some health behavioural determinants such as attitudes towards the environment, and lifestyles of people and consumption patterns, can impede the sustainability development process in the longer-term. Equally, development which is economically desirable e.g. in agriculture and industry, may have harmful consequences for health and the environment. Under different possible future scenarios, in order to manage health workforce labour markets and devise effective and efficient policies that respond to today's needs while anticipating tomorrow's expectations (Figure 3).

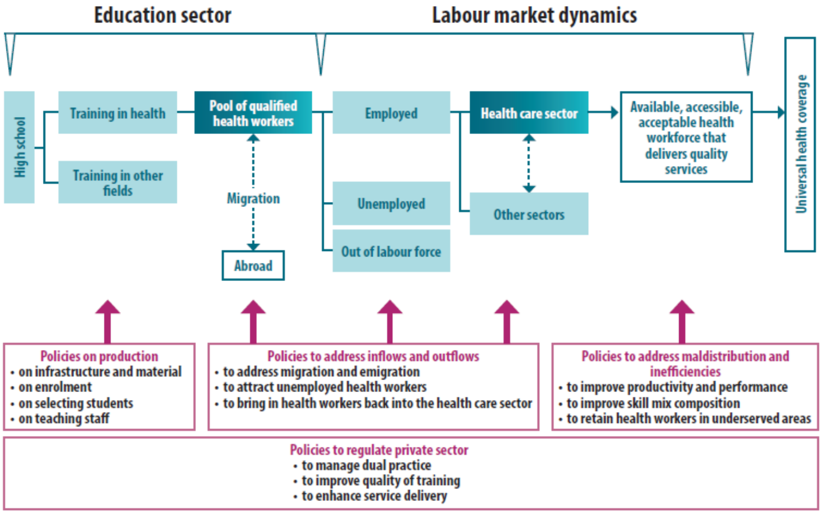

Figure 3. Policy levers to shape health labour markets (Source:[6]).

Genetical factors are more relevant at individual and family level than at the population level, but gene-environment interactions are responsible for much human diversity. Environmental determinants of health are too numerous and complex, nevertheless the wide range of possible exposures to pathogens and environmental pollutants, and the individual and population-level responses to these exposures, are well known. Yet pollution is preventable. But when compared with the attention given, for example, to AIDS, malaria, and tuberculosis, environmental pollution receives far less attention at the national and international levels, making it hard to put policy interventions and prevention strategies into practice.
In October, 2017, The Lancet, together with the Global Alliance on Health and Pollution and the Icahn School of Medicine at Mount Sinai in New York, will publish a Commission on Pollution, Health, and Development. The Commission will aim to catalyse attention to this escalating planetary danger, increase resources allocated for it, and initiate coordination of policy action at the global level. Environmental pollution should be tackled from multiple perspectives, including social, economic, legislative, and environmental approaches. It is time to take action to control the endemic pollution of our world.

COOPERATION PROGRAMMES

There is a wide scope to build on current development cooperation programmes for skills development. Fruitful avenues could include engaging national institutions in:

- Further exchange of experience, promotion of the training strategy for strong, sustainable and balanced growth;
- Integrating skills into national and sectoral development strategies through the UN Common Development Framework system;
- Providing capacity-building and financial help to expand the coverage and the quality of education and training available to disadvantaged groups;
- Upgrading the informal apprenticeship systems which are the only means of acquiring skills available to most young people;
- Building skills into current "aid for trade" initiatives.
- This in turn requires good-quality education in childhood;
- Good information on changes in demand for skills;
- Education and training systems that are responsive to structural changes in economy and society; and

- Recognition of skills and competencies, and their greater utilization in the workplace.

SUSTAINABLE DEVELOPMENT

Principle I of the Rio Declaration on Environment and Development states that “Human beings are at the centre of concerns for sustainable development. They are entitled to a healthy and productive life in harmony with nature”.
Sustainable development is frequently defined as development that meets the needs of present generations without compromising the ability of future generations to meet their own needs.
As evidence of the harm to health and well-being from widespread environmental degradation and global climate change grows, communities and governments are placing greater emphasis on assuring that economic development is achieved in a sustainable way.
In September 2015, during the UNs General Assembly, a new global development agenda was adopted by all the member states in order to define development priorities up to 2030 in line with the Millennium Development Goals and Education for All, which expired in 2015. The 2030 Agenda for Sustainable Development includes a set of 17 Sustainable Development Goals, which are reference objectives for post-2015 international development. Within this new international framework, education was identified as a standalone goal since it has a pivotal role as a key enabler of sustainable development. For these reasons, it is necessary to analyse in detail what kind of education we need to ensure its impact is positive: i.e., the best practices, tools and solutions that are able to foster sustainable development at a global level.
So, the action of Global Programme on Education for Sustainable Development is to mobilise the community of stakeholders in Education for Sustainable Development towards urgent action to further strengthen it and scale it up.
Technological innovations, environmental policies, the consequences of climate change and new habits of consumption are all factors that determine this new demand.
The growing number of people employed within the environmental economy since 2000 is mainly due to growth in the management of energy resources, especially those concerning the production of energy from renewable sources and the production of equipment and installations for heat and energy saving.
Within this complex framework of different actors, universities play a central role in education for sustainable development, as well as in networking, and often play a leading role in relation to local populations [7].
There are 3 main strategies currently in use for achieving these goals and integrating sustainability concerns into university activities:

- Classes in Sustainability
- Research on Sustainability, and
- Green campus.

Education for Sustainable Development is an “umbrella concept” that covers a broad range of topics and aspects to cope with the complexities posed by socio-environmental issues. Such complexities are often grouped into the well-known 3 dimensions: economic, social, and environmental Sustainability (Figure 4).

Figure 4. Matrix of Sustainability: economic, social, and environmental dimensions. [8]

From such processes of social study, it can be realised that sustainable development is a catalytic vision rather than a neatly defined, technical concept. Indeed, we have learnt that:

- Sustainable development is more a moral precept than a scientific concept, linked as much with notions of peace, human rights and fairness as with theories of ecology or global warning.
- Sustainable development involves the natural sciences, policy and economics; it is primarily a matter of culture.
- Sustainable development requires us to acknowledge the interdependent relationship between people and the natural environment. This interdependence means that no single social, economic, political or environmental objective be pursued to the detriment of others.

Rapid worldwide urbanization is at once the main cause and, potentially, the main solution to global sustainable development challenges [9]. The growth of cities is typically associated with increases in socioeconomic productivity, but it also creates strong inequalities. Rapid urbanization is creating the conditions for widespread economic growth and human development, but its consequences are very uneven.
Most nations worldwide have recently committed to solving their most severe challenges of sustainability by 2030, including eradicating extreme poverty and providing universal access to basic services. A new systematic understanding of these processes is critical for devising policies that produce faster and more equitable universal sustainable development.

CONCLUSION

Thus, underlying the concept of sustainable development is the increasing recognition that the goals of sustainable development cannot be achieved when there is a high prevalence of debilitating illnesses, and the health of the population cannot be maintained without ecologically sustainable development. In this respect “ecological” has both social and physical dimensions.

REFERENCES

[1] Makienko M., Panamaryova A., Project approach in humanities as a cognitive strategy of modern engineering education. Procedia – Soc. Behavioral Sci., vol. 166, pp. 415–421, 2015.
[2] UNESCO-UNEVOC, Virtual Conference. Bonn. 12-16 November 2013.
[3] UNESCO, Shaping the Education of Tomorrow. 2012 Report on the UN Decade of Education for Sustainable Development, Paris, UNESCO, 2012.
[4] UNESCO, GEM Global Education Monitoring Report. Education for People & Planet, Paris, UNESCO, 2016.
[5] Kazak R., EU and Ukraine Cooperation for Sustainable Environment: Historical and Legal Aspects. European J. Sustainable Development, vol. 3(4), pp. 53-60, 2014.
[6] Souza P. J., Gülmezoglu M. A., Vogel J., Carroli G., Lumbiganon P., Qureshi Z., et al., Moving beyond essential interventions for reduction of maternal mortality (the WHO

Multicountry Survey on Maternal and Newborn Health): a cross-sectional study. Lancet; 381(9879), pp.1747–1755, 2013.

[7] D. Tilbury, Higher education for sustainability: A global overview of commitment and progress. Higher education in the world, vol. 4, pp. 18-28, 2011.

[8] http://www.keywordsuggests.com.

[9] Brelsford C., Lobo J., Hand J., Bettencourt LM.A., Heterogeneity and scale of sustainable development in cities. PNAS, vol. 11(34), pp. 8963–8968, 2017.

DRYING OF SUSPENSIONS AND SOLUTIONS IN FLUIDIZED BED OF INERT PARTICLES – MATERIAL HOLD-UP AND ENERGY EFFICIENCY STUDY

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Abstract: The fluid bed dryer with inert particles was used as slurry dryer, producing a fine powder. Experiments were performed in a cylindrical column 215 mm in diameter and 1200 mm in height with glass spheres as inert particles (d_p=1.94 mm and 1.20 mm). Suspension of calcium hydroxide was used as the feed material in drying experiments. The physical phenomena occurring in this dryer was analyzed. In this paper, energy efficiency of the process and the dried material residual content in the bed were experimentally determined. A number of experiments were carried out in the pilot plant fluidized bed dryer of the nominal evaporation capacity of 20 kg_{H2O}/h and the influence of the choice of the process parameters on energy efficiency of the system was investigated, taking into account the specific conditions that need to be satisfied.
Key words: drying, fluidized bed, suspensions, powder, energy efficiency, hold-up

INTRODUCTION

Many processes in chemical, pharmaceutical and food processing industries involve drying of solutions, suspensions and pastes in order to obtain the final product in the form of powder. Various drying techniques can be used for this purpose, depending on the initial moisture content and physical and rheological properties of the material. In general, trends in drying technology are associated with achieving higher energy efficiency, enhanced drying rates, development of more compact dryers, better control for enhanced quality and optimal capacity, developments of multi-processing units (for example filter-dryer) [1].

Drying of slurries on inert particles is a relatively novel technology to produce powdery materials. It was originally developed for drying of pigments, chemicals and some biomaterials to eliminate constrains of spray, drum and paddle dryers. Classical fluid bed, spouted bed, spout-fluid bed, jet spouted bed and vibrated fluid bed are the most popular dryers used for drying on inert particles [2-10]. The principle behind this technology is based on drying of a thin layer of the slurry that coats the surface of inert particles. Depending on the dryer type, these particles can be vibrated, fluidized or spouted either by hot air only, or in combination with a mechanical device installed within the dryer, such as an agitator or conveyor screw. A high drying efficiency results from the large contact area and from the large temperature difference between the inlet and outlet air.

The generalized diagram of a fluidized bed drying system is presented in Figure 1. The feed material is directly supplied into the column where inert particles are fluidized by hot air. The product is separated from the exhaust air by a cyclone and a bag filter. The drying mechanism depends on the feed slurry density and consistency, as illustrated schematically in Figure 2. If the feed is relatively diluted (a solution or a suspension) the drying mechanism consists of three steps, which occur simultaneously in different regions of the bed. The charged material forms a film, which adheres to the surface of inert particles. Because of the very large surface area of the particles and intensive fluidization, moisture is removed in the time frame of few seconds. Solids remaining on the surface of inert particles are peeled off by friction and collisions. Finally, the powdery product is elutriated from the inert bed with the exhaust air (Figure 2a). If the feed is a dense slurry (paste) then wet paste aggregates fluidize together with the inert particles. During the drying process the size of aggregates decreases due to elutriation of dried particles from the bed surface (Figure 2b). In this case, a more homogenous and stable bed can be obtained by incorporation of a low-speed mechanical mixer. Note that a typical dry particle is about two orders of magnitude smaller than the inert particles in the bed.

Due to the intensive mixing of inert particles during fluidization the bed temperature is approximately uniform.

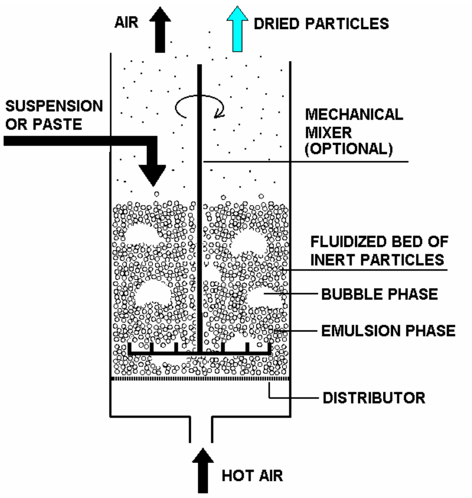

Figure 1. Drying of suspensions in a fluidized bed of inert particles [8, 11]

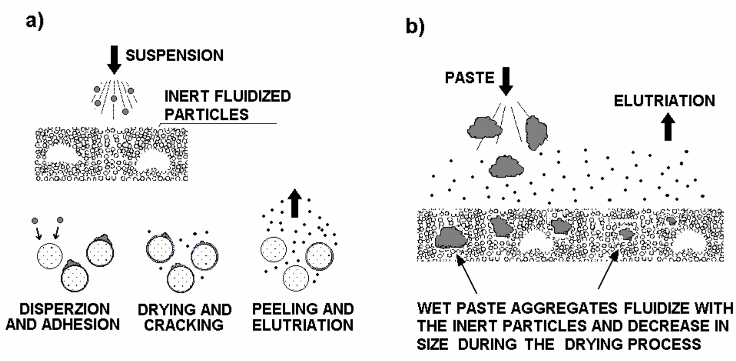

Figure 2. The drying mechanism: a) feed – suspension, b) feed – paste [8, 11]

Different investigations, with wet materials of varied nature, have shown that considerable product accumulation occurs on the surface of the inert particles. Thereupon, the dryer productivity is limited by cleaning of the surface of inert particles from the dried product [12-14]. Since the steady state drying can be achieved only if the drying time is shorter than coating time [15], the knowledge of the product hold-up in the bed is of great importance.

EXPERIMENTAL

The experimental set up is schematically shown in Figure 3. The drying chamber is a cylindrical column D_c = 215 mm i.d. and 300 mm high, connected by a conical section with the 320 mm i.d. and 300 mm high upper cylinder. The overall column height is 1200 mm, where the effective column height (above the distributor) is 900 mm. The inert particles were glass spheres with the mean diameter d_p = 1.94 mm (density 2460 kg/m^3) and d_p = 1.20 mm (density 2640 kg/m^3). The inert bed mass of larger glass particles was 5.6 kg, static bed height was 101 mm and the total inert particle area was 7.2 m^2, whereas for the smaller particles these values were 5.9 kg, 99 mm and 11.2 m^2, respectively. Minimum fluidization velocity was determined at ambient air temperature using standard procedure (U_{mF} = 1.00 m/s for d_p = 1.94 mm, and U_{mF} = 0.71 m/s for d_p = 1.20 mm). Superficial air velocity (at ambient temperature) was 1.76 m/s, inlet air temperature (T_{gi}) was nearly constant at 200°C, whereas the outlet air temperature (T_{ge}) was in the range of 60 to 120°C. The water content in the feed materials varied between 0.60 and 0.95 kg_{H2O}/kg_{sus}. The feed material is directly pumped into the bed axis using a peristaltic pump for suspensions and the feed outlet is located 100 mm above the gas distributor.

The product is separated from the air stream in a cyclone and a bag filter. Before leaving the system, the exhaust air is passed through a packed bed scrubber. A temperature controller TIC1 maintains the inlet air temperature at the desired level. A temperature controller TIC2, which is located 0.7 m above the distributor plate and connected with a feeding device, keeps the outlet air temperature constant (T_{ge}). A temperature controller TIC3, which is also placed 0.7 m above the distributor plate, is set at a temperature 20°C above the outlet air temperature. Its role is to prevent overheating of the bed, in the case of feeding device failure, by introducing pure water into the system. During experiments, the inlet air temperature and outlet air temperature were continuously recorded using a PC and a data acquisition system. Two set of experiments were performed with Calcium(II)-hydroxide suspension $Ca(OH)_2$ with glass spheres of 1.94 mm and 1.20 mm.

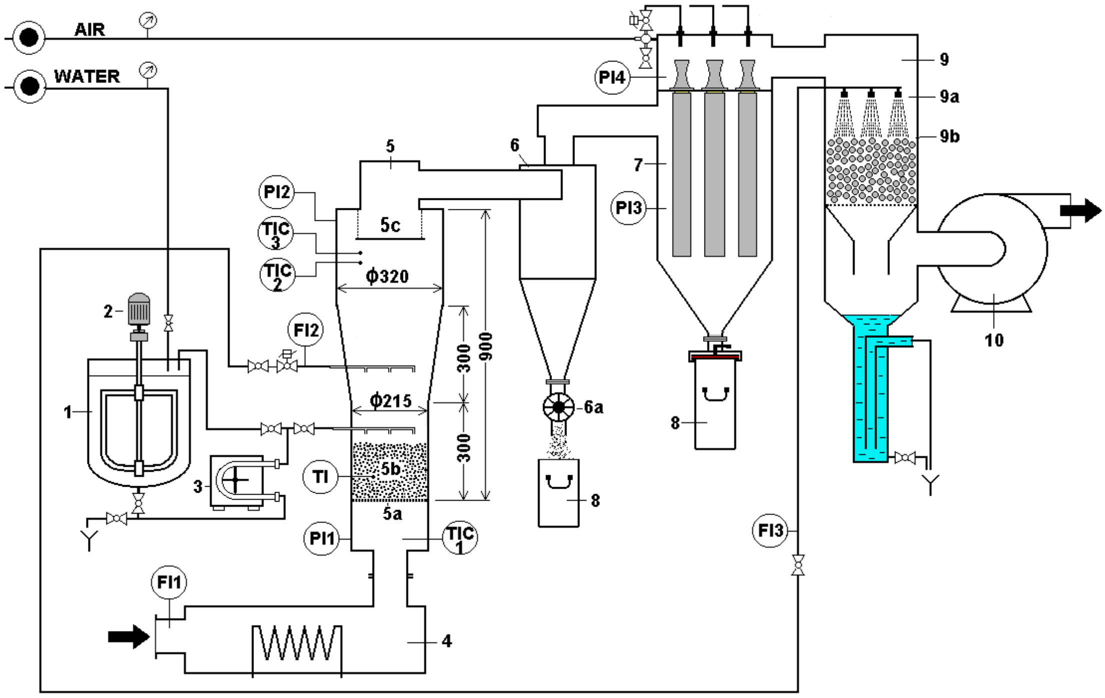

Figure 3. Schematic diagram of the drying system
(1 - Tank, 2 - Agitator, 3 - Pump, 4 - Air heater, 5 - Fluidization column, 5a - Distributor, 5b - Inert particles, 5c - Deflector, 6 - Cyclone, 6a - Rotary valve, 7 - Bag filter, 8 - Product containers, 9 - Scrubber, 9a - Nozzle, 9b - Packing, 10 - Blower, FI - Flowrate indicator, PI - Pressure indicator, TI - Movable temperature probe, TIC - Temperature indication and control)

RESULTS AND DISCUSSION

Drying experiments. The drying tests were performed continuously. For all runs, the desired air flowrate and air inlet temperature (TIC1) were selected. When the temperature above the bed (outlet air temperature) reached the set value (TIC2), the feeding process begun. In the further process the outlet air temperature was constant since TIC2 controls the feeding device. The stationary state was reached after several minutes since inlet air temperature had reached the set value TIC1. The system was very stable, i.e. during the operation the outlet air temperature variations (ΔT_{ge}) were less than 5°C. Each suspension was characterized by the water content and density, while each dried sample was characterized by the residual water content and bulk density.

Maximum feed rate. It was observed in our drying experiments that maximum feed rate securing stable hydrodynamics increases with the inlet air temperature. It also increases with the static bed height because of larger interfacial area is available for heat and mass transfer. The maximum feed rate increases with superficial air velocity as a result of more intense fluidization and enhanced evaporation rate due to higher heat transfer coefficients. These parameters can be set in such way to approach the optimum feed rate defined by energy efficiency and product moisture content. In order to obtain maximum process efficiency for a fixed inlet air temperature (T_{gi}), the outlet air temperature (T_{ge}) should be as low as possible with respect to the product quality and quality of fluidization. Usually, the residual moisture content of the product powder is the main criterion. Generally the powder moisture content decreases with an increase in outlet air temperature, as shown in Figure 4. However, the shape of this relationship depends on dried material characteristics. It can be seen that the residual powder moisture content is essentially independent of outlet air temperature above T_{ge}=100°C.

Material hold-up. The hold-up of the dried material on inert particles was measured. When temperatures of inlet and outlet air were nearly constant, suspension was fed continuously to the drying chamber. The experiments were run for additional 10-15 minutes after the steady state was reached with suspension feed. Then the air stream and suspension feed were stopped for a short time, which was enough to extract a sample of the bed. The sample was weighed, and the product film held on particles was washed off and then the mass of particles and the dry film were obtained in order to determine the material hold-up. The suspension used for this purpose was calcium hydroxide. For inert particles d_p = 1.94 mm, the hold-up varied between 7.2 and 24.2% and for inert particles d_p = 1.20 mm between 3.8 and 33.8% with respect to the inert bed mass. Based on these values, it can be observed that the higher hold-up is for the smaller particles. Mass of the product held by a unit of inert particles (m) varies from 0.02 to 0.19 kg/m^2. Assuming that the bulk density of a material surrounding inert particles is an arythmetic from the mean slurry and dry powder densities, a hypothetical thickness of the material film covering an inert particle (f) can be estimated. The calculations shows that the film thickness varies from 8.9 to 80.3 μm. Figure 5 clearly shows how the film thickness increases with the subsequent experiment, independent of the suspension concentration and temperature. For particles d_p=1.94 mm film thickness is about 80 μm, while for particles d_p=1.20 mm, the thickness is about 70 μm. This is a clear indication that cumulative formation of calcium hydroxide film on the particle surface occurs.

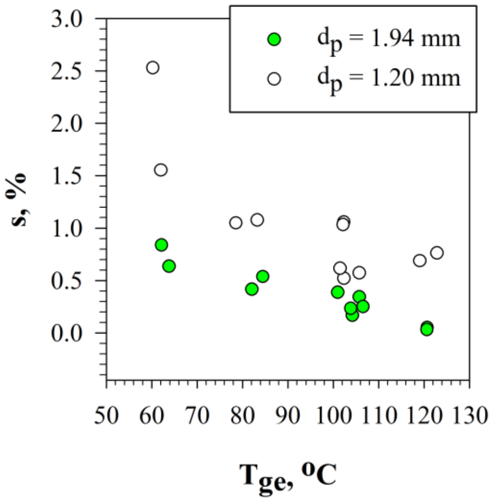

Figure 4. Product moisture content as a function of drying temperature

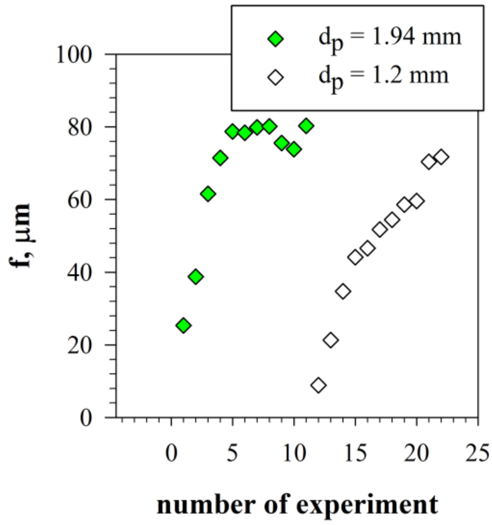

Figure 5. The thickness of the formed film on the particle surface through experiments

Mechanical grinding of the dried product from the inert particle, which determines the average thickness of this film and, consequently, the product hold-up, which is usually not constant because it depends on the process parameters, is not simple to be described quantitavely. It essentially depends on the adhesive properties of the product to the inert particles. As the viscosity of dried material is higher, the hold-up will be more pronounced [14]. Also, the material hold-ups are different for different types for inert particles, and Pan et. al. [16] observed that the soybean milk hold-up in the bed of Teflon pellets is lower than that in the bed of glass ballotini up to 15%. Stability of the drying process in fluidized bed depends on the shaking of the dried material and carrying off the powder. If stationary state conditions are not achieved the drying process would convert to that of coating. The coating process can be successfully achieved in such systems, but in the present investigation it was an unwanted effect.

Specific water evaporation rate. Figure 6 presents the specific water evaporation rate (kg_{H2O}/m^2h) as a function of the temperature difference (T_{gi}-T_{ge}), where T_{gi} and T_{ge} are the inlet and outlet air temperature, respectively. It can be seen that evaporation for a fixed gas velocity is directly proportional to the temperature difference. The highest evaporation rate in our runs was 451 $kg_{H_2O}m^{-2}h^{-1}$ at the superficial air velocity (calculated at 20°C) of U_0 = 1.76 ms^{-1} and at the inlet air temperature of T_{gi}=200°C and the outlet air temperature of T_{ge}=62°C.

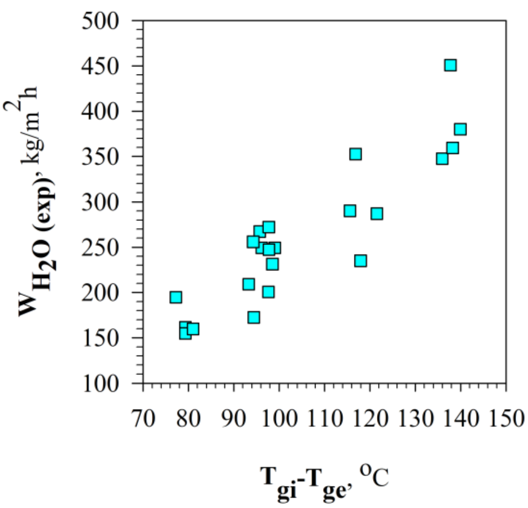

Figure 6. Specific water evaporation rate for $Ca(OH)_2$ suspension as a function of the temperature difference between the inlet and outlet air temperatures

Energy efficiency. Energy efficiency of a dryer, as well as the operating regime in which the drying process takes place, can be described using various parameters, such as the volumetric evaporation rate, heat losses to the environment, specific heat consumption and thermal (energy) efficiency. Of all the mentioned parameters, the most commonly encountered in the technical literature is the thermal efficiency [1, 2, 17]. This parameter (η'_T, η''_T or η_T) mainly relates the amount of heat required for evaporation of moisture calculated in relation either to the temperature of the surface of inert particles (T_p) or to the ambient temperature (T_0) or to the wet bulb temperature (T_{wb}), respectively, with the total energy brought to the dryer. Thus, it is defined by one of the following equations:

$$\eta'_T = \frac{(T_{gi} - T_{ge})}{(T_{gi} - T_p)}, \quad or \quad \eta''_T = \frac{(T_{gi} - T_{ge})}{(T_{gi} - T_{wb})}, \quad or \quad \eta_T = \frac{(T_{gi} - T_{ge})}{(T_{gi} - T_0)} \tag{1}$$

In Figure 7 the thermal efficiency, η_T, calculated in relation to the ambient temperature according to the Eq. (1) is shown for different inlet air temperatures. As can be seen, the thermal efficiencies are in the interval η_T = 0.44÷0.78 in our system for all the performed experiments with $Ca(OH)_2$ suspension, compared to $\eta_T \approx$ 0.3 reported for soybean milk drying in a vibro-fluidized bed at similar operating conditions ($T_{gi} \approx$ 150-160 °C) [17]. Drying efficiency increases with the increase in the temperature difference. This would mean that for a fixed inlet air temperature (T_{gi}), the drying temperature (T_{ge}) should be as low as possible in order to maximise the temperature difference T_{gi}-T_{ge}. The main factors influencing the choice of the T_{ge} value are the product quality and quality of fluidization. Usually, the residual moisture content of the product powder is the main criterion.

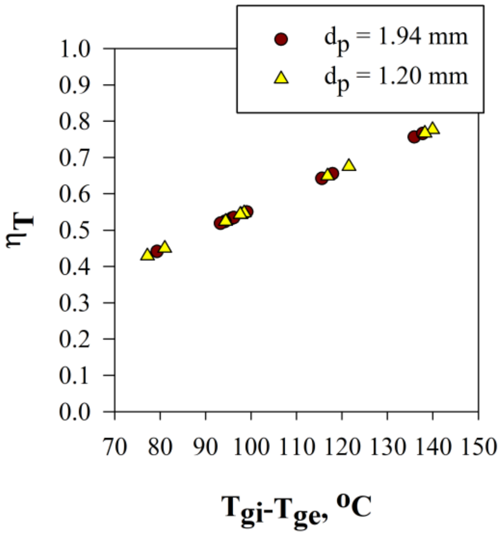

Figure 7. Thermal efficiency as a function of the temperature difference between the inlet and outlet air temperatures

Heat and mass balances. From the overall mass and heat balance follows a simple relationship between the inlet air temperature (T_{gi}) and the specific water evaporation rate (W_{H2O}) [8, 11]:

$$W_{H_2O} = \frac{G_{H_2O}}{A_c} = \frac{1}{A_c} \cdot \frac{G_v c_v \left(T_{gi} - T_{ge}\right) - Q_g}{\left[\left(1-x\right)/x\right] c_{dm} \left(T_{ge} - T_0\right) + c_{H_2O}\left(T_{ge} - T_0\right) + r_{H_2O}} \tag{2}$$

For a fixed geometry of the fluidized bed (A_c), the air flowrate, i.e., the superficial air velocity follows from the fluid bed mechanics and it should be usually 2–3-fold higher than the minimum fluidization velocity (U_{mF}). A comparison between experimental and calculated values of W_{H2O}, by using c_{dm}≈1.18 kJ kg^{-1}°C^{-1}, is shown in Figure 8. The mean absolute deviation between the experimental and calculated values is 9.2%, while 85% of the data falls within ±10%. Differences between the experimental and calculated values are probably due to the fact that heat losses were neglected in the calculations.

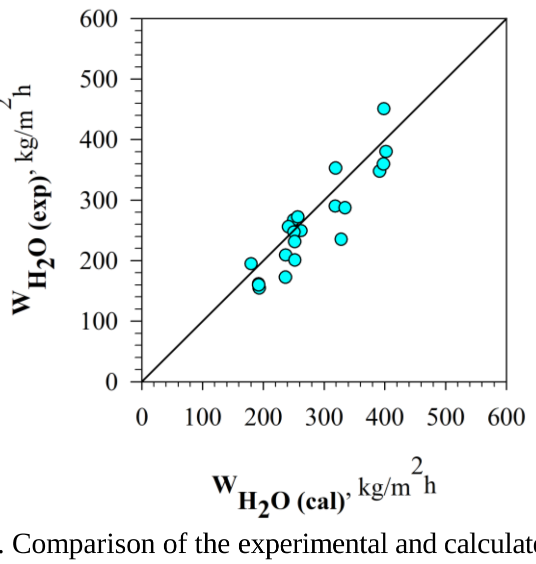

Figure 8. Comparison of the experimental and calculated values of the specific water evaporation rate.

CONCLUSION

Drying of solutions, suspensions and pastes in a fluidized bed of inert particles is characterized by high evaporative capacity per unit volume of the dryer, low energy consumption, and low specific air consumption. The high drying efficiency results from the large contact area and from the large temperature difference between the inlet and outlet air. Intensive mixing of particles leads to nearly isothermal conditions throughout the bed. Powdery product moisture content decreases with an increase in outlet air temperature and the shape of this relationship depends on dried material characteristics. Inlet air temperature, superficial air velocity and static bed height can be set in such way to approach the optimum feed rate defined by energy efficiency and product moisture content.

NOMENCLATURE

Latin symbols

A_c – Cross-sectional area of the column at distributor plate, m^2

A_p – Total area of the inert particles in the fluidized bed, m^2

c_{dm} – Specific heat of dry matter, kJ kg^{-1} K^{-1}

c_{H2O} - Specific heat of water, kJ kg^{-1} K^{-1}

c_v – Specific heat of air, kJ kg^{-1} K^{-1}

d_p – Inert particle diameter, m

D_c – Column diameter (at distributor plate), m

f – Hypothetical thickness of the material film covering an inert particle, µm

G_{dm} – Mass flowrate of dry matter, kg s^{-1}

G_{H2O} – Water mass flowrate, kg s^{-1}

G_{sus} – Suspension mass flowrate, kg s^{-1}

G_v – Air mass flowrate, kg s^{-1}

M – Mass of the bed of inert particles, kg

m – Mass of the product held by a unit of inert particles, kg m^{-2}

q – Specific heat consumption, based on T_{gi}-T_{ge}, kJ kg_{H2O}^{-1}

q' – Specific heat consumption, based on T_{gi}-T_0, kJ kg_{H2O}^{-1}

Q_g – Heat losses, kJ s^{-1}

r_{H2O} – Latent heat of water evaporation, kJ kg_{H2O}^{-1}

s – Product moisture content, % kg_{H2O}^{-1}

T_{gi} – Inlet air temperature, °C

T_{ge} – Outlet air temperature, °C

T_0 – Ambient temperature, °C

T_{wb} – Wet bulb temperature, °C

U_0 – Superficial fluid velocity at distributor plate (at T_0), m s^{-1}

U_{mF} – Minimum fluidization velocity at distributor plate (at T_0), m s^{-1}

V_0 – Air flowrate (at T_0), m^3 s^{-1}

W_{H2O} – Specific water evaporation rate ($=G_{H2O}/A_c$), kg $m^{-2}s^{-1}$

x – Water content in the suspension (G_{H2O}/G_{sus}), kg kg^{-1}

Greek symbols

η_T – Thermal efficiency, in relation to the ambient temperature (T_0)

η'_T – Thermal efficiency, in relation to the temperature of the surface of inert particles (T_p)

η''_T – Thermal efficiency, in relation to the wet bulb temperature (T_{wb})

ACKNOWLEDGEMENT

Financial support of the Serbian Ministry of Education and Science (Project ON172022) is gratefully acknowledged.

REFERENCES

[1] Mujumdar AS. *Handbook of Industrial Drying*. 4th ed., New York, NY: Marcel Dekker; 2014.
[2] Kudra T., Mujumdar AS. *Advanced Drying Technologies*. 2nd ed., New York, NY: Marcel Dekker; 2009.
[3] Kudra T, Mujumdar AS. Special Drying Technologies and Novel Dryers. In Mujumdar AS, ed. *Handbook of Industrial Drying*. 4th ed., New York, NY: Marcel Dekker; 2009:1087-1149.
[4] Reger EO, Romankov PG, Rashkovskaya NB. Drying of Paste-like Materials in Spouted Beds with Inert Bodies. *Zhurn.Prikl.Khim*. 1967; 40:2276. (in Russian)
[5] Romankov PG. Drying. In: Davidson JF, Harrison D, eds. *Fluidization*. London: Academic Press; 1971:569-598.

[6] Pham QT. Behavior of a Conical Spouted-Bed Dryer for Animal Blood. *Can.J.Chem.Eng*. 1983; 61:426-434.
[7] Hadžismajlović DžE, Povrenović DS, Grbavčić ŽB, Vuković DV, Littman HA. Spout-Fluid Bed Drier for Dilute Solutions Containing Solids. In: Grace JR, Shemilt LW, Bergougnou MA, eds. *Fluidization VI*. New York, NY: Engineering Foundation; 1989:277-283
[8] Grbavcic ZB, Arsenijevic ZL, Garic-Grulovic RV. Drying of slurries in fluidized bed of inert particles. *Drying Technol.* 2004; 22:1793-1812.
[9] Arsenijević Z. Drying suspension in the industry, 1st ed. Serbia, Andrejevic Foundation; 2008. (in Serbian)
[10] Reyes A, Diaz G, Marquardt F-H. Analysis of Mechanically Agitated Fluid-Particle Contact Dryers. *Drying Technol*. 2001; 19:2235-2259.
[11] Grbavcic ZB, Arsenijevic ZL, Garic-Grulovic RV. Drying of suspension and pastes in fluidized bed of inert particles. *J.Serb.Chem.Soc.* 2000; 65:963–974.
[12] Vieira, M.G.A., Donida, M.W. and Rocha, S.C.S., Adhesion of an aqueous polymeric suspension to inert particles in a spouted bed, Drying Technol., 22 (2004) 1069-1085.
[13] Leontieva, A.I., Bryankin, K.V., Konovalov. V.I. and Utrobin, N.P., Heat and mass transfer during drying of a liquid film from the surface of a single inert particle, Drying Technol. 20 (2002) 729-747.
[14] Spitzner Neto, P.I., Cunha, F.O. and Freire, J.T., Effect of the presence of paste in a conical spouted bed dryer with continuous feeding, Drying Technol. 20 (2002) 789-811.
[15] Kutsakova, V.E., Drying of liquid and pasty products in a modified spouted bed of inert particles, Drying *technol.*, 22 (2004) 2343-2350.
[16] Pan, Y.K., Li, J.G., Zhao, L.J., Ye, W.H., Mujumdar, A.S. and Kudra, T., Performance characteristics of the vibrated fluid bed of inert particles for drying of liquid feeds, *Drying Technol.*, 2001 19(2001) 2003-2018.
[17] Pan YK, Li JG, Zhao LJ, Ye WH, Mujumdar AS, Kudra T. Performance characteristics of the vibrated fluid bed of inert particles for drying of liquid feeds. *Drying Technol*. 2001; 19:2003-2018.

APPLICATION OF IRON-OXIDE LOADED ALGINATE BEADS IN REMOVAL OF ARSENIC FROM WATER

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Abstract: In this paper, adsorption of arsenic (V) ions from aqueous solutions was investigated, using iron oxide particles immobilized in Ca-, Al-, and Cu-alginate particles as adsorbents in order to determine the kinetics for these processes. The concentrations of arsenic ions after the adsorption were monitored using atomic absorption spectrophotometry (AAS). Based on the experimental results, kinetic parameters for pseudo-first order and pseudo-second order were determined. The obtained results showed that investigated adsorbents have very promising potential for fast reduction of arsenic (V) ion concentrations in polluted waters to desirable levels in a cost-effective and efficient manner.
Key words: arsenic, adsorption, ferric oxide, alginate beads

INTRODUCTION

Pollution of water is one of the most important ecological issues nowadays. Heavy metal contamination of water poses as the main threat to human health. These toxic inorganic chemicals may have very harmful health effects, if not immediate, then after continued exposure. Arsenic, considered as one of the most dangerous heavy metals, is present in natural waters – it exists in the Earth's crust, which is the main source of water contamination. Arsenic is a steel-gray, brittle, toxic, non-degradable heavy metal which exists in nature in different oxidation states, out of which the most frequent are -III (arsines), zero (arsenic), +III (arsenite) and +V (arsenate) [1]. Presence of arsenic in ground water is induced by weathering of rocks, volcanic emissions, biological activities and geochemical reactions. In ground water, arsenic is present in forms of arsenite (III) and arsenate (V) [2]. Epidemiological studies have shown that high levels of arsenic in drinking water can be associated with a significant increase in the risks of lung, skin, bladder, liver cancer and vascular disorders. In order to avoid health problems associated with arsenic contamination of drinking water, the World Health Organization (WHO) has recommended a maximum contamination limit of 10 μg/L [3]. Therefore, removal of arsenic from water becomes an essential task in environmental engineering. With the aim of attaining required standards, many approaches have been developed recently, including adsorption, ion exchange, reverse osmosis, nano-filtration, coagulation, membrane permeation and oxidation. Adsorption is a highly efficient and practical, low cost method. It is a process by which solute molecules attach to the surface of an adsorbent. This method doesn't involve undesirable by-products and the used adsorbents can be regenerated for reuse up to a quite good number of times. Then again, adsorption has its flaws – same adsorbent won't show good results for different kinds of water pollutants, and also, there are difficulties with using this method on the commercial level, caused by unavailability of suitable adsorbents and commercial scale columns.

THEORETICAL PART

Use of nano-particles in adsorption of heavy metals

Researchers have developed nano-size adsorbents with the intention of developing an effective adsorbent adequate for arsenic removal. Unlike macromolecules, which have intra-particle diffusion that decreases the adsorption rate and available capacity of the adsorbent, nanoparticles have small diffusion resistance, which puts them ahead of macromolecules when it comes to adsorption power. [4]. Nanoparticles are small atomic clusters with <100 nm size [5] which are 5-10 times more efficient than their micron size equivalents when it comes to arsenic removal [6]. A material has better adsorption capacity if it has larger surface area, and according to that many studies have shown that amorphous metal oxides have high adsorption capacities [7]. Iron compounds have shown the lowest leaching of adsorbed arsenic from exhausted adsorbent, therefore they are recommended for use in arsenic removal from water. Use of iron-oxide has presented good results in arsenic adsorption, but the biggest challenge for using these particles is their fine powder form. The fine powder form leads to low hydraulic conductivity, due to which these materials are not fit for using in column applications [8]. There are a few exceptions for using these materials in fixed-bed columns – if they are granular in shape supported on relatively larger size porous materials such as polymers, sand, activated carbon etc. Although there are number of options, selecting the suitable supporting material for nano-particles is rather demanding [9].

Alginates as immobilization agents

Challenges that come along with nano-particles were overcome by using different materials as immobilization agents. In this study, alginate has been used as an immobilization agent for iron-oxide nano-particles. Alginate is a biopolymer, mainly made by extraction from brown seaweed. It is a linear polysaccharide of (1→4)-linked R-L-guluronate (G) and α-D-mannuronate (M) residues arranged in a nonregular, block-wise pattern along the linear chain [10,11]. We must also mention that alginates have noticeable sorption capacity towards several heavy metal ions, such as Pb^{2+}, Zn^{2+}, Cd^{2+}, and Ni^{2+} from aqueous solutions, although they are typically used as immobilization agents [11]. As a result of combining monovalent cations with alginic acid we get monovalent salts which are known as water-soluble types of alginate, while divalent cations in combination with alginic acid give us thermally irreversible gels, insoluble in water [12]. In this study, we used two different kinds of divalent cations combined with alginic acid, and one trivalent cation in order to have wider range of results – Ca^{2+}, Cu^{2+} and Al^{3+}. Those thermally irreversible gels, when combined with ferric oxides, gave us ferric oxide doped alginate beads which we used in our adsorption experiments.

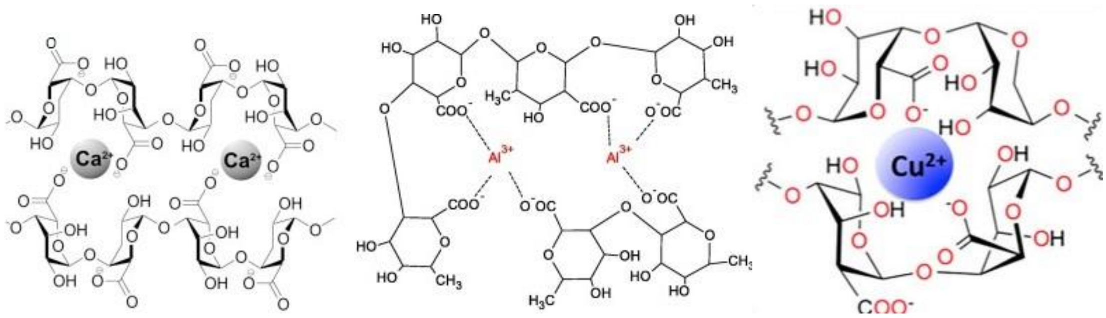

Figure 1. Ca, Al and Cu combined with alginates

Adsorption kinetics

Aiming to design and optimise an adsorption process, the crucial parameter to consider is the adsorption kinetics. Kinetics dictates the rate at which the adsorption occurs. Solute concentration and flow and surface complexity of the adsorbent affect the adsorption kinetics [13]. Adsorption on a solid surface includes following processes:

1. Transporting the adsorbate from the liquid phase to the boundary layer of the adsorbent
2. Film diffusion – transport of the adsorbate through the boundary layer to the external surface of the adsorbent
3. Intraparticle diffusion – transport of the adsorbate to the inside of the adsorbent by pore diffusion or diffusion along the inner surface
4. Establishing the interactions between the adsorbate and adsorbent

We assume that first and fourth processes are fast-moving and that the total adsorption rate depends only on film diffusion and/or intraparticle diffusion. Since these two processes are happening simultaneously, slower process is the adsorption rate limiting step – it is essential to determine which one is it. Hydrodynamic conditions and the size of the adsorbent particles affect the speed of the film

and intraparticle diffusion. Besides that, size of the adsorbent also affects the external diffusion. Mass transport inside the adsorbent consists of pore diffusion and surface diffusion, where these are parallel processes and their individual contributions are hard to determine, so we consider one of these as a dominant mechanism [13].
Adsorption rate changes with time – from the highest values at the beginning, to the end of the process when dynamic equilibrium is acquired (adsorption is completed – adsorption rate is equal to zero).
Mathematical models are used to describe the adsorption kinetics – the most commonly used are Pseudo-First-Order (PFO) [14] and Pseudo-Second-Order (PSO) [15], they have been broadly applied in nearly every adsorption process.

Pseudo-First-Order model (PFO)

PFO, also known as the Lagergren model, describes the adsorption rate based on the adsorption capacity [16]. This model links the adsorption rate to the number of free active spaces on the surface of the adsorbent.
It is presented by the equation [13,17]:

$$\frac{dq_t}{dt} = k_1(q_e - q_t) \tag{1}$$

When we linearize the equation, we get:

$$\ln(q_e - q_t) = \ln(q_e) + k_1 \cdot t \tag{2}$$

where q_e (mg/g) is equilibrium adsorption capacity, q_t (mg/g) is adsorption capacity in time t (min) and k_1 (min^{-1}) is the PFO adsorption rate constant.

Pseudo-Second-Order model (PSO)

Kinetic PSO model is based on the assumption that adsorption can be presented as the second order chemisorption. This model assumes that the rate of adsorption is proportional to the number of the available active sites on the adsorbent – the driving force (q_e–q_t) is proportional to the number of active sites available on the adsorbent [13]. PSO model is based on the equilibrium adsorption capacity and it is described with following equations:

$$\frac{dq_t}{dt} = k_2(q_e - q_t)^2 \tag{3}$$

$$\frac{d(q_e - q_t)}{q_e - q_t} = -k_2 dt \tag{4}$$

$$q_t = \frac{k_2 q_e t}{(1 + q_e t)} \tag{5}$$

Linear shape of the equation:

$$\frac{t}{q_t} = \frac{t}{q_e} + \frac{1}{k_2 {q_e}^2} \tag{6}$$

where q_e, q_t and t are the same as in the PFO model, and k_2 (min^{-1}) is the PSO adsorption rate constant.

EXPERIMENTAL PART

Materials

Materials used in those experiments were:

1) 2% Natrium-alginate solution (water + Na-alginate);
2) Arsenate (V) solution, 5ppm;
3) Calcium-chloride, $CaCl_2*2H_2O$;
4) Aluminum-chloride, $AlCl_3$;
5) Copper-sulfate, $CuSO_4$.

Preparation of the adsorbent particles

Standard 2% Na-alginate solution was made by dissolving 1g of Na-alginate in 50ml of distilled water. Ferric oxide nano-particles are made by oxidation of the iron(II)-sulfate, Fe_2SO_4 with the adequate amount of the sodium bicarbonate, $NaHCO_3$. Adding the nano-particles to the alginate solution and then dripping that mixture into the 2% solution of the calcium, aluminum and copper ions gives us the adsorbent particles.
As a result of dripping, alginate gel adsorbent particles (Ca, Al and Cu) were formed. These adsorbents were used separately in three identical experiments done simultaneously – particles were put in the 50ml glasses with 5 ppm arsenate (V) solution, and the arsenate concentration was measured in each of these solutions in specified intervals of time (5min, 10min, 20min, 30min, 45min, 60min, 90min, 120min).

Figure 2. Dripping alginate and ferric oxide mixture into the $CaCl_2$ solution

RESULTS AND DISCUSSION

On the basis of the measured arsenate concentrations from the experiments, following graphs will be presented:

1. Adsorption capacity, q_t (mg/g) – amount of arsenate adsorbed per mass unit of the adsorbent is presented with the following equation:

$$q_t = \frac{(c_0 - c_t)V}{m} \qquad (7)$$

where c_0 (mg/dm^3) is the concentration of the arsenate at the beginning of the process, c_t (mg/dm^3) is the concentration of arsenate in time t, m (g) is the mass of the adsorbent and V (dm^3) is the volume of the arsenate solution. Graphical comparison of adsorption capacity for all three cases is presented below. Following graphs show change of adsorption capacities vs. time.

As it can be seen from those graphs, the maximum adsorption capacity for investigated concentration of arsenate ions is reached in the first 5 min of the process which is considered as very fast in terms of kinetics.

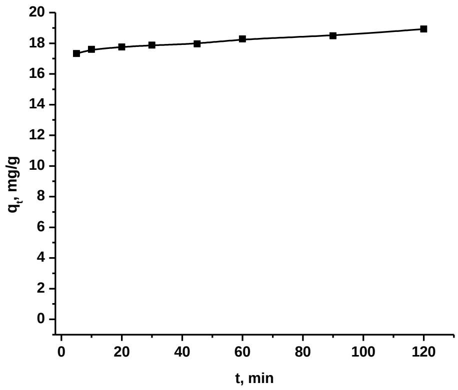

Figure 3. q_t – t for Ca^{2+}

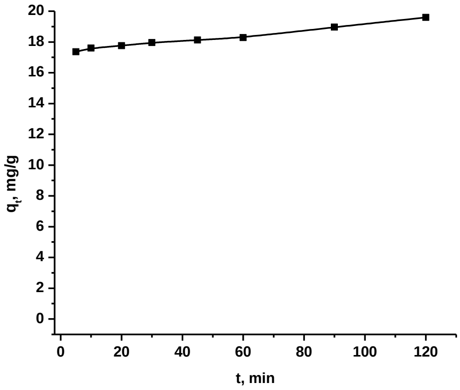

Figure 4. q_t – t for Al^{3+}

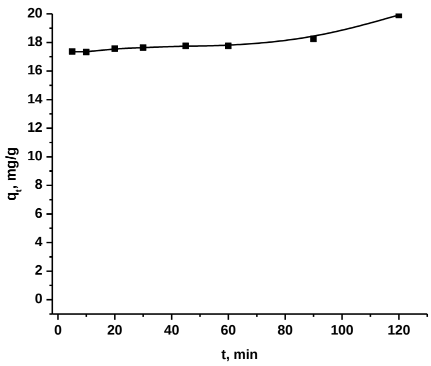

Figure 5. q_t – t for Cu^{2+}

2. <u>Adsorption efficiency</u>, *R* (%) is calculated with the following equation:

$$R = (c_0 - c_t) / c_0 * 100 \tag{8}$$

Graphs given below show dependencies of adsorption efficiencies vs. time for all three cases. As it can be seen from Figures 6-8. adsorption efficiency of more than 85% was achieved in first 5 minutes for investigated concentration of arsenate ions while almost total removal was acquired after 2 hours.

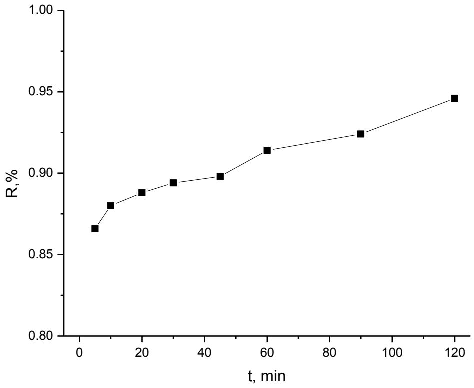

Figure 6. R – t for Ca^{2+}

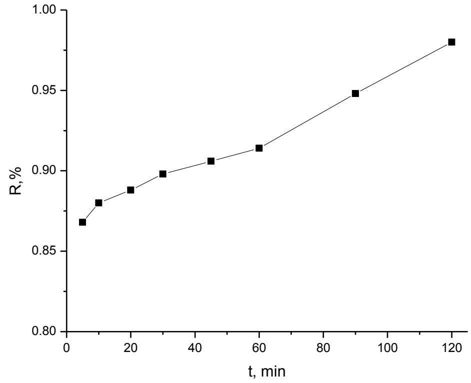

Figure 7. R – t for Al^{3+}

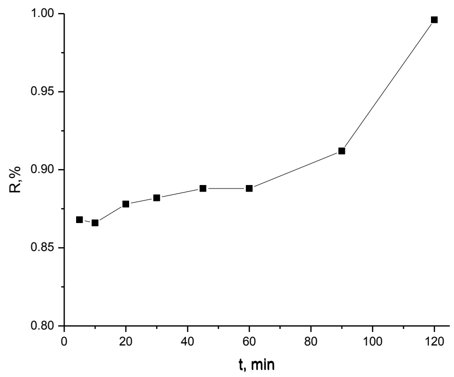

Figure 8. R – t for Cu^{2+}

3. Adsorption kinetics. Adsorption kinetics was investigated by Pseudo First Order (PFO) and Pseudo Second Order (PSO) models. Based on the analysis, it was concluded that PSO model describes adsorption kinetics better (higher R^2 values and the adsorption capacity value which were close to the experimental ones). For PSO graphs are presented in Figures 9-11. which represent PSO models for all three cases. Obtained kinetic data for PFO and PSO models and for all adsorbents are summarized in Table 1.

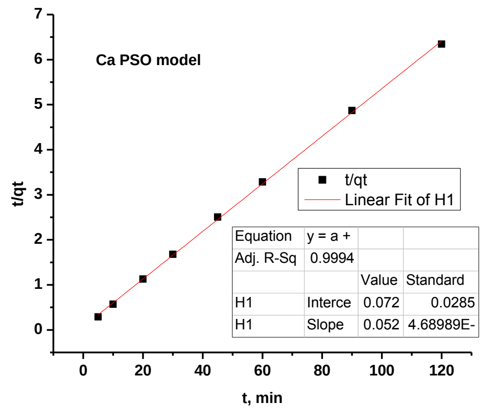

Figure 9. t/q_t – t for Ca^{2+}

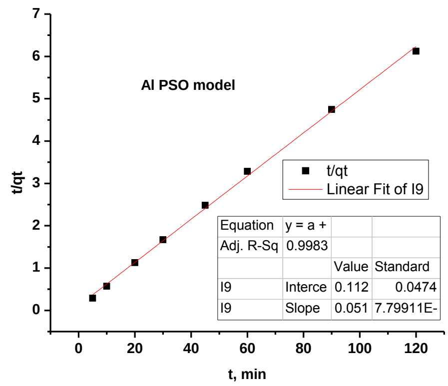

Figure 10. t/q_t – t for Al^{3+}

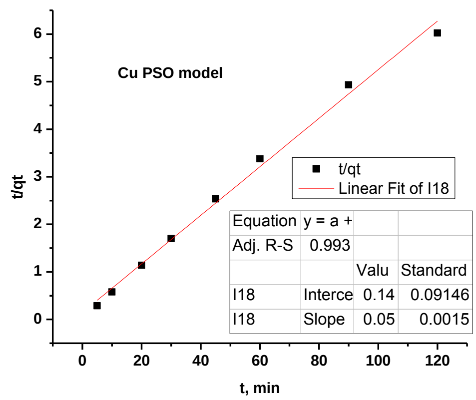

Figure 11. t/q_t – t for Cu^{2+}

Table 1. The obtained parameters for pseudo-first-order, pseudo-second-order

Kinetic model		Ca-gelled	Al-gelled	Cu-gelled
Pseudo-first-order	**K_1 (min^{-1})**	-0.0124	-0.0101	-0.0128
	q_e (mg/g)	1.481	1.710	2.072
	R^2	0.7709	0.7927	0.5394
Pseudo-second-order	**K_2 (min^{-1})**	0.0384	0.0231	0.0178
	q_e (mg/g)	18.93	19.61	19.61
	R^2	0.9995	0.9983	0.9940

CONCLUSION

Based on the performed experiments, obtained results and presented discussion, the following conclusions may be derived:

- The type of ions used for alginate particles gelling has very small influence on the adsorption process of arsenate ions.
- The sorption kinetics of As (V) onto tested adsorbents could be represented by the pseudo-second-order kinetic model. Since for the pseudo-first-order kinetics the rate-limiting step is diffusion (physical process), while for the pseudo-second-order the rate-limiting step is the chemical reaction (chemical process) it may be concluded that those adsorbents have good mass transfer properties, or in other words that they have easily available surface for adsorption.
- The kinetic parameters of investigated adsorbents indicate that they have very fast adsorption kinetics with preferable adsorption capacities.
- Further investigations are needed in order to determine other important adsorption parameters of investigated materials.

REFERENCES

[1] Oremland, R.S., Stolz, J.F., The ecology of arsenic. Science, No, 300, pp. 939–944, 2003.

[2] Kanel, S.R., Manning, B., Charlet, L., Choi, H., Removal ofarsenic (III) from groundwater by nanoscale zero-valent iron, Environmental Science and Technology, Vol. 39, pp. 1291–1298, 2005.

[3] Yamamura, S., Bartram, J., Csanady, M.H., Gorchev, G., Redekopp, A., Drinking water guidelines and standards, Arsenic, water, and health: the state of the art, 2003.

[4] Attia, T.M.S., Hu, X.L., Yin, D.Q., Synthesised magnetic nanoparticles coated zeolite (MNCZ) for the removal of arsenic (As) from aqueous solution, Journa of Experimental Nanoscience, Vol. 9, pp. 1–10, 2012.

[5] Husein, M.M., Nassar, N.N., Nanoparticle preparation using the single microemulsions scheme. Current Nanoscience, Vol. 4, pp. 370–380, 2008.

[6] Ponder, S.M., Darab, J.G., Bucher, J., Caulder, D., Craig, I., Davis, L., Edelstein, N., Lukens, W., Nitsche, H., Rao, L., Shuh, D.K., Mallouk, T.E., Surface chemistry and electrochemistry of supported zerovalent iron nanoparticles in the remediation of aqueous metal contaminants, Chemistry of Materials, Vol. 13, pp. 479–486, 2001.

[7] Trivedi, P., Axe, L.A., Comparison of strontium sorption to hydrous aluminum, iron, and manganese oxides, Journal of Colloid and Interface Science, Vol. 218, pp. 554–563, 1999.

[8] Zeng, L.A.A., Method for preparing silica-containing iron (III) oxide adsorbents for arsenic removal. Water Research, Vol. 37, pp. 4351–4358, 2003.

[9] Balaji, T., Matsunaga, H., Adsorption characteristics of As(III) and As(V) with titanium dioxide loaded with amberlite XAD-7 resin, Analitical Sciences, Vol. 18, pp. 1345–1349. 2002.

[10] Milivojevic, M., Pajic-Lijakovic, I., Levic, S., Nedovic, V., Bugarski, B. Alginic Acid: Sources, Modifications and Main Applications, In: Alginic Acid - Chemical Structure, Uses and Health Benefits, Adrianna Moore, Ed., Chapter 3, pp. 45-88, Nova Science Publishers Inc., New York, 2015.

[11] Fundueanu, G., Nastruzzi, C., Carpov, A., Desbrieres, J., Rinaudo, M., Physicochemical characterization of Ca-alginate beads microparticles produced with different methods, Biomaterials, Vol. 20, pp. 1427-1435, 1999.
[12] Velings, N., Mestdagh, M., Physicochemical properties of alginate gel beads, Polymer Gels and Networks, Vol. 3, pp. 311-330, 1995.
[13] Kajjumba, G.W., Emik,S., Öngen, A., Özcan, H.K., Aydın S., Modelling of Adsorption Kinetic Processes—Errors, Theory and Application, Advanced Sorption Process Applications, IntechOpen Ltd., 2018.
[14] Lagergren, S., About the theory of so called adsorption of soluble substances, Kungliga Svenska Vetenskapsakademiens Handlingar, Vol. 24, pp. 1-39, 1898.
[15] Ho, Y.S. McKay, G., Pseudo-second order model for sorption process, Process Biochemistry, Vol. 34, pp. 451-465, 1999.
[16] Taleb,K. Markovski, J. Milosavljević, M. Marinović-Cincović, M. Rusmirović, J. Ristić, M. Marinković, A., Efficient arsenic removal by cross-linked macroporous polymer impregnated with hydrous iron oxide: Material performance, Chemical Engineering Journal, Vol. 279, pp. 66-78, 2015.
[17] Gallegos-Garcia, M. Ramírez-Muñiz, K. Song, S., Arsenic removal from water by adsorption using iron oxide minerals as adsorbents: a review, Mineral Processing and Extractive Metallurgy Review, Vol. 33, pp. 301-315, 2012.

SESSION 1. MECHANICAL ENGINEERING

A PERSPECTIVE APPROACH TO HAZELNUT HARVESTING FOR SLOPING PLANTAGE

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Abstract: The total amount of world production of hazelnut is mainly around 800.000 tons/year. About 65% of world's hazelnut production is harvesting in Turkey. Hazelnut is a crucial and non-equivalent material for praline production, which is semi-finished product of chocolate industry. Moreover, hazelnut has an annual export revenue of approximately $ 2 billion as an important product for Turkey. Due to the appropriate climatic conditions and availability of harvesting in the extreme sloppy and less qualified agricultural land of Ordu, Giresun and Trabzon, the protection and development of hazelnut-planted areas becomes among the priority issues. The slope fragmentation of cultivated areas and cultivar characteristics do not allow for mechanization, except for lowlands. This leads to increases in hazelnut production costs and also in labor-intensive requirements during the harvest period. In Turkey, most hazelnuts remain multistemmed and are planted in brush. All of the hazelnut harvesting is still done entirely by hand in this region of Turkey. Due to the fact that machine farming has not been passed or not widespread in this region, production costs have increased such that they remain at very high levels when compared with other countries or other cities in Turkey. In this study, it has focused on the mechanized harvesting, and sustainability of the hazelnut cultivation in less qualified sloppy mountainous agricultural lands.

INTRODUCTION

Hazelnut, a non-hygroscopic porous material with high oil content, is accepted as grains [1]. The rapid increase in population, the need of healthy nutrition and provide of sufficient food materials reveal the need for optimum evaluation of the agricultural areas. On the other side, hazelnut has an annual export revenue of approximately $2 billion as an important product for Turkey. Due to the appropriate climatic conditions and availability of harvesting in the extreme sloppy and less qualified agricultural land of Ordu, Giresun and Trabzon, the protection and development of hazelnut-planted areas becomes among the priority issues [2].

The slope fragmentation of cultivated areas and cultivar characteristics do not allow for mechanization, except for lowlands. This leads to increases in hazelnut production costs and also in labor-intensive requirements during the harvest period. In Turkey, most hazelnuts remain multistemmed and are planted in brush. All of the hazelnut harvesting is still done entirely by hand in Turkey [3].

Due to the fact that machine farming has not been passed or not widespread in this region, production costs have increased such that they remain at very high levels when compared with other countries or other cities in Turkey. In this study, it has focused on the mechanized harvesting, and sustainability of the hazelnut cultivation in less qualified sloppy mountainous agricultural lands [2].

MATERIAL AND METHODS

Harvesting machines for some fruits such as apples and some nuts such as walnuts, chestnuts, hazelnuts, and olives are similar to each other. It is possible to group the harvesting machines suitable for these products into two categories as picking from branches or collecting from ground border. In this study, the machines that collect the products from ground borde will be investigated. It is possible to classify this machines as rotary brush with moving band, and vacuum suction systems. These types of machines were commercialized nowadays.

Current status and systems

Machines with rotary brush and moving band

Such machines have been developed for collecting ground falling fruits such as apples, pears, etc, which are suitable for fruit juice for further evaluation. This kind of machines can be easily adapted to nuts such as hazelnuts, walnuts and chestnuts, and olives due to use of some appropriate equipments. They are driven by its own gasoline engines. This motor drives the machine with adjustable slow speeds. At the same time, it rotates the conveying band mechanism from bottom to the top to fill the product available for the vehicle width. The driver or the operator can change the direction of the vehicle / machine from back side of the machine Figure 1 [4, 5].

Figure 1. Machines with rotary brush and moving band

Vacuum suction machines

Vacuum suction machines can pick up the product by vacuum hose and brushed or unbrushed nozzles. High pressure type radial fans are used for vacuum. The fan powers vary according to the suction distance. Commercializing units can reach up to 100 meters of suction distance. The harvesting products are picked up by vacuum power from the ground conveyed by the high air velocities in the suitable diameter hose and come to the collection and precipitation chamber. In the collecting chamber, harvesting product are seperated due to the sufficient big cross-sectional area of chamber. The collected product can be taken off due to suitable air lock mechanism continuously or sliding door mechanism batchwise. Hose suction machine adaptation was applied in Italy as follows [6].

a) Portable back type vacuum suction unit

The product, which is sucked and conveyed through the hose, accumulates due to its weight in the precipitation chamber. The hopper must be emptied at various intervals.

Figure 2 Portable back type vacuum suction unit

b) Tractor-adapted vacuum suction unit with grain extraction function

The system is driven by the tail shaft of the tractor. Therefore, it requires working with large tractors. The system is equipped with an airlock mechanism for vacuum suction and continuous discharge of the product. Also the grain extraction function is also available in the system. The same system is available in self-propelled and small tractor-mounted applications [7].

Figure 3. Tractor-adapted vacuum suction unit with grain extraction function

c) Vacuum suction unit adapted to the crawler digger

In order to carry the vacuum suction harvesting system in the case of sloping and high sloping land, the system is installed is on a crawler digger which is applied and tried in sicily, Figure 4 [8].

Figure 4. Vacuum suction unit adapted to the crawler digger

RESULTS AND DISCUSSION

Recommended compact portable system

The cultivation of hazelnuts at sloping lands is characterized by several factors that make it difficult and dangerous to use mechanization systems for operators, at all stages of cultivation, especially in the harvesting phase. Some of these factors are predominantly irregular plantations, a high degree of acclimatization of the land slopes, uneven ground conditions, a lack or absence of business and interpersonal viability, presence of obstacles to the passage of machines, and unusual soil management with the abandonment of pruning residues on the ground.

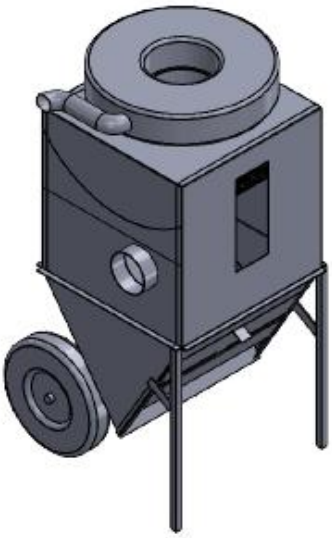

Figure 5. Recommended compact portable system

Considering the heavy conditions and the slope of the terrain, a functionable system is required. Also, the initial investment cost should not be high. Even though their catalogs value of 1 ton/hour of flatland type harvester, they can barely reach to 1-2 ton/day because of unexpected difficult conditions. have a capacity of 1 ton per hour, even harvesting machines requiring flat tractors can collect around 1 tons of hazelnuts per day. Manually, 20-30 kg of nuts per day can be picked up.. It is aimed that the designed system can be operated with minimum labor force, compact and small structure, low energy requirement, suitable for various heavy conditions. Considering all these, harvesting capacity shall be between 100-200 kg per day with one or two operators. The self propelled gasoline motor suction system can be driven manually or electrically by a two or three wheeled structure in the form of a platform Figure 4. System hopper can have batch type unloading mechanism or if needed suitable for continuous operation.The design of lightweight, small size and compact unit is crucial, Figure 5. It shall be passed on the small pathway either hand-driven or electrically driven. This small and compact unit shall take the harvesting product from reasonable and appropriate distances, be able to work in all heavy conditions and to reduce the labor costs of harvesting generally in significant amount.

CONCLUSION

Principally, both kind of harvester should be adapted and used on sloping land. Optimum evaluation of suitable land for agriculture is an issue that should be taken into consideration in terms of food safety. In the first class irrigable lands, all kinds of agriculture can be made easily and productive in 2, 3 and 4 times per year depending on the climate conditions. In Turkey, the ratio of first class irrigable land to total surface area is one of the lowest in the world. This is a critical disadvantage compared to other countries. Nuts such as hazelnut, walnuts and almonds do not require such lands generally. On the other side, hazelnuts need to have high relative air humidity level in June and July. This high relative humidity is available in the Eastern Black Sea region. The products grown in appropriate climatic conditions of eastern blacksea are superior to other regions via product feature, especially in terms of flavor. The heavy and challenging geographic conditions in this region make he cultivation and harvesting process difficult and expensive. Therefore, the unit harvesting cost of product in this region are also higher than other regions. The high cultivation cost causes to the fact that the hazelnut producers in our region do not apply adequate yearly maintenance and fertilization work to their plantage. It is crucial to preservation hazelnut planting areas in the Eastern Black Sea region with high slopin land structure and to reduce total cultivation costs inclusive harvesting.

Hazelnut lands in the provinces of Ordu, Giresun and Trabzon generally have moderate and high slope. The lands in this region are divided into small parts by inheritance. It is almost impossible alternative agricultural production in the lands of this region. Moreover, ensuring the sustainability of hazelnut agriculture in this region and to keep and protect the first class irrigable lands for other products not suitable for sloping subjected second class lands for world agricultural food safety policy. Therefore, it is important to apply mechanical harvesting methods to reduce harvest costs in this region.

REFERENCES

[1] Guney M.S., Tepey. : Improving the roasting process and efficiency of hazelnut Advances in Food Science Volume 38 No 3 pp 109-116, 2016
[2] Guney M.S., Guner F.,, Türk Tarım-Gıda Bilim ve Teknoloji Dergisi 6(9),1141-1147, 2018
[3] Yildiz T., Labor requirements and work efficiencies of hazelnut harvesting using traditional and mechanical pick-up methods, Turkish Journal of Agricultural Forestry (2016) 40: 301-310
[4] https://www.feucht-obsttechnik.de/de/
[5] https://www.tekna-srl.com/it/
[6] www.cifarelli.it
[7] https://www.facma.it/img/prodotti/raccoglitrici-trainate/c120t-max.jpg
[8] Monarca D. Cecchini M., Colantoni A.,. Bedini R., Longo L., Bessone W., Caruso L., Schillaci G., Evaluation of safety aspects for a small-scale machine for nuts harvesting., MECHTECH 2016 Conference, Alghero, Italy, 29th May-1st June 2016.

MANAGING THE RISK OF ACCIDENTS FOR AXLE BEARINGS IN THE RAILWAY TRANSPORT

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Abstract: This paper present the usage of the remote control system while measuring the temperature of bearings at an axle assembly of railway vehicle (locomotive and wagon) in motion, as a precautions for reducing the risk of sudden accidents of bearings. Using this kind of devices the accidents of axle bearings in railway transport are avoided or just minimized.
Key words: bearings, temperature, remote control system, risk

INTRODUCTION

Risk management involves a set of management and technique methods that are used to reduce the potential risk of accidents and consequences and on that way increased the potential for the results that are intended to be achieved [1, 2].
As the risk of breakage the machinery, appliances or some parts, primarily implyes the risk of damaging or destruction of them due to accidents or by insufficient care in some operation. The specificity of fracture risk is reflected in its manufacture process such as: defects in design, material and workmanship; direct action of the electric current: short circuit, atmospheric or other voltage, electric arc, etc .; decay due to centrifugal force; lack of water in steam boilers and steam appliances, except in cases of explosion; frost, pressure of ice or snow, or currently movement of ice; atmosperic pressure and subpressure (implosion); failure of the protection and control devices or failure of automatic control to which the machine is equipped; clumsiness, negligence or malicious intent of the worker or another person; fall of the secured object, impact or intrusion of a foreign body into the secured object; inadequate maintenance [2, 3].
The axle bearing temperature is a very important parameter based on which the bearing condition can be estimated [4, 5]. The special advantage of remote controling is that the complete measurement and monitoring takes place in real time and without interrupting the production or transport process. The need for this kind of monitoring and measurement is multifaceted. From an economic point of view, on this way the service life of the axle assembly bearings are extended and the gradual first replacement of those bearings that are heated above the expected temperature in particular exploitation are enabled, so it isn't necessary to replace all of the bearings whose guaranteed service life has passed. In a broader sense, this system reduces the probability of freight wagons accidents caused by the axle bearing overheating [6, 7]..

MATERIAL AND METHOD

Devices for measuring the temperature of axle bearing of railways vehicles in motion

The device for measuring the temperature of the axles assembly of the rolling stock (locomotives and wagons) in montion is used for timely detection and alarming of malfunctions of the axle assemblies, which can cause damage during the movement (the occurrence of overheating of the wheel bearings most often indicates on damage to the bearing, and as a consequence he accidents during movement).
The measuring device consists of:

- The external part of the device (measuring point) is installed in front of the first entry turn of the station, with whom the measuring of the bearings temperaturethe is directly done, calculates, records and sends all the necessary data.
- Alarm-controling place, installed in the train dispatcher's office, and with whom the measured values of the temperature of the bearings on the train are recorded.
- PC (a computer place with software), with whom the processing and archiving of all results of the measuring the axle bearings heat of the vehicle are performed.

Alarm-controling place has these following functions : receiving data from the measuring point, sending the data to a pc, displaying the temperature of all bearings of the axle assembly , displaying the temperature of the overheated bearings, sound and light alarms if there is an overheated bearing, setting the temperature limit value [6, 8].

Practical realization of the measurement system for measuring the temperature of bearings

The conception of the measuring system is based on the contactless measurement of the absolute temperature of the cover of bearing of the axle assembly of the freight wagon in motion (3km / h to 40km / h) in the conditions of a large change of ambiental temperature (-40 ° C to + 70 ° C), of large electromagnetic interferences, of vibrations , of dust along the rails and weather conditions (sun, rain, snow). The bearing temperature is measured by the non-contact infrared (IR) detector located within the measuring spot next to the rail [6, 9, 10]. The bearing temperature detection system must provide the reliable measurement of the absolute bearing temperature in the range of 40ºC to 125ºC with the measurement accuracy of ± 2 ºC. One of the basic requirements is that the whole system can continuously and independently work without an serviceman. The system is seted up on several spatially different locations. (Figure 1).
Nearbuy, an optical-electronic measuring devices are installed for measuring the temperature and the necessary sensors to control the overall measurement process. An alarming device is usually installed to the unloading station, which has the function of displaying the temperatures of all the bearings for particular train and function to alarm the elevated temperature of an bearing (from the set limit temperature) if such a case occurs.
Complete monitoring of the measurement process and the recording of all measurement results is done by an computer which is located in the remote control center.

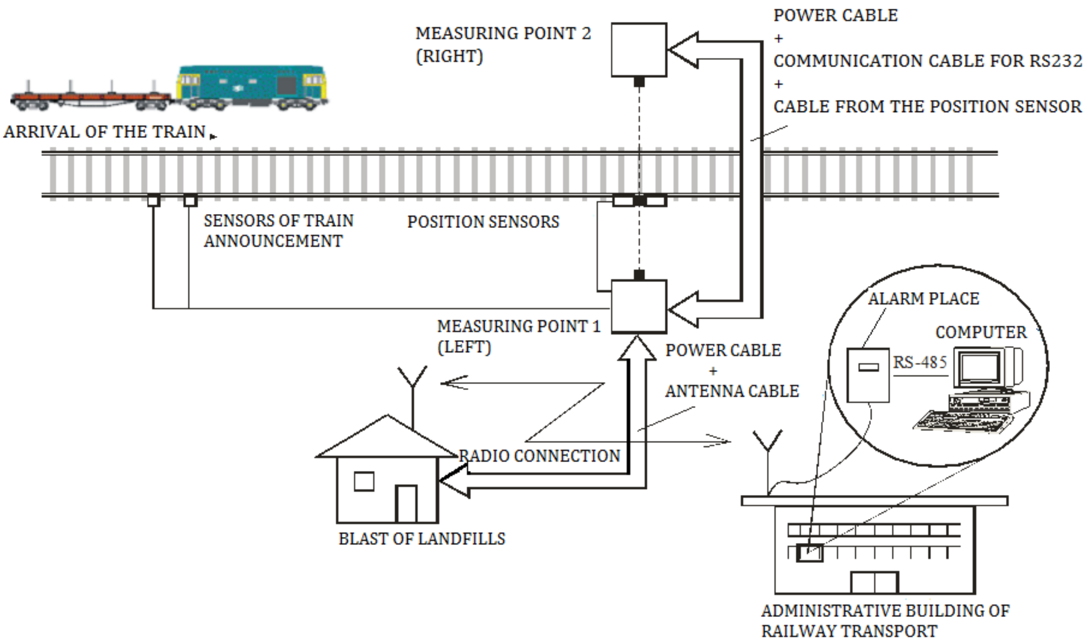

Figure 1. Spatial arrangement of measuring system

The basic block-scheme for the whole measuring system is presented on Figure 2. The measuring device is a part of the whole measuring system, which is installed next to the rail at the measuring point where only the measurements are made and represented an complex synthesis of optical, mechanical, electronic-measuring, sensor, processor and telecommunication assemblies.

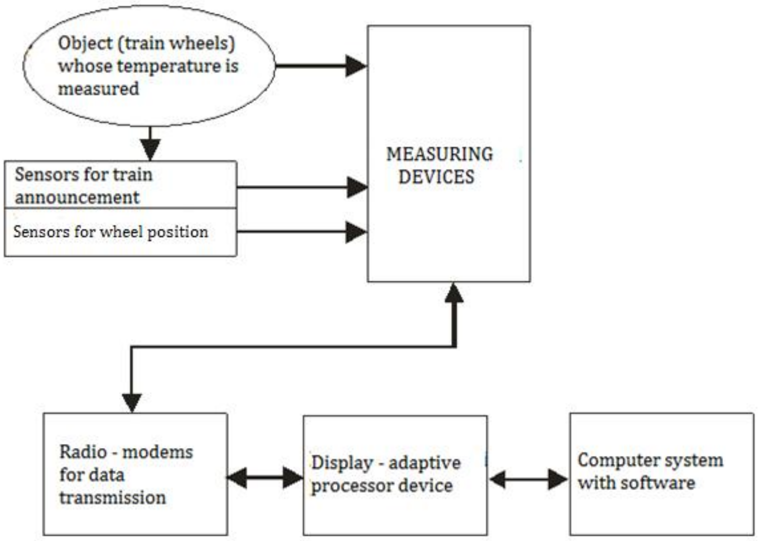

Figure 2. Basic block diagram of measuring system

The main parts of the measuring system

The main parts of the measuring system are given on the block diagram on Figure 2.
The object of measuring represents the covers of the axle bearings housing of the freight wagon whose temperature is measured.
Measuring devices are positioned on the measuring place on the both sides of the rail and they are used for measur, calculate, record and sending all necessary data. The measuring device basically uses infrared sensors.
Sensors for train announcement are placed at distance of 100m from the measuring place and they are used for announcing and logging out of the train (in order to prepare the measuring system for the measuring at the sufficient time - at least 5 seconds or more) in order to detect the direction of train movement.
Sensors for wheel positions are magnetic type and connected into one mechanical unit. They serve to define the position of the wheel in the spatial zone of measurement and the time interval in which the temperature is measured, or the time at which the measuring signal from the infrared sensor is taken as the desired temperature measure.
Radio - modems are installed at the measuring and also control-alarm places and they are used for wireless data transmission from the measuring place to the alarm place and vice versa.
Control - alarming processor device is located at the alarm-control place and it is used to receive data about the bearing temperatures of the current train, their processing in order to activate the alarms (sound and light) and further forward to the computer. During the passage of the train through the measuring place, the temperatures of bearings of the axle assemblies of the freight wagons are measured. Immediately after the train passsed, the measured values are processed and sent by radio connection (by radio modem). After receiving the data, the bearings are then controled to check if they are overheated at the alarm-control place, and then the data is sent to the personal computer. This device has the possibility of alarm if there is an overheated bearing of the axle assembly. The alarm-control place is consists of an display, keyboard, microprocessor card with a communicational multiplexer, radio modems, signaling LEDs, sirens and assembly for the power supply.

RESULTS AND DISCUSSION

After the complete measurement system has been installed and commissioned, it is necessary to carried out the final test under the realistic operating conditions and at different train speeds. One heater with temperature controller is installed on each side of the freight wagon. Positioning of the heating elements is performed on the cover of axle bearing, which ensures absolutely correct simulation of an certain overheated bearings during the testing. As the secondary standard etalon for checking the temperature of heating panels it would be used the handheld IC measurer Meterman IR610 (range is from -20ºC to + 260ºC; field of view is 100 mm at distances of 1m or 10: 1) and the thermovision camera.
Circular heating plates (ringla) with temperature regulators in declared measuring range and dimensions that match the dimensions of the cover of the axle bearing are used as the heating element. Using the thermovision camera, one thing can clearly see the expected inhomogeneous temperature distribution over the surface of cover of the bearing and the heaters. The temperature of the heating elements on the move and at the measuring place itself, can also be monitored by that camera. It should be emphasized that this system measures only the warmth of the cover of bearing and the warmness of the wheel rim from the brake pedal it just eliminat [6, 7, 11, 12].
Computer system with software is used to displaying and archiving the measurement results and also it is connected to the alarm-control place with an wired connection. The basic function is to display the temperatures of the axle bearings of the freight wagons on the diagram in the form of rectangular impulses (Figure 3) and to store the data in files of the appropriate format. The temperature data comes to the PC, on series connection from the microcontroller from the alarm place. The creation of the user masks is done on such way that the user can both numerically and visually (graphically) follow the ongoing measurement process (Figure 3).

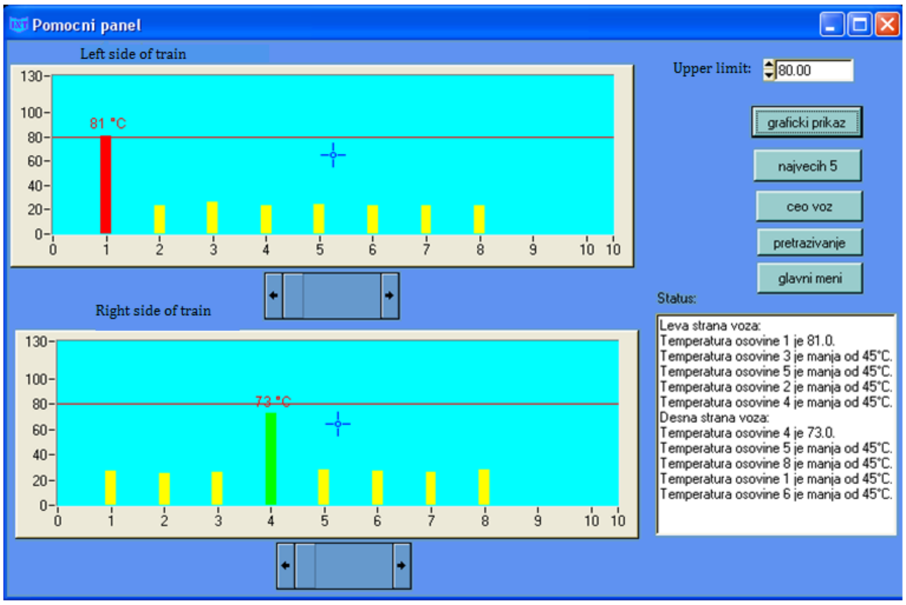

Figure 3. The measurement results presented on computer

CONCLUSION

Based on the global trends regarding the rationalization of the number of the executives, the increase in reliability (especially from the point of view of lower transport speeds and shorter sections), this system brings significant advantages and improvements in the transport of goods and passengers and also in the production process in the industries that are directly dependents from the railway transport.
By installing these systems, the multiple positive and economically justifiable effects are achieved on the rail, such as: Reduction the costs for replacement of still usable bearings, reduction of freight wagon immobilization, increase of reliability during mandatory inspection of the wagons, increase the reliability of transport due to reduction of accident risk .

It can be concluded, that the presented system serves for timely detection and alarming the malfunctions of bearings as parts of axle assemblies [6, 8, 11].

REFERENCES

[1] Stavek, M., Ales, Z., Legat, V., Teringl, A., Operational risk management and treatment at technical systems with maintenance support, Manufacturing Technology, 15(3), pp. 429-435, 2015.

[2] Fallet-fidry, G., Duval Duval, C., Simon, C.,, Weber, P., Iung, B.: Risk Analysis and Management in Systems Integrating Technical, Human, Organizational and Environmental Aspects, Supervision and Safety of Complex Systems, pp. 267-291, 2013

[3] Potryasaev, S. A., Sokolov, B.V., Yusupov, R.M., Merkuryev, Y.A.: Management risks integrated modelling with regards to complex organizational and technical systems, IFAC Proceedings Volumes (IFAC-PapersOnline), 46(9), pp. 631-636, 2013.

[4] Blanuša, V., Zeljković, M., Milisavlevich, M. B., Savić, B.: Mathematical modeling of thermal behaviour of cylindrical roller bearing for towed railway vehicles, Technical Gazette, 24(3), pp. 211-217, 2017.

[5] Blanuša, V., Zeljković, M., Živković, A., Štrbac, B., Hadžistević, M.: Primena savremenih metoda za merenje temperature, Zbornik radova, CD rom, Infoteh-Jahorina, Sesija PRS-Proizvodni sistemi [Application of modern methods for temperature measurement, Proceedings, CD rom, Infoteh-Jahorina, Session PRS-Production systems], ISBN: 99938-624-8-2, pp. 491-496, 2012.

[6] Blanuša, V., Živković, A., Zeljković, M.: Računarska analiza toplotnog ponašanja sklopa glavnog vretena uležištenog valjčastim dvoredim ležajima, Zbornik radova, CD rom, 38 JUPITER konferencija, 25 Simpozijum CAD/CAM [Computational Analysis of the Thermal Behavior of a Main Spindle Assembly Bearing Roller Bearings, Proceedings, CD Rom, 38 JUPITER Conference, 25 CAD / CAM Symposium], ISBN: 978-86-7083-757-7, pp.: 32-38, 2012.

[7] Chen, C. Y., Chen, W. L., Lee, Y. S., Kuang, H. J.: A wheel and a corrugated rail thermal contact simulation during braking sliding, 12th IFT0MM World Congress, Besancon (France), ISSN: ,pp. 1-7, 2007.

[8] Bižić, M., Tomić, M., Đinović, Z., Petrović, D.: Detekcija neispravnosti ležajeva osovinskih sklopova železničkih vozila, TEHNIKA – Mašinstvo [Detection of malfunctioning of the axles of the rolling stock of railway vehicles, TECHNICS - Mechanical Engineering], No 5, pp.702-709, 2016.

[9] Bin Sudin, W., Baharom, B. M.: Prediction of contact temperature on interaction betwen rail and wheel materials using pin-on disc method, Joural of Applied Sciences, Vol. 12, pp. 2424-2429, 2012.

[10] Tanvir, A. M: Temperature rise due to slip between wheel and rail-an analytical solution for hertzian contact, WEAR, Vol. 61, pp. 295-308, 1980.

[11] Blanuša, V., Zeljković, M., Živković, A. : Prediction thermal elastic behavior of the cylindrical roller bearing for railway vehicles and calculating bearing life, Acta tehnica corviniensis-Bulletin of Engineering, 8(1), ISSN: 2067-3809,pp. 21-26, 2015.

[12] Milošević, M., Stamenković, D., Milojević, A., Tomić, M.: Modeling thermal effects in braking systems of railway vehicles, Thermal science, 16 (2) ISSN: 2334-7163,pp. 515-526, 2012.

HIGHER HARMONICS OF CURRENT CAUSED BY THE OPERATION OF ROLLING MILL

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Abstract: Three-phase controlled rectifiers have a wide range of applications, from small rectifiers to large. They are used for electro-chemical process, many kinds of motor drives, traction equipment, controlled power supplies, and many other applications. A simple analytic method of calculating higher harmonics of current generated by a three phase bridge rectifier at its network end is represented in this paper. This method is used for calculating higher harmonics of current with all inductance relationships of the circuits of the alternating and direct ends of a three phase bridge rectifier, at various rectifier loads and at various thyristor control angles.
Key words: higher harmonics, rolling mill

INTRODUCTION

One of the most characteristic tendencies in the development of electromotive drives of cylindrical dwellings and their respective auxiliary drives is based on the large application of thyristor rectifiers for powering the armature and the excitation of their drive single-stroke engines. The installed power of thyristor rectifiers of some larger roller bearings reaches up to 100 MW and even more. Facilities equipped with industrial electronics components operate back to the electrical network [1-9]. The return operation of rectifier drive continuous rolling mills, which are the subject of this paper, manifested in the form of taking a reactive power from the network and network load with a higher harmonics current. Higher harmonics with network impedance create more harmonics in the network voltage. Distorted voltage has the adverse effect of the consumers who are supplied from such a network. Therefore, the method for the determination of harmonics in the current drawn from the network indicated consumers seems very current.
Rolling is a continuous process of metal processing, whereby the piece is passed between two rollers and changes its shape. The length increases, and reduces the cross-section. The rolls are placed in the roller housing and rotate around their longitudinal axis. When rolling, the piece is passed through the gap of the roller. Rollers rotate in the opposite direction (Fig. 1) [4].

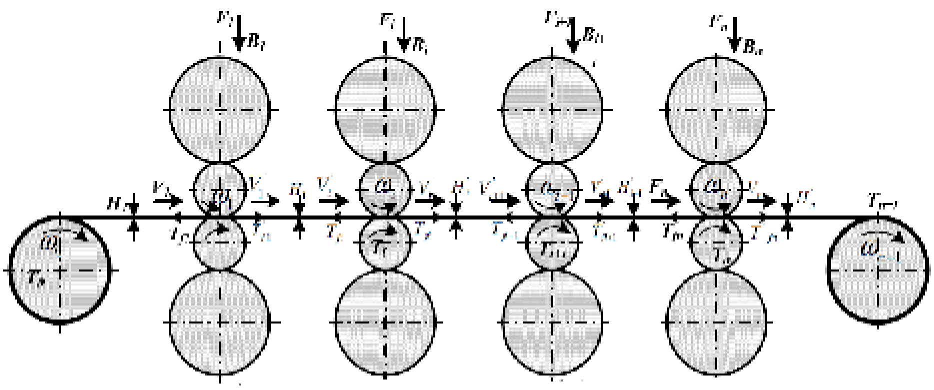

Figure 1. Scheme of multistage tandem strip for continuous cold rolling of sheet metal

METHOD OF CALCULATING HIGHER HARMONICS OF CURRENT

The operation of a thyristor bridge rectifier is based on the switching operation of strong semiconductor components, so that, together with the consumer, it exhibits a non-linear load on the network. Such operation results in distorted waveforms of voltage and current, i.e. in higher harmonics of the network. The presence of higher harmonics in the network is considered to be "contamination" of the network and may cause undesired effects on electrical equipment and other consumers.

Considering a three phase bridge rectifier with the counter-electromotive force E as a load, there are analytic equations derived to calculate higher harmonics of current generated by the rectifier at its network end.

Basic starting assumptions in this analysis were the following:

- the rectifier was fed from a symetrical sinusoidal three phase network; the network had the short circuit final strength; the operational and capacitance resistance of the network were neglected;
- the decrease of resistance in the thyristor conducting direction was neglected;
- higher harmonics were calculated in the stationary state;
- it was assumed that the thyristor current commutation was linear and that no more than two thyristors were involved in the commutation;
- the current of the transformer magnetization was neglected.

As for the three phase bridge rectifier with the counter-electromotive force E as a load, we shall derive now equations in order to calculate the value of higher harmonics of current generated by the rectifier at its network end. The parameters of the network and transformer are supposed to be reduced to the secondary phase voltage of the rectifying transformer U_S so that an appropriate scheme of the six-pulse three phase rectifier with the network may be represented as shown in Fig. 2. Thus Figure 1 shows: U_R, U_S, U_T -phase voltages of the rectifying transformer secondary, X_K -induction resistance of the phase containing the induction resistance of the network, electric lines and rectifying transformer reduced to its secondary end X -induction resistance at the direct end of the rectifying transformer including the inductance of the smoothing filter and the inductance of the consumer, Ra-active resistance at the direct end of the rectifier, u_1 and i_1- instantaneous values of the line voltage and filament current, i_d – instantaneous value of the direct current, and i_1 to i_6 – instantaneous values of thyristor currents 1 to 6.

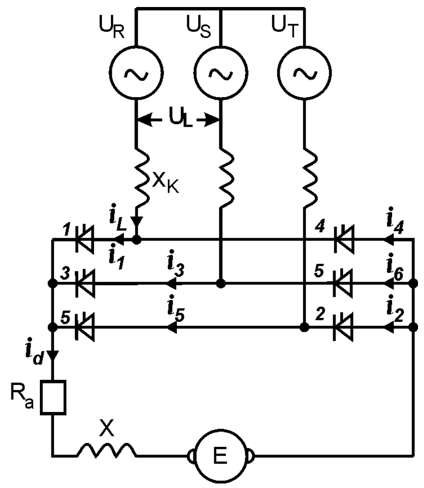

Figure 2. Scheme of the three phase bridge rectifier with reduced parameters of the rectifying transformer and the network at the secondary end of the rectifying transformer

If the rectifier load corresponds to the value of the intermittent current limit, the filament current time i_L may be represented as in Fig. 3.

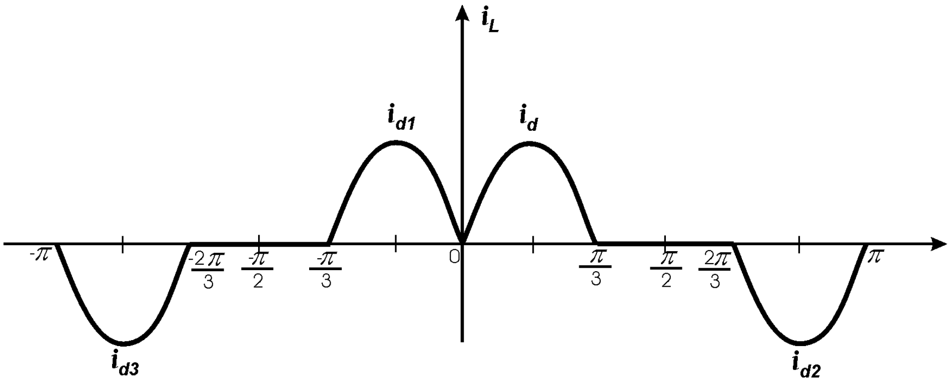

Figure 3. Flow of the current i_L of the three phase bridge rectifier with the load at the intermittent current limit

Let us perform a harmonic analysis of the completely smoothed current at the direct end of the three phase bridge rectifier with the flow of the filament current i_L shown in Fig. 4.

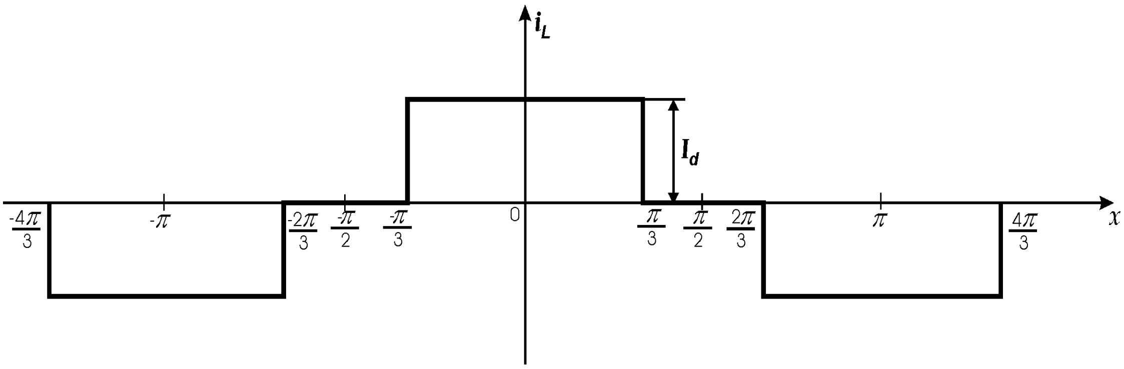

Figure 4. Flow of the filament current i_L of the three phase bridge rectifier with ideally smoothed direct current

In the literature [7], the relative values of higher current harmonics in the case of the last two images were derived.

When the three phase bridge rectifier load is greater than $I_{d\alpha}$ and when the effect of the thyristor commutation is neglected, the filament current i_L flows as shown in Fig. 5. It is obvious that such a flow of the current i_L is obtained by superpositioning the current flows shown in Fig. (3) and (4).

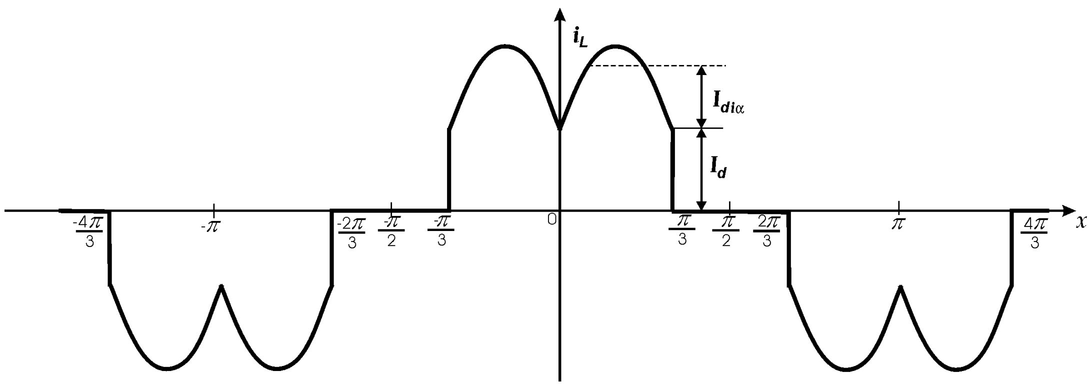

Figure 5. Flow of the filament current i_L of the three phase bridge rectifier with a load greater than $I_{di\alpha}$ and with the thyristor commutation effect neglected

In the literature [7], the relative values of the higher current harmonics in the case of the last two images were derived. Based on [7] and after certain transformations, the expression for the relative value of the harmonic n = 5, 11, 17, ... in = 7., 13., 19. .... becomes:

$$i^{-}_{n\alpha(5.,11.,17.,...)} = \frac{-\dfrac{9.56}{n(n-1)}}{1+0.9814634(\dfrac{I_d}{I_{di\alpha}}-1)} - \frac{0.9812379(\dfrac{I_d}{I_{di\alpha}}-1)\dfrac{1}{n}}{1+0.9814634(\dfrac{I_d}{I_{di\alpha}}-1)} \tag{1}$$

$$i^{-}_{n\alpha(7.,13.,19.,....)} = \frac{-\dfrac{9.56}{n(n+1)}}{1+0.9814634(\dfrac{I_d}{I_{di\alpha}}-1)} + \frac{0.981379(\dfrac{I_d}{I_{di\alpha}}-1)\dfrac{1}{n}}{1+0.9814634(\dfrac{I_d}{I_{di\alpha}}-1)} \tag{2}$$

In order to analyse the effect of the relative voltage of the rectifier phase short circuit u_k, the relationship of, X / X_K and the thyristor ignition control angle α, on higher harmonics generation in the filament current of the three phase bridge rectifier, we should perform certain transformations of equations (1) and (2).
If the relationship between the induction resistance of the direct circuit X and the induction resistance of the phase of the rectifier commutating circuit X_K is marked by "n", i.e. n = X / X_K - , then the current $I_{di\alpha}$ determined by equation in [2], [7], may be expressed as follows:

$$I_{di\alpha} = 0.0931\frac{U_{di0}}{X_K(n+2)}\sin\alpha \tag{3}$$

If U_{di0} is expressed using the voltage U_s, in accordance with equation in [7], the current $I_{di\alpha}$ determined by equation (3) may be expressed as follows:

$$I_{di\alpha} = \frac{3\cdot 0.0931\sqrt{6}}{\pi}\frac{U_S\sin\alpha}{X_K(n+2)} = 0.217769\frac{U_S\sin\alpha}{X_K(n+2)} \tag{4}$$

The parameter X_K contained in equation (4) is determined by the following equation:

$$X_K = \frac{U_S u_k\sqrt{3}}{\sqrt{2}I_d} \quad \text{ie.} \quad I_d = \frac{U_S u_k\sqrt{3}}{\sqrt{2}X_K} \tag{5}$$

In accordance with equation (5) it follows that the relationship of $I_d / I_{di\alpha}$ contained in equations in [7], may be expressed as follows:

$$\frac{I_d}{I_{di\alpha}} = \frac{U_S u_k\sqrt{3}}{\sqrt{2}X_K}\frac{X_K(n+2)}{0.217769U_S\sin\alpha} = 5.624\frac{u_k(n+2)}{\sin\alpha} \tag{6}$$

Using equation (6) and equations (1) and (2), the relative values of the higher harmonics of h = 5., 11., 17.,… may be calculated as follows:

$$\bar{i}_{h\alpha(5.,11.,17.,...)} = \left| \frac{-\dfrac{9.56}{h(h-1)}}{1+0.981\cdot\left[5.624\dfrac{u_k(n+2)}{\sin\alpha}-1\right]} - \frac{\dfrac{1}{h}\cdot 0.981\cdot\left[5.624\dfrac{u_k(n+2)}{\sin\alpha}-1\right]}{1+0.981\cdot\left[5.624\dfrac{u_k(n+2)}{\sin\alpha}-1\right]} \right| \quad (7)$$

and the relative values of the higher harmonics of h = 7., 13., 19.,… may be calculated as follows:

$$\bar{i}_{h\alpha(7.,13.,19.,...)} = \left| \frac{-\dfrac{9.56}{h(h-1)}}{1+0.981\cdot\left[5.624\dfrac{u_k(n+2)}{\sin\alpha}-1\right]} + \frac{\dfrac{1}{h}\cdot 0.981\cdot\left[5.624\dfrac{u_k(n+2)}{\sin\alpha}-1\right]}{1+0.981\cdot\left[5.624\dfrac{u_k(n+2)}{\sin\alpha}-1\right]} \right| \quad (8)$$

The last equations (7) and (8) may be used for calculating higher harmonics of the filament current of the three phase bridge rectifier, if the effect of commutation on the value of generated higher harmonics is taken into account together with the factor f (h,u). In this particular case equations (7) and (8) have the following form:

$$\bar{i}_{h\alpha(5.,11.,17.,...)} = \left| \frac{-\dfrac{9.56}{h(h-1)}}{1+0.981\cdot\left[5.624\dfrac{u_k(n+2)}{\sin\alpha}-1\right]} - \frac{f(h,u)\dfrac{1}{h}\cdot 0.981\cdot\left[5.624\dfrac{u_k(n+2)}{\sin\alpha}-1\right]}{1+0.981\cdot\left[5.624\dfrac{u_k(n+2)}{\sin\alpha}-1\right]} \right| \quad (9)$$

$$\bar{i}_{h\alpha(7.,13.,19.,...)} = \left| \frac{-\dfrac{9.56}{h(h+1)}}{1+0.9814634\left[5.624\dfrac{u_k(n+2)}{\sin\alpha}-1\right]} + \frac{f(h,u)\dfrac{1}{h}0.981379\left[5.624\dfrac{u_k(n+2)}{\sin\alpha}-1\right]}{1+0.9814634[5.624\dfrac{u_k(n+2)}{\sin\alpha}-1]} \right| \quad (10)$$

The factor of the effect of commutation on the value of generated harmonics of current f(h,u) in the last two equations may be calculated in accordance with the following equation :

$$f(h,u)=\frac{\sin(h\frac{u}{2})}{h\frac{u}{2}} \quad (11)$$

where $u = \arccos(\cos\alpha - u_k) - \alpha$, ($u$ – angle of commutation). Assuming that the commutation is linear and that the direct current of the rectifier is ideally smoothed, the effective relative value of higher harmonics of current generated by the rectifier at its network end may be calculated using the following equation:

$$\frac{I_h^I}{I_1^I} = \frac{1}{h}\frac{\sin(h\frac{u}{2})}{h\frac{u}{2}} = \frac{1}{h}f(h,u) \quad (12)$$

RESULTS OF THE ANALYSIS

In order to compare the corresponding values of higher harmonics of current at the rectifier network end calculated in accordance with equations (7),(8), (9),(10) and (12), Fig. 6, Fig 7, Fig.8, shows the simultaneous flows of the functions $I_h / I_1 = f(\alpha)$ (obtained by the given equations) for various parameters of X/Xk and u_k in the function of the thyristor ignition angle.

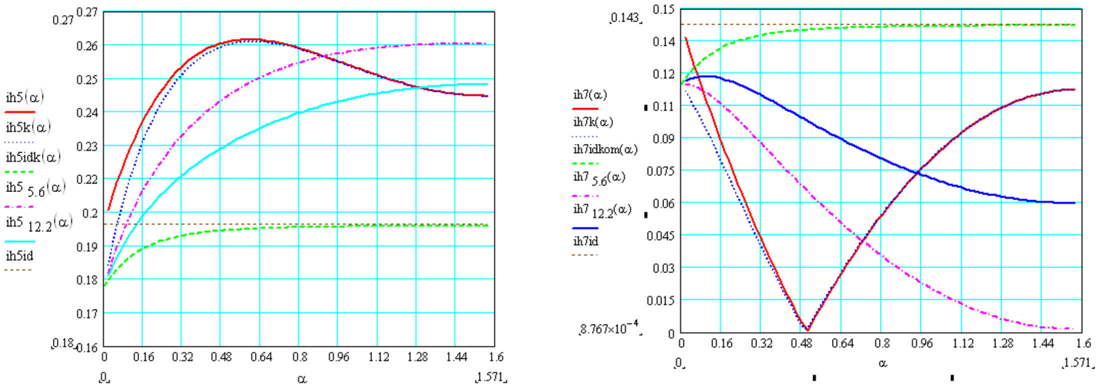

Figure 6. Flows of the relative values of the harmonics of current of 5., 7., ranges at the network end of the three phase bridge rectifier in the function of the thyristor ignition angle, the various parameters of u_k=0.05 and the relationship of X / X_K =(1.6.,5.6.,12.2.)

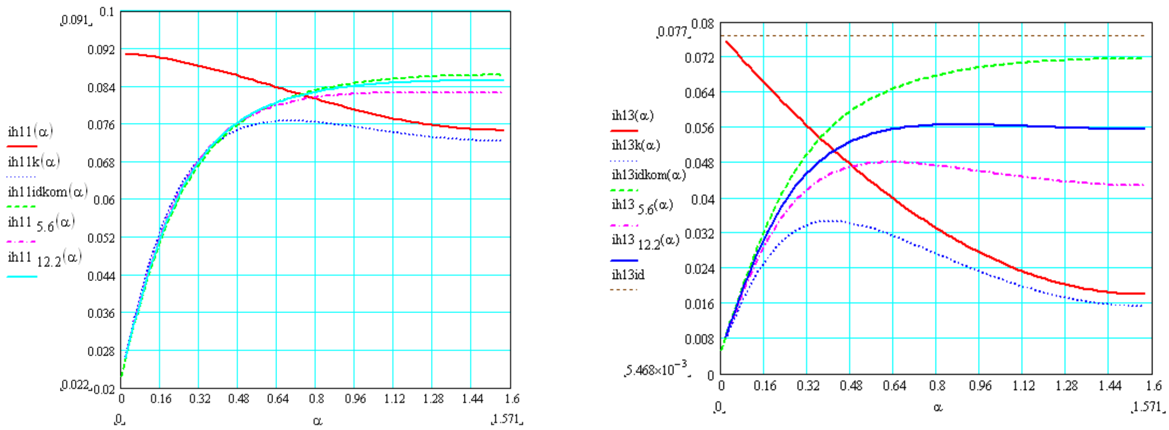

Figure 7. Flows of the relative values of the harmonics of current of 11., 13., ranges at the network end of the three phase bridge rectifier in the function of the thyristor ignition angle, the various parameters of u_k=0.05 and the relationship of X / X_K =(1.6.,5.6.,12.2.)

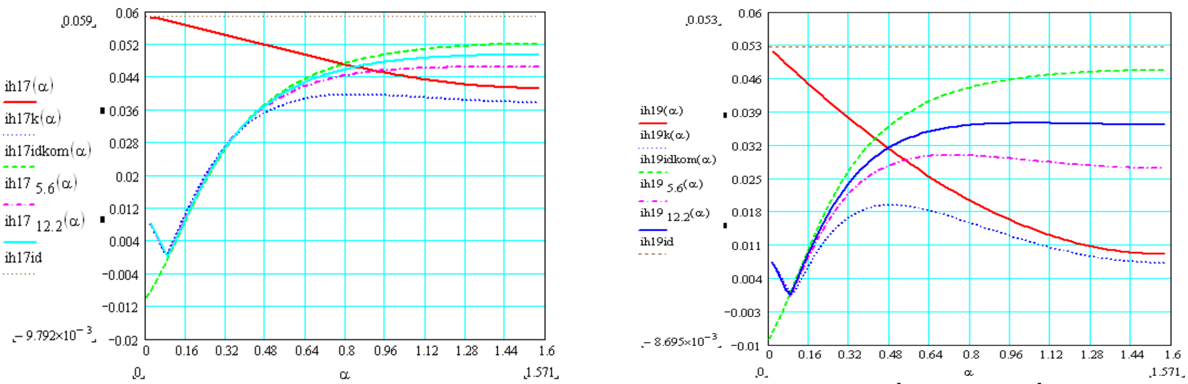

Figure 8. Flows of the relative values of the harmonics of current of 17., 19., ranges at the network end of the three phase bridge rectifier in the function of the thyristor ignition angle, the various parameters of u_k=0.05 and the relationship of X / X_K =(1.6.,5.6.,12.2.)

_____ (red) – relative value of a h-range harmonic of current (without taking into account the thyristor commutation) obtained by equations (7) and (8) with u_k =(0.05) and n = 1.6

……… (blue) – relative value of a h-range harmonic of current (taking into account the thyristor commutation) obtained by equations (9) and (10) with u_k =(0.05) and n = 1.6
------- (green) – relative value of a h-range harmonic of current with the assumption of linear commutation and ideally smoothed direct current of the rectifier obtained by equation (12)
-·-·-·· (pink) – relative value of a h-range harmonic of current in the function of the thyristor ignition angle (α) taking into account the thyristor commutation for n = 5.6 and u_k =(0.05)
____ (blue) – relative value of a h-range harmonic of current in the function of the thyristor ignition angle (α) taking into account the thyristor commutation with n = 12.2 and u_k =(0.05)
…….. (black) – relative value of a h-range harmonic of current obtained by the following equation:

$$\frac{I_h}{I_1} = \frac{1}{h} \tag{13}$$

In accordance with the analysis of the flows of functions $I_h / I_1 = f(\alpha)$ shown in Fig. 6, Fig. 7, Fig. 8, it can be concluded that:

- The value of the inductance L in the output circuit of the rectifier has a significant effect on the value of the generated harmonics of current of 5., 7., 11., 13., 17., 19.,… ranges.
- The effect of the thyristor commutation (with the assumption that I_d is ideally smoothed current and that the thyristor current has a linear flow during the commutation) on decreasing the generated harmonic value grows with u_k, ie. with the increase of the rectifier power.
- The effect of the thyristor commutation on decreasing the generated harmonics value grows with the increase of the harmonic range h, particularly when the values of the thyristor ignition angle are low.
- By the increase of the inductance at the rectifier direct end, the value of the harmonic of current of range 5 decreases.

In all the cases of the given relationships X / X_K, the value of the harmonic of current of range 5 is greater than 20 % of the fundamental harmonic in major part of the change of the thyristor ignition angle (α).

With three phase bridge rectifiers having $u_k \leq 0.05$, the harmonic of current of range 5 may be calculated accurately enough by equation (7). With three phase bridge rectifiers having $u_k \geq 0.05$, the effect of the thyristor commutation should be taken into account when calculating the value of the harmonic of current of range 5, ie. the calculation should be done by equation (9).

- Except in the case of the intermittent current limit ($X / X_K = 1.6$, u_k = 0.05), the value of the harmonic of current of range 7 generated in the network by the three phase bridge rectifier is lower than the value obtained with the assumption of ideally smoothed direct current (I_7,/I_1 = 1/7 = 0.1428).
- Except in the case of X/X_k = 1.6 and u_k = 0.05, with all rectifiers, the obtained value of the harmonic of current of range 7, calculated with the assumption of linear commutation and smoothed direct current (I_7/I_1 = 1/7 . f (7, u), is greater than the corresponding values obtained by equations (8) and (10).
- Except in the case of X/X_k = 1.6 and u_k = 0.05, the value of the generated harmonic of current of range 7 increases with the increase of the inductance at the rectifier direct end.
- With all rectifiers, the value of the harmonic of current of range 11, calculated by equation (7), is lower than the value I_{11}/I_1 = 1/11 obtained with the assumption of ideally smoothed direct current of the rectifier.
- The value of the generated harmonic of current of range 11 decreases with the increase of the rectifier u_k.
- With the increase of the inductance value L in the rectifier direct circuit, and with the given values of u_k and α, the value of the harmonic of current of range 11 changes slightly.

- With all rectifiers, the value of the harmonic of current of range 13, calculated by equation (8), is considerably lower than the value I_{13}/I_1 = 1/13 obtained with the assumption of ideally smoothed direct current of the rectifier.
- Except in the case of the limit of the intermittent current I_d, the value of the generated harmonic of current of range 13 increases with the increase of the inductance at the rectifier direct end.

The higher harmonics of current of ranges 17 and 19 have the same law as the harmonics of current of ranges 11 and 13.

CONCLUSION

In the given analytic method of calculating and analysing higher harmonics of current at the network end of a three phase bridge rectifier, a simple mathematical instrument is used. The contribution of this work is that it adequately shows the effect of the network inductance and final inductance at the direct end of the rectifier, which may be used for calculating higher harmonics of current with any relationships of L/L_K in the function of the thyristor control angle α. Using derived equations and taking into account (or not taking into account) the thyristor commutation for calculating higher harmonics of current at the network end of the three phase bridge rectifier and then comparing them with those measured in the rectifying drive, it is possible to confirm the accuracy and justifiability of the proposed method of calculating higher harmonics of current.

REFERENCES

[1] I.V. Žeželenko: »Vissie garmoniki v sistemah elektrosnabženija prompredprijatij« , »Energija« Moskva 1974.
[2] V.Šinik, "Improving Performance in Automatic Powerless Power Systems", Master thesis, Faculty of Electrical Engineering, Sarajevo, June, 1991
[3] Ž. Janda, One class of three-phase rectifiers with sinusoidal current using injection of higher current harmonics, Doctoral dissertation, Belgrade 2004.
[4] N. Jevtić. Dynamic Simulation of Electrohydraulic Servosystems for Adjusting Rolling Gaps on Five-Way Tandem Rail in Smederevo Iron, Doctoral Dissertation, University of Novi Sad Technical Faculty "Mihajlo Pupin" Zrenjanin 2013
[5] B. Kovač., »The reduction of harmonics distortion by resonant filters«, VI Conf in Power Electronics, Subotica, jun 1986, pp. 291-296.
[6] E. Schonholzer., A. Graham.: »Line harmonics of Converters with DC-motor Loads » IEEE Tran. on ind. Applic., No. 1, Jan/Feb 1983., pp. 84-93
[7] A.Gavranovic.,«Higher Harmonics of Current Caused by the Operation of Rolling Mill Continuous Rectifying Electric-Motor Drives«, Doctoral dissertation, Faculty of Electrical Engineering, Zagreb 1981.
[8] V. Katic, "Power Quality-higher harmonics", Faculty of Technical Sciences Novi Sad, Novi Sad 2002nd
[9] D. Graovac,"Universal system for power quality correction", Ph.D. Thesis, Faculty of Technical Sciences, Novi Sad, 2000.

MODERN APPROACHES WITH PYTHON IN SENSORY FUSION

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Abstract: The work presents real-time data acquisition and monitoring for environmental sensors. This paper presents data fetching and processing implemented by modern approaches of Python. A functional diagram of a materialized system and algorithmic diagrams for Python 3 implemented programs are given. The functionality of the programmed system has been checked by testing the implemented program structures and performing experiments under different environmental conditions with actual results obtained.
Key words: environmental monitoring, sensory fusion, Raspberry Pi, PiJuice, Sense HAT, Python,

INTRODUCTION

Data collection and accuracy are an important aspect in each type of science research. The concept of open source has been applied to the overall realization and use of a computerized system for collecting environmental data. The hardware platform Raspberry Pi 3 [2] and two expansion modules - PiJuice [5] and Sense HAT [6] are chosen to materialize such a system. The purpose of assembling a data collection architecture is to obtain the information through a primary source - directly through the set of sensors embedded in the Sense HAT module. The information received from the system sensors is recorded in the form of tabular data (spreadsheets) which can then be processed manually or automatically by programs (scripts) programmed in the Python language. Drawing of graphs based on the collected and recorded data is done by available free Python libraries [4] designed and written by enthusiasts of the language. The freedom provided by open source and Python 3 [1] allows to realize a system that is useful for exploring different environmental conditions, not only through data that is recorded and stored locally, but also through remote wireless access via mobile devices.

MATERIAL AND METHODS

Hardware overview

The system hardware is implemented by the structure shown in Figure 1.

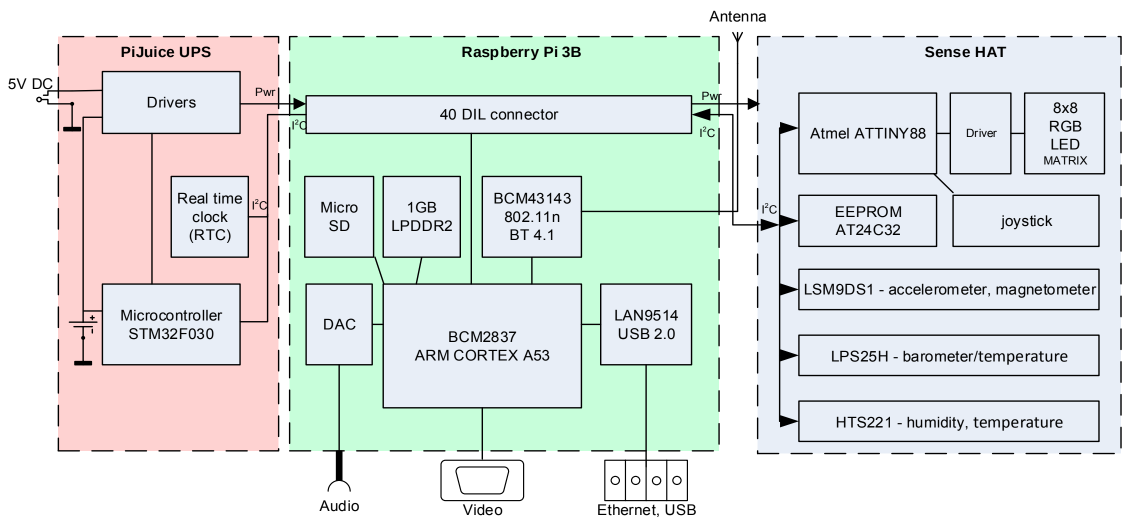

Figure 1. Structure diagram of the system

The hardware of the system consists of the three main modules - Raspberry Pi 3B, PiJuice UPS and Sense HAT, Drone DJI and main companion components such as smartphones, an SD (Secure Digital) card, power adapter, batteries, cables, and computer peripherals are also involved in the implementation of the system and its equipment [3].

The expansion module Sense HAT for Raspberry Pi, which is a fundamental part of the Astro Pi mission [7], provides temperature, humidity, pressure and orientation measurements, visually outputs via its built-in 8x8 RGB LED matrix and control by a 5-button joystick. Integrated circuit based sensors can be used for different types of experiments, applications and even games. The available IMU (Inertial Measurement Unit) chip in Sense HAT includes a set of three sensors in one that capture movements - a gyroscope, an accelerometer and a magnetometer. The joystick can also be used as an opportunity for user interaction with the executed programs which is implemented in the system. The purpose of Sense HAT in the current system is to collect data from its built-in sensors. The module can be attached to the 40-pin GPIO block of RPi but in this system it is attached to the PiJuice's extension block. The functional diagram of the system is given on Figure 2.

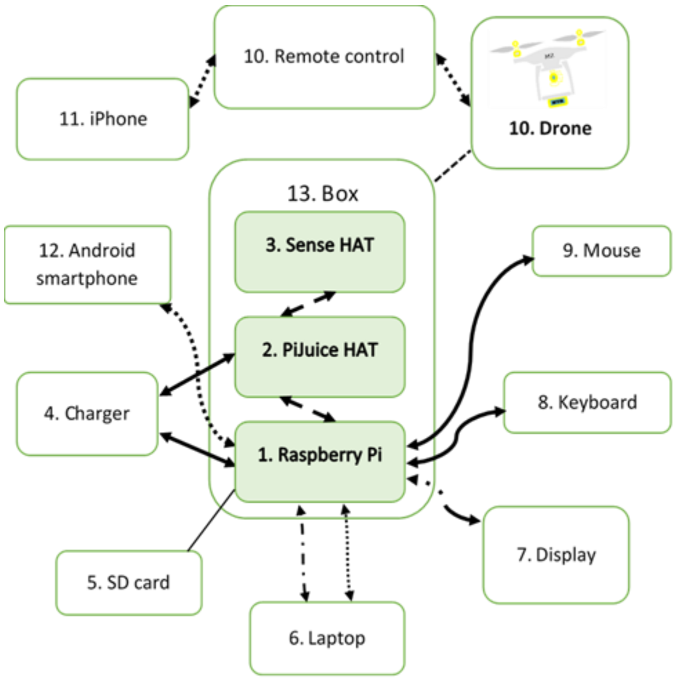

Figure 2. Functional diagram of the system

Bold font indicates the main participants in the system. Linking lines in different styles indicate the type of the connections (of information/energy exchange) between the hardware components as follows:

- Wi-Fi transceiver connection;
- Mechanical connection;
- 40-GPIO-link;
- USB or micro USB connection;
- MicroSD (Secure Digital) connection;
- Ethernet with RJ45 connection;
- HDMI-DVI connection.

The assembled state of the system is depicted in Fig. 3, where the 3-module box is presented. In the figure is shown the way that the Sense HAT LED display illuminates each time the system is being switched on.

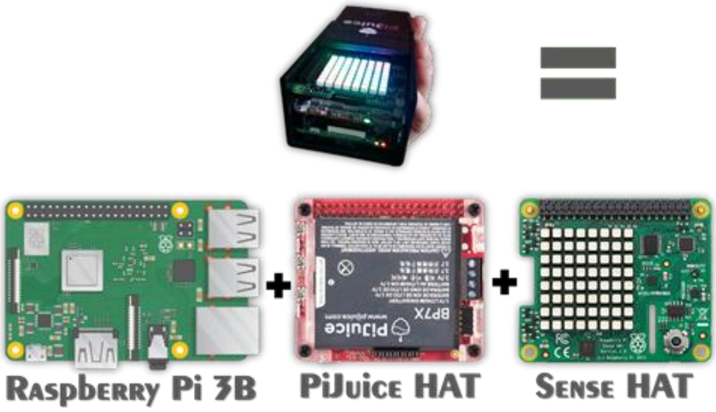

Figure 3. Assembled hardware of the system

Software overview

We use the officially supported operating system of the Raspberry Pi Foundation the Raspbian GNU/Linux 9 (stretch) version. It contains software programs for training, programming and general use (Python, Scratch, Java, Mathematica and others). The great advantage of the computer RPi - the capabilities it offers along with its Raspbian operating system are communication interfaces such as the SSH (Secure Shell) protocol and VNC (Virtual Network Computing) using RFB (Remote Frame Buffer) protocol. These may allow both remote wireless access to the PC without need for a mandatory connection of RPi to a local network with the device to communicate with, as well as a wired connection. In both cases the IP address of RPi is necessary. In our system both interfaces are enabled and other third-party communication programs are used too. Except direct connection, remote connection is provided free of charge thanks to RealVNC cloud service, underwriting for educational or non-profit purposed remote access only. Cloud connections are convenient and with end-to-end encryption, which is a design framework in computer networks. In networks designed in accordance with this principle the application-specific features are located in the network termination nodes instead in intermediate nodes, such as gateways and routers that exist for the creation of the network. They are highly recommended for connection to Raspberry Pi over the Internet. There is no firewall or router reconfiguration and no need to know the IP address of the Raspberry Pi computer or provide a static one. Remote connection is available free after signing up for the official website of VNC, (www.realvnc.com/en/raspberrypi/#sign-up) [3].
For users owning Raspberry Pi without Sense HAT it is designed a special Sense HAT Emulator, which works naturally on Raspberry Pi's desktop rather than a browser and it is included in Raspbian's standard installation package in the main menu. There is also an online version of an emulator in Trinket which is developed in the United States as a tool for code sharing from any device in any browser and works instantly without the need to log in, download plugins or install additional software. To convert the code from emulator to a real physical device Sense HAT it is necessary a replacement of sense_emu with sense_hat everywhere in the source code. This usually happens when a program is transferred to a physical Sense HAT module.
When programming it is useful to keep in mind that the computer program resembles a recipe of a list of ingredients - data in variables and a list of instructions - functions or methods. Following the instructions correctly described one by one using the variables, the computer "prepares the dish" of the user. It is a good practice in programming to use an integrated development environment (IDE). There are many programming languages and they all offer something special. Python is a challenge for today's computer engineer. Its syntax is understandable and logical, allowing "programming at the speed of thought." Being a high-level language used for industrial, medical, scientific and other purposes it is ideal for both beginners and advanced. Currently there are two versions - Python 2 and Python 3, as the 3.x releases are different from 2.x and are not directly mutually compatible. Raspbian comes with a version of Python 3 so it can be started programming as soon as it is installed.

Python IDLE (Integrated Development and Learning Environment) provides REPL (Read-Evaluate-Print-Loop) so that the environment prompts for Python commands and has built-in syntax for autocompleting. Some languages like Java and C# use curly brackets to enclose a block of code which is a main feature missing in Python and instead it uses indentation to indicate the belonging of the respective block of code. Python is a cross-platform language which means you can write a program on a Windows or Mac computer, save the program and run on Raspbian in RPi. PyCharm IDE is an integrated development environment used in computer programming, specifically for Python. It offers code analysis, graphical debugger, integrated tester, integration with version control systems (VCSes) and support for web frameworks like Django.

RESULTS AND DISCUSSION

The configuration of the system is preceded by its programming except for a few additional settings that are made after the actual implementation of the programs. One of these is setting up the user scripts from the PiJuice GUI menu which must be preceded by the programmed scripts.
There is no real-time clock (RTC) in Raspberry Pi, so in our system the built-in RTC of the PiJuice module is configured and used. The RTC is supported by the PiJuice battery and uses the I2C which allows Raspberry Pi to communicate with many different devices at the same time.
By default, the EEPROM address in PiJuice is 0x50 and the RTC driver is automatically loaded when Raspberry Pi starts, but in our system, due to the additionally attached Sense HAT module on PiJuice, the EEPROM address is changed to 0x52 address, which requires manual loading of the driver each time the system is started. This is implemented by editing the config.txt file of Raspberry Pi. The system time of Raspberry can be set up in two ways if the Raspbian time zone is already set - when the Internet connection is automatically set up after booting and thus syncing with RTC time or manually with commands in the Terminal. After each reboot of the system, it is necessary to copy the RTC time back to the system clock. Thus even after system restart the RPi system time is read from the time of the RTC. All of the busy addresses by EEPROM, sensors and the RTC on the pair of I^2C buses 0 and 1 of Raspberry Pi can be visualized by using both of the commands sudo i2cdetect -y 0 and sudo i2cdetect -y 1 in the RPi's Terminal, where UU is displayed at 0x68 for the RTC address shown in Figure 4.

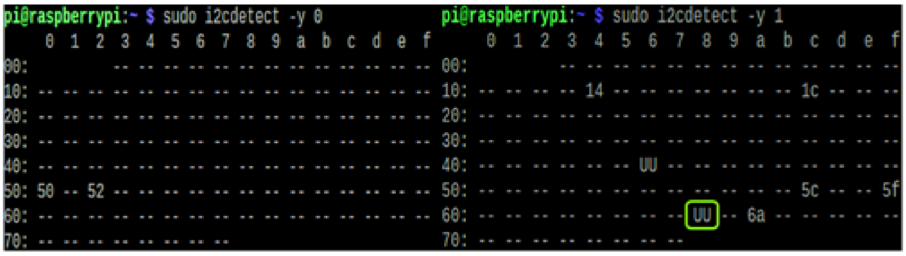

Figure 4. Visualization of the pair of I^2C buses of Raspberry Pi

The application software consists of several scripts alongside of a graphical user interfaced program, which combines the action of all scripting programs and provides visual management of the system. The program files are organized into special directories given in Fig. 5 as a tree structure.

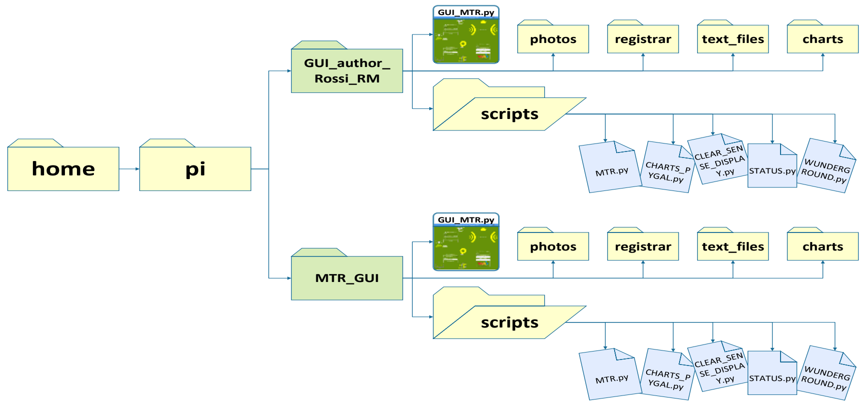

Figure 5. Directory organization

The MTR_GUI folder contains the source code using absolute or full paths, and the GUI_author_Rossi_RM folder contains the same scripts as MTR_GUI but with relative paths. All scripts are programmed in Python 3 IDLE on Raspbian and in PyCharm installed on Windows 10 Education.

The first script of our system, named as MTR.py, performs the actual data fetching by the system via Sense HAT's pressure, humidity, temperature and orientation sensors. In addition to these data, the relative altitude is calculated on the basis of the measured pressure and temperature values using a mean sea level pressure correction known as QNH in aviation and used by pilots as a secondary value for altitude information during flying. This factor is calculated and available as a value in the constantly updated information of each general airport - METAR. Each time before measurement the value of the QNH factor of the nearest airport to our location is taken via third party METAR-based mobile applications. All of the collected data is being saved as a spreadsheet in a .CSV file, which is being uniquely named each time the program is started, due to the fact that the system time is being called. Other data recorded in the file is collected by Sense HAT's get_accelerometer_raw() method, which measures the gravitational acceleration or G, acting on each of the three axes (x, y, z). For G > 1, the value of G is recorded along with the axis on which the value is measured, for
G <= 1, then G is saved as "Normal: G = 1". The purpose of this measurement by the system is to detect possible system shocks with force above the standard gravity force of G = 1.

Maintaining a reasonably sized script is a basic programming goal, as this facilitates the subsequent modification and management of the code. With Python 3 this goal is being achieved by using modules or libraries.

A module can be imported by specifying its name preceded by the import keyword, and it is good practice to do it at the very beginning of the code. After importing the module names into the script, all module methods become available within the new script. Thus a script can call up the functions of another script and thus communication between two or more scripts is provided. The modules in Python can be either standard from the Python's standard functional library set included in the standard language installation package, or third-party modules (for example: sense-hat, pygal, requests etc.) written by keen users of the language. An algorithmic diagram for the logic of the MTR.py program is given in Fig. 6.

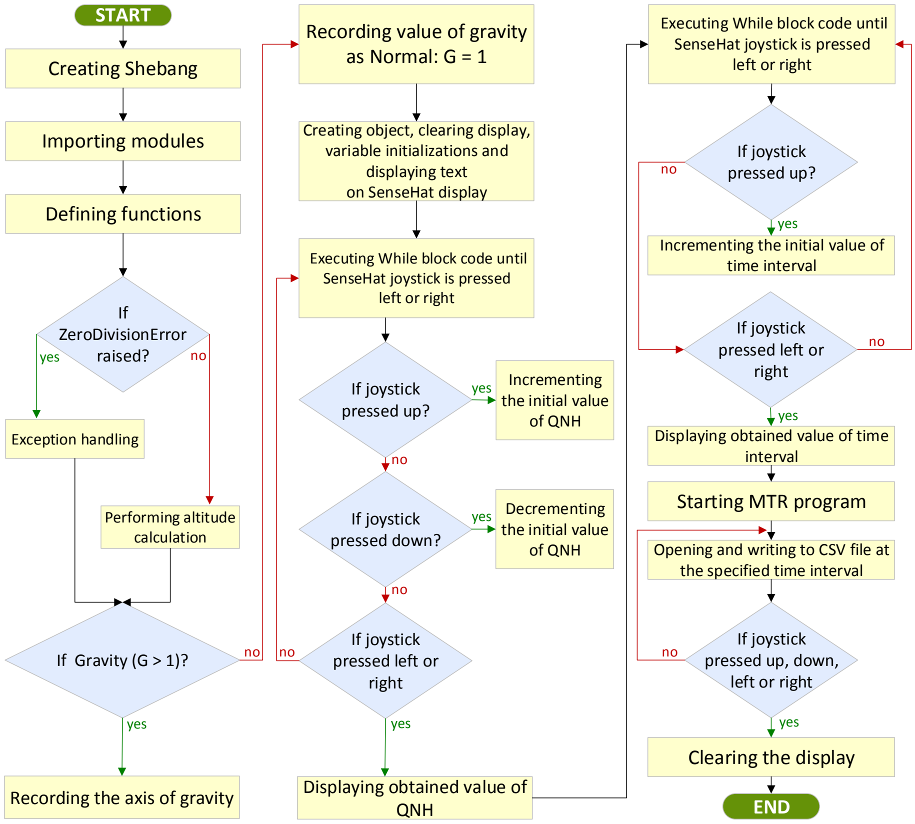

Figure 6. Algorithmic diagram of the MTR program

The modules imported in the MTR.py script are:

import sys
from sense_hat Import SenseHat
import csv
from csv import writer
from time import sleep
from datetime import date, datetime, timedelta

Thanks to the CHARTS_PYGAL.py program, the collected and saved data is processed converting the data from the CSV file to a graphical and text formats. The script reads the name of the CSV file as an input without the name extension and draws separate graphs of the measured values from each of the sensors - pressure, temperature and humidity alongside of the calculated altitude during the recording, common chart of all measurement and calculation values together, as well as the map of the world in which the data collection is processed. The program also converts each column of the spreadsheet from the CSV file into a separate text file to a specific directory. This is done in order to make raw data available for subsequent data processing. The third-party library pygal is used. An algorithmic diagram for the logic of the CHARTS_PYGAL program is given in Fig. 7. The modules imported in the script are:

import sys
import os
import csv
import pygal
from pygal.maps.world import World
from pygal.style Import Style
from datetime import datetime

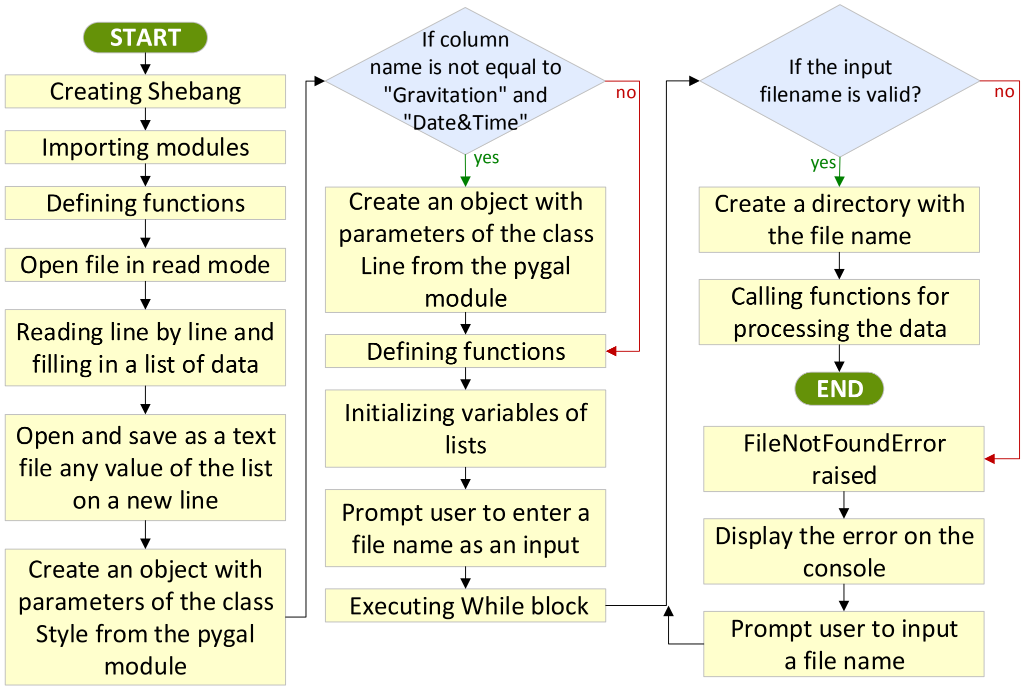

Figure 7. Algorithmic diagram of the CHARTS_PYGAL program

Each script can be run through a specially created text files with the .DESKTOP extension on the RPi's desktop. However almost every operating system includes some kind of a graphical user interface (GUI) to allow users to input data and see the results. Graphical programming handles a specific set of terms. For example, the primary area of the GUI is called a window, and the area in the window is frame. The frame may contain various widgets such as text boxes, buttons, sliders etc. that the program uses to interact with users. Each widget has its own set of properties that determine how it is displayed in the window and what features it performs. The implementation of various functions is preceded by the concept of event handling. Thus the graphical application does not have a sequence of tasks but instead relies on a set of functions (methods) that are executed individually in response to a particular event.

In order for the program to work it is necessary to create separate functions that Python calls when an event occurs. The standard tkinter library of Python is one of the most popular for GUI programming. Since Python includes the standard tkinter library in its default library set, it is typically used to create graphical Python programs in Raspberry Pi too. The GUI_MTR program (Fig. 8) in our system is written in Python 3 using the third-party guizero library, which is a private case of the tkinter library.

Figure 8. Main window of the GUI_MTR program

The GUI_MTR window is mentally divided into 4 sections where the individual scripts are located and performing. Thus the MTR program is located and started form the first section, whereby the value of the QNH and the time interval are being set by sliders. The third section is dedicated to the CHARTS_PYGAL graphics drawing program which has a dropdown menu for selection of the country where the data acquisition takes place thanks to the pygal-maps-world library. Currently the country of Bulgaria is selected. Below the dropdown menu there is a text box where you enter the name of the CSV file without its extension in which the data is stored. After starting the program from the specified button, the program automatically creates a directory containing text files, graphics and map of the world with .TXT, .PNG, and .SVG extensions.
Environmental data obtained by MTR system are shown in Fig. 9.

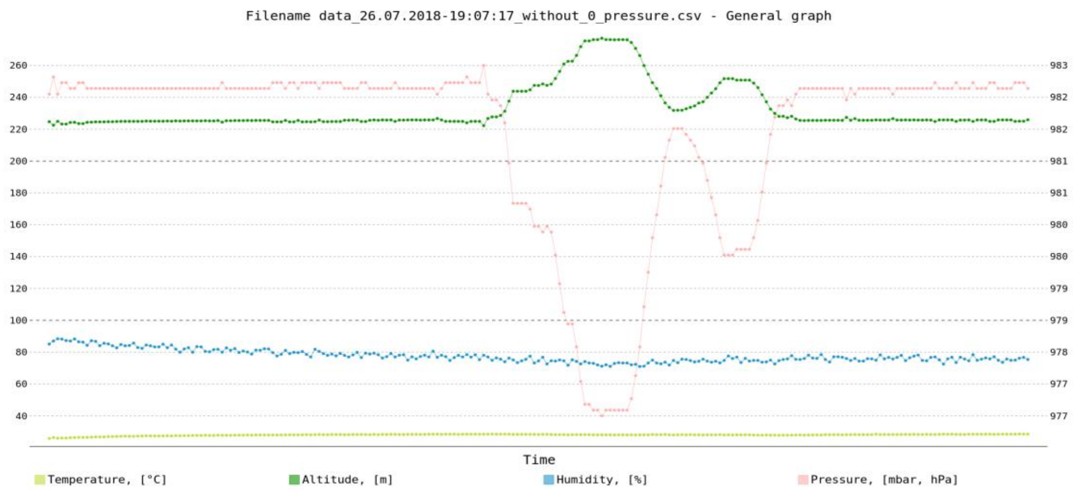

Figure 9. Environmental data obtained by MTR system

CONCLUSION

The assembled hardware of the mentioned data acquisition computer system fetching a whole range of direct sensory information about the immediate environment can be used to conduct personal and scientific experiments in various scientific fields, due to the fact that all processes are automated by programs in Python 3. In case a specific set of sensor data is required, the Python language easily provides the flexibility of the code for subsequent modifications. The ability for remote access from each Internet connected node of the world provides the freedom and the sense of IoT with no need for a local area network. The advantage of our system over other ready systems is the ability and flexibility of its programming code. The fact that this system can be adapted to different needs allows it to be used not only in the world of computer technology but also in interdisciplinary science fields where various fundamental natural processes can be monitored through the available sensors. Main application of developed system is to be used for monitoring and data acquisition with environmental sensors. The presented paper provides results of the master thesis afterwards published as a book of Rositsa Maksimova with the scientific coordination of Assoc. Prof. Krassimir Kolev.

REFERENCES

[1] Blum R., C. Bresnahan, Teach Yourself Python Programming for Raspberry Pi in 24 Hours, SAMS, USA, 2016.
[2] Charleston T., RASPBERRY PI 3:2016 USER GUIDE FOR BEGINNERS, CreateSpace Independent Publishing Platform, 2016.
[3] Maksimova R., Open source computer system for data acquisition – MTR, Saypres OOD, Plovdiv, 2019. (in Bulgarian)
[4] Mounier F., pygal Documentation Release 2.0.0, pygal.org, 2016.
[5] PiJuice HAT - A Portable Power Platform For Every Raspberry Pi – Pi Supply, website: https://uk.pi-supply.com/products/pijuice-standardBest
[6] Sense HAT - Raspberry Pi, website: https://www.raspberrypi.org/products/sense-hat/
[7] The European Astro Pi Challenge, website: https://astro-pi.org

CONSTRUCTION OF THE PUNCH MACHINE FOR CUTTING POCKETS IN THE CAR BUMPERS

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Abstract: In this paper the construction of the punch machine for cutting pockets in the car bumpers was described. The machine consists of a press cylinders with working elements and a safety fence. The SolidWorks software with a base of standardized elements was used for machine modeling and drafting of technical documentation. CAM technology was used to production of non-standard machine parts.
Key words: CAD, CAM, SolidWorks, punching, bumper

INTRODUCTION

A bumper is a structure attached to or integrated with the front and rear ends of a motor vehicle, to absorb impact in a minor collision, ideally minimizing repair costs [1]. Stiff metal bumpers appeared on automobiles as early as 1904 that had a mainly ornamental function [2]. The bumper of modern cars consists of plastic cover over a reinforcement bar made of steel, aluminum, fiberglass composite, or plastic.

It is often necessary to make holes or pockets in the bumpers used for various purposes. In this paper, the machine for making two pockets along an irregular shape (Fig. 1) of car bumper was constructed. The bumper material is plastic. Punching was chosen as the type of forming, since this is part that come in sheet form and large-scale production.

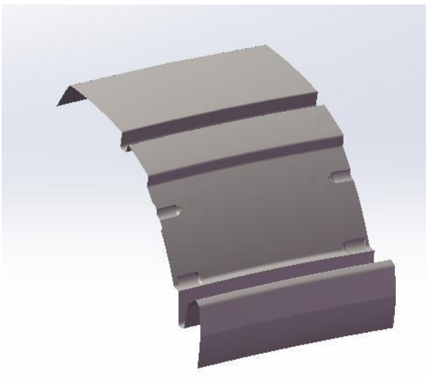

Figure 1. Rest of punching

ANALYSIS OF FUNCTIONAL REQUIREMENTS

As part of the analysis of functional requirements of punch machine for cutting pockets in the car bumpers, the division was made at the requirements for the construction of the press itself and the requirements for the construction of the safety fence.

The requirements to be met by the press construction are:

- The complete construction should be made of steel tubes whose dimensions will satisfy calculated characteristics,
- The construction itself must have tubes through which the forklift will be able to carry the construction,
- The forklift must have access to the construction from the front and back,
- The tubes on the front of the machine mustn't be longer than the construction,
- The construction must allow easy change of workpieces,
- It is necessary to make it possible to punch one or two different parts together or each separately,

- Each part must be accurately, quickly and easily positioned in the machine,
- The supports on which the workpiece is positioned must be of material that will not damage the workpiece,
- The lower part of the punching tool (die) must be able to be positioned horizontally,
- The lower part of the punching tool (die) must follow the contour of the workpiece,
- The upper part of the punching tool (punch) must be able to quickly reach the workpiece,
- The upper parts of the punching tool (punches) must be able to operate independently of one another,
- The upper part of the punching tool (punch) must follow the contour of the workpiece,
- The precision of the punch contour must be up to 0,001mm,
- The movement of the upper part of the punching tool (punch) must be carried out using hydraulic or hydraulic-pneumatic cylinders,
- The rest of punching must have a smooth fall out of the tool,
- The presence of parts in the machine must be detected by sensors,
- The machine must be activated by the worker.

The requirements to be met by the safety fence construction are:

- It must ensure the safety of the press, respectively the workers must not be inside the workplace while the machine is in operation,
- It must be provided enough space on the front side of machine that workers cannot come inside the workplace while the machine is in operation,
- The space in front of the construction of the press and inside the safety fence must be covered with light sensors in color,
- The dimensions of the fence must be such that the worker can fast and easily place and take the workpiece into/from the press,
- Install an electrical panel on the construction of the safety fence that must have access from the outside,
- Install the ventilator on the safety fence which will regulate the temperature in the workspace,
- Place the display inside the machine from which the worker will follow the machine cycle and the steps to be taken,
- Place the display outside the machine on which the worker will follow the machine cycles,
- The cycle start switch must be outside the workspace of the machine and it mustn't be able to activate while the worker is in the workplace.

Based on these requirements, the conceptual design was created, as shown in Fig. 2.

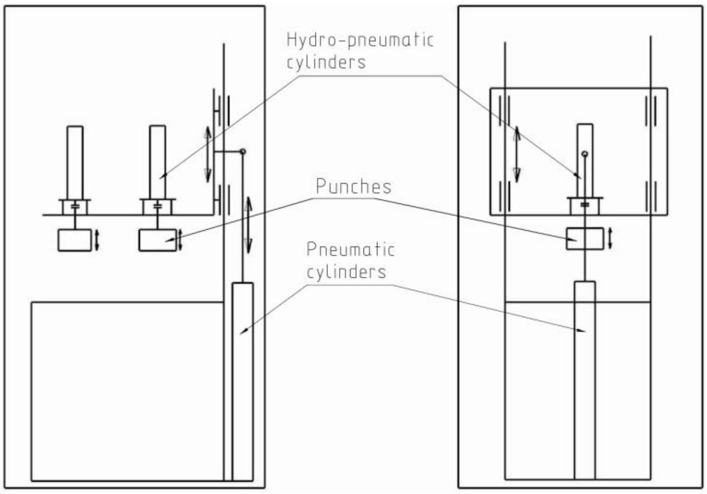

Figure 2. Conceptual design

EMBODIMENT DESIGN OF MACHINE

The punch machine was designed in SolidWorks computer software, which is a solid modeler, and utilizes a parametric feature-based approach. The plastic part of this bumper consists of two elements that are assembled after the punching. Both punch shapes are irregular form as shown in Fig. 3.

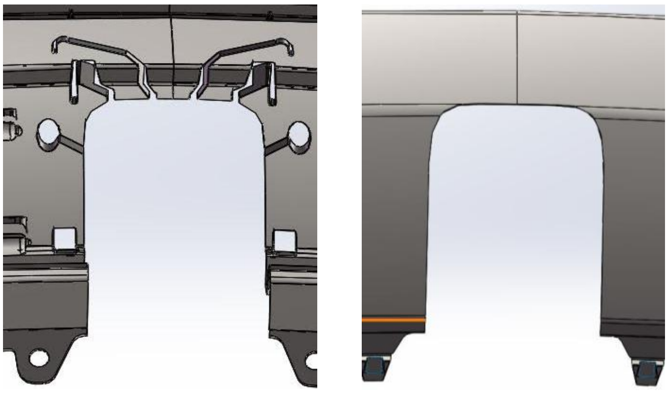

Figure 3. Punch shapes before and after punching

The machine is designed so that both parts can be positioned at a time, and if necessary, only one part can be processed. The tool work elements, two punches and dies are designed to follow the shape of the workpiece, as it shown in Fig. 4.

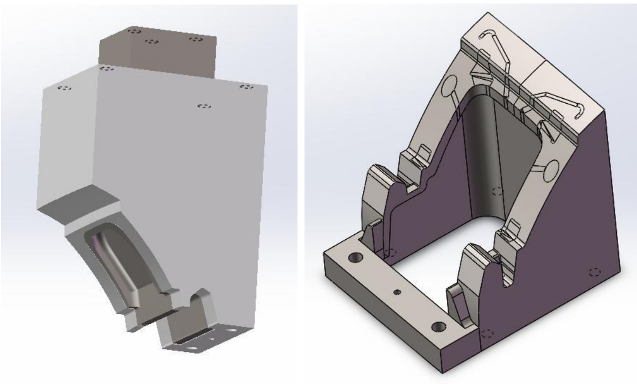

Figure 4. Punch and die

Special attention has been given to the support elements, because of the irregular shape of the workpiece as shown in Fig. 4. Twelve elements (six for one workpiece) which are connected to the base plate by screws and pins, were used for this purpose.

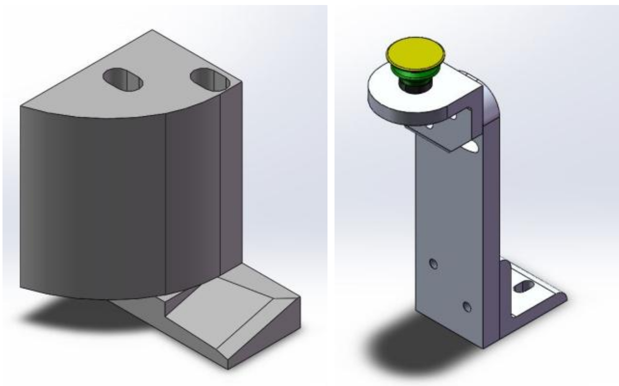

Figure 5. Support and locations elements

The machine has three cylinders, one pneumatic and two hydro-pneumatic. The total motion of the punches is 1152,4 mm, of which 1000 mm is achieved by a pneumatic cylinder and the rest by a hydro-pneumatic cylinder. The punching is hydraulic due to the punching force which is [3]:

$$F = O \cdot s \cdot \tau_m \text{ (N)} \tag{1}$$

Where are:
O(mm)- punch shape length
s(mm) - material thickness
τ_m(N/mm^2)- shear stress

In addition to the model of machine in SolidWorks (Fig. 6), a complete technical documentation with all standard and non-standard parts was made. Non-standard parts were made on the waterjet and CNC machining center using CAM technology. The work elements of the punch machine (punches and dies) are made of steel A2 and the support elements are made of hot rolled steel (HRS).

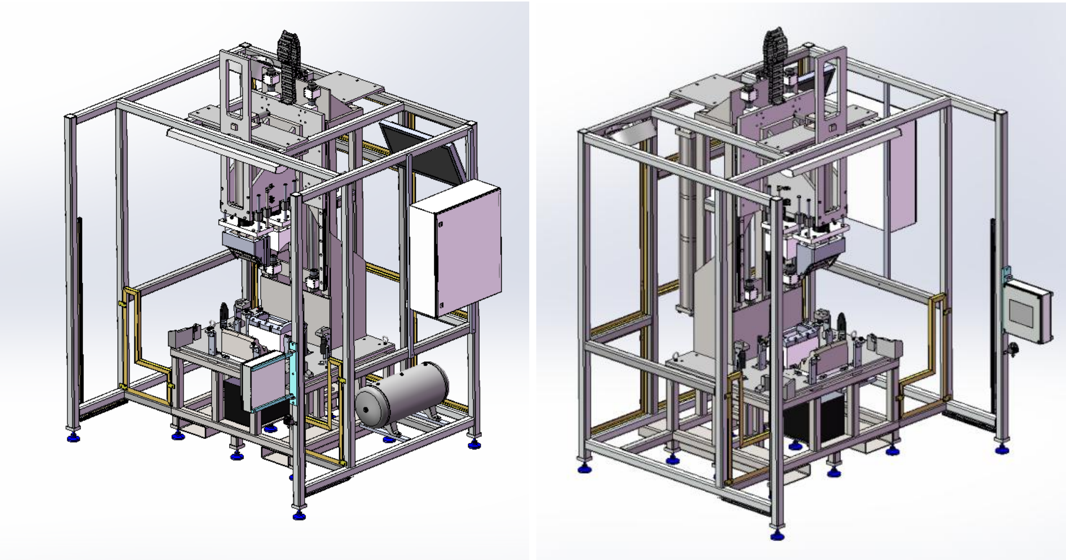

Figure 6. SolidWorks model of punch machine

CONCLUSION

The modeling of modern machines, such as plastic processing machines, is much easier with the application of CAD software. In this paper the benefits of geometric modeling in SolidWorks were shown, which, among other things, enables quick corrections on the model, if necessary in the later stages of construction. Also, standardized tool parts from the SolidWorks databases or from the available manufacturer models are easily used. The final step in the design and construction of the machine is the use of CAM technologies. In this case it is Mastercam. The advantage of the CAM system is that the complexity of the geometric shape of the workpiece does not affect the complexity of making NC programs.

REFERENCES

[1] Helps, Ian G. (2001). Plastics in European cars, 2000 - 2008. Shawbury RAPRA Technology. pp. 99.
[2] Bumper Development, Automobile Trade Journal. Vol. 29 (6): 301.1924.
[3] Plančak, M., Vilotić D., Dies and Tools for Metal Forming, Faculty of Technical Sciences, Novi Sad, 2011, (in Serbian).

DETERMINATION OF INJECTION MOLDING PARAMETERS FOR PRODUCTION OF PLASTIC COVER

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Abstract: This paper presents numerical simulation method for determining injection molding parameters for plastic cover production. The purpose is to assess plastic mixture that consist of ABS and PP. The part must have suitable geometry from the standpoint of mold ability. This paper describes the CAD-to-part inspection procedure for verification of the dimensional accuracy of the plastic product.
Key words: injection molding parameters, CAD inspection, plastic product

INTRODUCTION

Today, more than one-third of all polymers are injection molded [1]. Injection molding is a suitable process for manufacturing of large numbers of geometrically complex parts. Many everyday items, such as mobile phone covers, automobile bumpers, television cabinets, compact discs and lunch boxes are all examples of injection-molded parts [2]. Generally, plastic injection molding design includes plastic part design, mold design, and injection molding process design, all of which contribute to the quality of the molded product, as well as production efficiency [3]. The mold industry represents a key position in overall manufacturing chain, affecting the costs, quality and lead-time of a product. Besides, in order to fulfill the market demand, designers have been using free form geometries in the product shape, to be more attractive for marketing purposes. This fact increases the product manufacturing complexity [4]. Boujoelbene et al. [5] investigated the costs of plastic products, and concluded that 30% of these product costs is related to the mold manufacturing, 25% related to the injection process, 25% to the plastic material, 10% to design and simulation, 5% mold material and 5% is related to other costs. Therefore, mold manufacturing is the most represented item in the cost of a plastic product. Injection molding process is one of the most important process of manufacturing of plastic parts [1, 3, 6, 7]. The visual appearance and characteristics of the injected components are highly dependent on the raw material, mold design and injection molding parameters. Plastic Advisor software provides numerical simulation of molding process and it's also intended for molding and cooling time determination and detection of potential problematic areas. CAD-to-part inspection is a very widespread process for proving the accuracy of product dimensions [8].

MATERIAL AND METHODS

Plastic cover production workflow of plastic cover consists of several stages:

- CAD modelling of the part i.e. product design,
- Analysis surfaces of the part,
- Numerical simulation of injection molding process,
- Mold design and manufacturing of the mold,
- Injection molding process and cutting the gate subsystem,
- CAD inspection and
- Generating technical documentation.

Production workflow is shown in Figure 1.

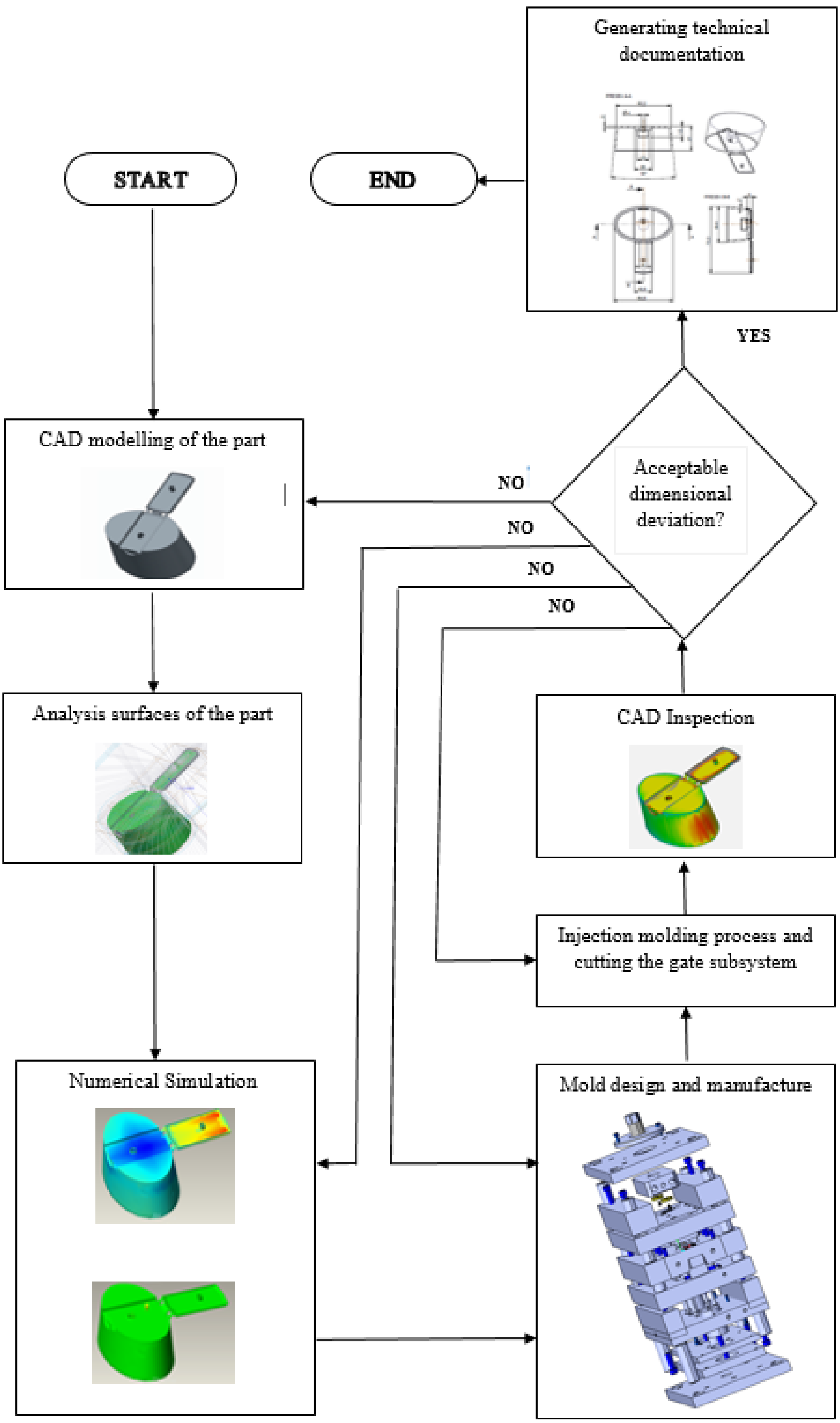

Figure 1. Plastic cover production workflow

CAD modelling of the part

Usually, the initial plastic part CAD model is provided by the customers to meet their specific requirements, such as dimensions and/or aesthetic shape. Then numerical simulation is carried out to investigate how the production process will influence the part dimensions and identify shrinkage rates. Then design updates are carried out by incorporating the production induced shrinkage rates to the initial part design, so that the updated design will satisfy the dimensional requirements after going through the injection molding process. Usually, shrinkage rates induced by injection-molded process are small and shrinkage pattern for the updated design is similar to the initial product design. Therefore, another stage of the numerical simulation is not necessary in most cases. Finally, the mold can be designed based on the updated product design. In this way, the possible production-induced problems can be addressed in the design stage [9, 10].
Creo Parametric software, and especially designed system SAPA [10] are used for generating CAD model of the plastic cover and appropriate simulation model. The result of this program system is solid model of plastic part with all necessary geometrical and precision specifications. Precision specifications are: project name, number, feature ID, feature name, position of base point, code number of simulation annealing, trade material name, material grade, part tolerance, machine specification (name, clamping force, maximal pressure, dimensions of work piece), and number of cavities. If geometrical and precision specification is specified (given) with product model, the same are used as input to the next application, while this module is used only to generate the simulation model.

Analysis of the surfaces

The next stage of the production workflow is analysis of the surfaces. This stage provides clearence geometry and usable CAD model. Creo Parametric software is sufficient for complete surface analysis and geometry check. The most used analyzes are [10]:

- verification of G1 surfaces,
- verification of drafts,
- verification of radii,
- verification of dihedral angle,
- verification of the patches,
- verification of the tangency between surfaces and
- verification of the curvature continous.

One of the above mentioned analyzes is shown in Figure 1.

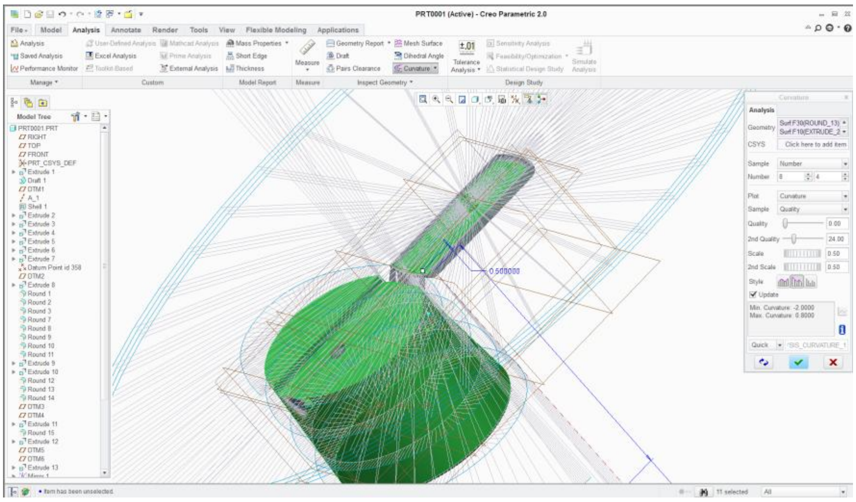

Figure 2. Verification of the „G1 surfaces“

Numerical simulation of injection molding process

After creation of CAD model of plastic part, analysis and numerical simulation of injection molding process can be performed in commercial software such as AutoDesk Moldflow, Moldex 3D, SIGMASOFT, CadMouldPro, MoldFlow Plastic Advisor and PTC Pro/Plastic Advisor. Pro/Plastic Advisor software supports also other neutral CAD formats such as IGES, STEP, DXF, STL, STP etc. It means that this module is possible to carry out a simulation that is not designed in Creo Parametric software. After importing CAD model, based on the material choice from the database and definition of injection molding parameters, system will automatically apply the suggested parameters for chosen material, but there is also a possibility to make subsequent changes and alterations. Database of plastic materials included consists of more than 6000 plastic materials. The database include components of the plastic mixture Acrylonitrile butadiene styrene **(**ABS) and polypropylene (PP), but does not contain their compound. The injection molding process is typically divided into four phases [11, 12, 13, 14, 15, 16, 17]: filling, packing, cooling and ejection. Among these, the cooling phase takes the longest time and accounts for 80% of the injection molding cycle. A shorter cycle time means lower production costs and in return it's increasing company's competitiveness on the market. Numerical simulation offers four different types of mold flow analysis:

- Part analysis - This analysis is used to test a known gate location, material, and part geometry and to verify that a part will have acceptable processing conditions.
- Gate analysis - This analysis tests multiple gate locations and compares the analysis outputs to determine the optimal gate location.
- Sink Mark Analysis - This analysis detects sink mark locations and depths to resolve cosmetic problems before the mold is built eliminating quality disputes that could arise between the molder and the customer. The part molding process is heavily affected by factors of the part design. If the injection molding parameters of a part are not set correctly, the part will have quality issues during the injection molding process. The most critical of injection molding parameters is as follows:
- Part thickness,
- Part flow length,
- Thickness transitions,
- Part material,
- Location of gates,
- Number of gates,
- Mold temperature and
- Melt temperature.

All injection molds require a gate or gates at which the molten plastic is introduced into them. If not considered at the design stage using numerical simulation, this can leave unsightly surface blemishes on the finished molding which require a further stage to remove them, incurring extra costs.
Injection molding parameters and material properties of the plastic mixture used in the case study iare shown in Table 1, where words „high“ and „uniform“ are means of generated results of the „Confidence of fill“ analysis using numerical simulation in Pro/Plastic Advisor software. The simulation model is completely filled. All regions are marked with green colour which means that the chosen injection molding parameters are fully acceptable (see Figure 1).

Table 1. Injection molding parameters

Material	**Plastic mixture (ABS 650 + PP 65)**
Mold temperature (^{0}C)	55
Melt temperature (^{0}C)	238
Transition temperature (^{0}C)	112
Injection Time (s)	0,6
Injection Pressure (MPa)	175

Table 1. Injection molding parameters (continuation)

Material	Plastic mixture (ABS 650 + PP 65)
Recommended ejection temperature (0C)	108
Modulus of elasticity, flow direction for mixture (MPa)	2440
Modulus of elasticity, transverse direction for mixture (MPa)	2440
Poison ratio in all directions	0,392
Shear modulus (MPa)	805
Density in liquid state (g/cm3)	0,72
Density in solid state (g/cm3)	0,89
Pressure drop (MPa)	17.75
Skin orientation	Uniform
Confidence of fill	High
Quality prediction	High
Cooling quality	High
Surface temperature variance (0C)	-5.33 to 3.93
Maximal sink mark estimated	0.014
Maximal machine pressure (MPa)	190
Machine open clamp time (s)	4
Maximal shear stress (MPa)	0,3
Specific heat (J/kg0C)	2740
Thermal conductivity (W/m0C)	0,164 on 2400C
Heating/cooling rate (0C/s)	-0,1667 0C/s
Maximal packing clamp force estimate (MPa)	21,30
Estimated cycle time (s)	11

Plastic materials for injection molding can be divided into crystalline, semi-crystalline and amorphous plastics, based on whether crystallization occurs during the cooling phase. Semi-crystalline plastics have an ordered pattern of molecular chain, while the molecular chain for amorphous plastics is randomly distributed. Injection molding parameters and material properties of the components (constituent materials) are shown in Table 2. The qualitative analysis is presented in the words such as „higher" (higher value) and "lower" (lower value) as indicated in Table 2.

Table 2. Comparative analysis of the properties of constituent materials

Material grade	Acrylonitrile butadiene styrene 780 (ABS 780)	Polypropylene (PP65)
Structure	Amorphous	Semi-crystalline
Max injection pressure	lower	higher
Mold temperature	lower	higher
Melt Temperature	higher	lower
Injection Time	lower	higher
Shear modulus	higher	lower
Density in liquid state	higher	lower
Density in solid state	higher	lower
Injection time	lower	higher
Maximal shear stress	higher	lower
Maximal shear rate	lower	higher
Specific heat	higher	lower
Thermal conductivity	lower	higher
Ejection temperature	higher	lower

Mold design and manufacturing of the mold

The next stage is mold design can be divided into:

- mold plates with appropriate runners, gates and waterlines dimensions design (which was estimated using numerical simulation and calculated using SAPA software),
- core and cavity inserts design,
- sliders selection,
- ejector pins selection and
- other components design and/or selection that defines a shape of molded part.

The PTC Mold Design software was used for final modelling of the mold assembly. This software used additional software tools for automation creating core and cavity from CAD model including shrinkage factor of plastics and automation splitting mold volumes of the fixed and movable plates. Creo Tool Design Extension software was used for modelling the cavity molds and core with ease. The software was used for generation of mold draft, undercut and thickness, and then automatically creating parting surface and splitting mold volumes. Creo Tool Design Extension contains a database of the mold components. The resulting CAD model is then used for interference checking during mold opening, as well as automatic generation of deliverables such as detailed drawings and bill of materials (BOM).

CAD-Inspection of the part

CAD-Inspection of the part i.e. CAD-to-part inspection is used for dimensional verification of the manufactured part. After the manufactured part is scanned, nominal CAD model is compared against it. Alignment was performed using best-fit method. Results are presented in a color-coded model showing deviations of the scanned 3D model from the CAD model for both internal and external geometry. In order to verify the accuracy of the obtained CAD model, it was compared against its nominal CAD model that was previously designed. CAD-Inspection serves as a tool for dimensional verification of accuracy of obtained objects compared against their nominal geometry as shown in Figure 3. From the CAD-Inspection it can be seen that the deviation is in the range ±0.30 mm, and the concentration of the deviation is around 0.01 mm, which presents a satisfactory result as shown in Figure 3, and Figure 4.

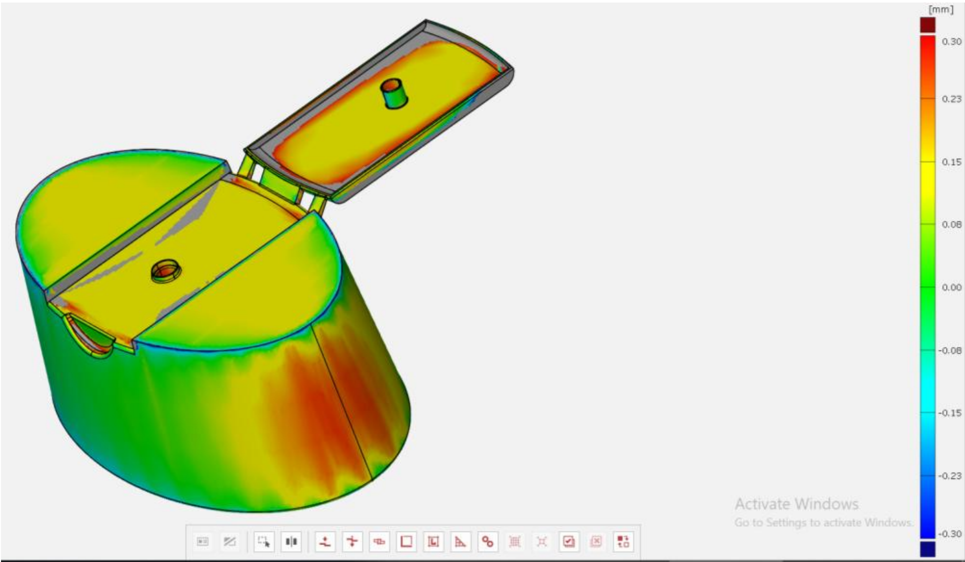

Figure 3. CAD inspection between the nominal CAD model of the cover and the scanned 3D model

The most critical segment on the manufactured product is the hinge. The hinge suffers the highest dynamic loads due to the cyclic opening and closing of the cover. CAD-inspection between hinge from the CAD model and the hinge from the scanned 3D model of the manufactured product is shown in Figure 4.

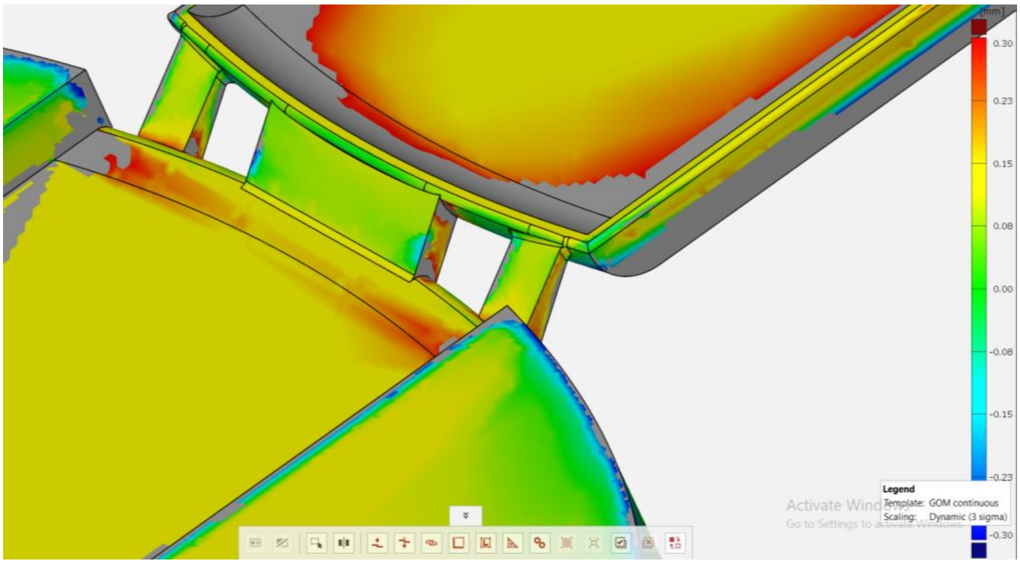

Figure 4. CAD inspection beetween hinge from the nominal CAD model and the hinge from the scanned 3D model of the manufactured product

Generating technical documentation

The next stage (see Figure 1) presents completing the detailed technical documentation and upgrading the database. The technical documentation can be divided into:

- Drawings of the product,
- Drawings of the simulation model,
- Injection molding report,
- Mold assembly drawings with BOM, mold component drawings, and
- CAD inspection report.

CONCLUSION

Overall, the presented results show fully applicable method and full usability of the product from the point of dimensional accuracy. Values of the dimensional deviation showed that the plastic part has good surface quality, which is more than enough and useful for exploitation. The results indicate that the use of described designing process can enhance performance of the injection molding, which can further improve the quality of the manufactured part. The injection molding parameters are correctly determined, which ensures stable production of the part and high dimensional accuracy.

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REFERENCES

[1] Raos P, Stojsic J, Prajkovic D.: Effects of injection molded parameters on flexural properties of polystyrene molded part, International Conference on Innovative Technologies IN-TECH, pp. 61-64, ISSN 0184-9069, 2017.

[2] Kennedy P.K.: Practical and Scientific Aspects of of Injection Molding Simulation, Technische Universiteit Eindhoven, Proefschrift, Eindhoven, ISBN 978-90-386-1275-1, 2008.

[3] Matin, I., Hadzistevic, M., Hodolic, J., Vukelic, Dj., Tadic, B.: Development of CAD/CAE system for mold design, Journal of Production Engineering, Vol. 16, No.2, pp. 61-64, 2010.

[4] Fagali de Souza A, Machado A, Fischer Beckert A, Diniz A.E., Evaluating the roughness according to the tool path strategy when milling free form surfaces for mold application, Procedia CIRP, Vol. 14, pp. 188-193, 2014.

[5] Boujelbene M, Moisan A, Tounsi N, Brenier B.: Productivity enhancement in dies and molds manufacturing by the use of C1 continuous tool path, International Journal of Machine Tool and Manufacture, Vol. 44, No.1, pp. 101-107, 2004.

[6] Tang S.H, Kong Y.M, Sapuan S.M, Samin R, Sulaiman S.: Design and thermal analysis of plastic injection mould, Journal of Materials Processing Technology, Vol. 171, pp. 259-267, 2006.

[7] Matin I, Hadzistevic M, Vukelic Dj, Milutinovic M, Golebski R.: Application of numerical simulation of injection molding of medical accessory, Journal for technology of plasticity, Vol. 41, No.1, pp. 47-55, 2016.

[8] Sokac M, Santosi Z, Budak I, Car Z, Vukelic Dj.: Combination of contact and optical 3D digitizing methods for their application in reverse engineering, International Conference on Innovative Technologies IN-TECH, pp. 65-68, ISSN 0184-9069, 2017.

[9] Matin I, Hadzistevic M, Hodolic J, Vukelic Dj, Lukic A.: CAD/CAE-integrated injection mold design system for plastic products, International Journal of Advanced Manufacturing Technology, Vol. 63, pp. 595-607, 2012.

[10] Matin I, Vukelic Dj, Hadzistevic M, Strbac B, Lukic D.: An integrated approach for design and manufacture of plastic product, Applied Engineering Letters, Vol. 4, No.1, pp. 1-5, 2019.

[11] Fu J, Ma Y.: A method to predict early-ejected plastic part air-cooling behavior towards quality mold design and less molding cycle time, Robotics and Computer Integrated Manufacturing, Vol. 56, pp. 66-74, 2019.

[12] Randjelovic S, Milutinovic M, Nikolic S, Pepeljnjak T, Movrin D.: Application of FEM for analysis of injection molding process and mold design, International Conference on Innovative Technologies IN-TECH, pp. 185-188, ISSN 0184-9069, 2017.

[13] Öktem H.: Optimum process conditions on shrinkage of an injected-molded part of DVD-ROM cover using Taguchi robust method, International Journal of Advanced Manufacturing Technology, Vol. 61, pp. 519-528, 2012.

[14] Koc B, Thangaswamy S.: Design and analysis of a reconfigurable discrete pin tooling system for molding of three-dimensional free-form objects, Robotics and Computer Integrated Manufacturing, Vol. 27, pp. 335-348, 2011.

[15] Mercado-Colmenero J.M, Rubio-Paramio M.A, Vizan-Idoipe A.: A new procedure for the automated design of ejection systems in injection molds, Robotics and Computer Integrated Manufacturing, Vol. 46, pp. 68-85, 2017.

[16] Sun, Y.F, Lee, K.S, Nee A.Y.: Design and FEM analysis of the milled groove insert method for cooling of plastic injection moulds, International Journal of Advanced Manufacturing Technology, Vol. 24, pp. 715-726, 2004.

[17] Hassan H, Regnier N, Lebot C, Pujos C, Defaye G.: Effect of cooling system on the polymer temperature and solidification during injection molding, Applied Thermal Engineering, Vol. 29, pp. 1786-1791, 2009.

COMPARISON OF POWER FLOW CALCULATIONS USING I AND Π POVER LINE MODELS

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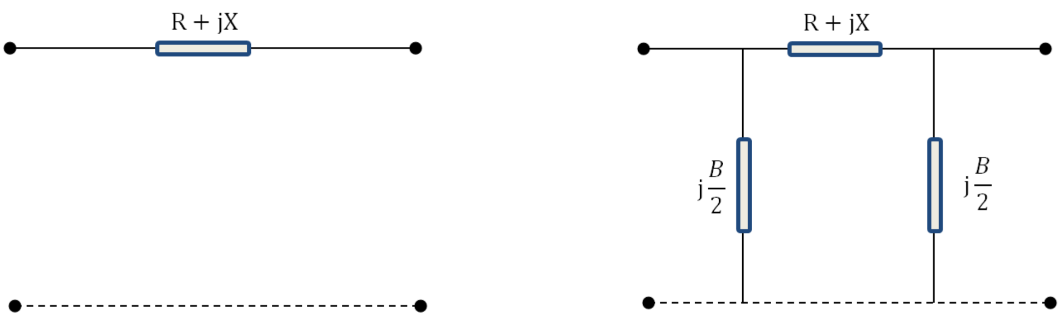
Abstract: This article contains detailed results of power flow calculations for low – voltage distribution network with overhead power lines, using both i and π power line models. Calculations were done using two separate software applications for each model. Power flow calculations for π model were done using EMTP/ATP Draw and calculations for I model byusing iterative method of calculation implemented by MATLAB code. Results were compared both in tables and graphic diagrams.
Key words: Power flow, ATPDraw, MATLAB, I model, π model

INTRODUCTION

During the process of distribution power grid planning there are many calculations that need to be done. One of the main calculations are power flow calculations which show voltage and current profiles as well as estimated power losses of power lines. Most of the standard power plow calculations for low voltage, 0.4 kV, power grid are using I power line model for modeling of the grid - mainly because of its simplicity, but the downside of this model is that the results are not completely realistic. In this article we will show the difference in power flow results using standard I model and a more complex π model for overhead power lines. To eliminate any errors we will use two programs – EMTP/ATPDraw (π model)and MATLAB (I model).

USED POWER LINE MODELS

There are many different modeling techniques but we will be using two most commonly used today – I (Figure 1a) and π models (Figure 1b). The main difference between these models is that I model disregards the capacitance of the power lines while π model incorporates it as two equal susceptants [1]. Each of susceptants holds half of the total capacitance of the modeled power line. Even though the capacitance of the low voltage power lines is usually negligible, we will show the difference in power flow calculations using both methods of modeling.



a) b)

Figure 1. Power line models [2]

POWER FLOW CALCULATIONS

Power flow equations

Equations for power flow calculations consist of system of equations which as a result show voltage and current profiles as well as estimated power losses of power lines. System of equations varies based on the model of power lines but we will use π model as its more complex.
Using model shown on Figure 2 we can write power flow system of equations [3].

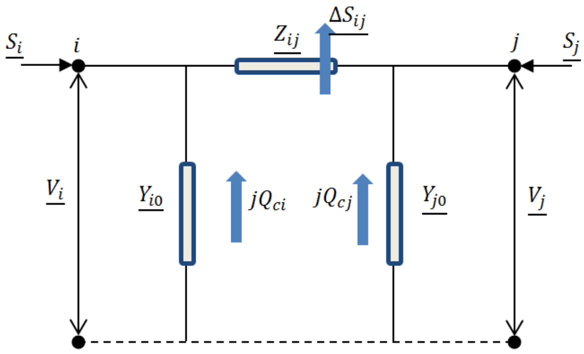


Figure 2. Π model for power lines

Total power injected into point *i* can be calculated as subtraction of generated and consumed power as is shown by equation bellow.

$$\underline{S_i} = P_i + jQ_i = \underline{S_{Gi}} - \underline{S_{Li}} = P_{Gi} + P_{Li} + j(Q_{Gi} + Q_{Li}) \quad (1)$$

where:

- $\underline{S_i}$ – Total power injected into point *i*;
- P_i – Total active power injected into point *i*;
- Q_i – Total reactive power injected into point *i*;
- $\underline{S_{Gi}}$ – Total generated power injected into point *i*;
- $\underline{S_{Li}}$ – Total power consumed by a load placed at point *i*;
- P_{Gi} – Total generated active power injected into point *i*;
- P_{Li} – Total active power consumed by a load placed at point *i*;
- Q_{Gi} - Total generated reactive power injected into point *i*;
- Q_{Li} - Total reactive power consumed by a load placed at point *i*.

Power loss between points *i* and *j* can be calculated as sum of power transferred from point *i* to *j* and from point *j* to *i*.
Power transferred from point *i* to *j* is calculated as:

$$\underline{S_{ij}} = P_{ij} + jQ_{ij} = \underline{V_i}\underline{I_{ij}^*} = \underline{V_i}\left[\left(\underline{V_i} - \underline{V_j}\right)\underline{Y_{ij}} + \underline{V_i}\underline{Y_{0i}}\right]^* \quad (2)$$

where:

- $\underline{S_{ij}}$–Total power transferred from point *i* to *j*;
- P_{ij} - Active power transferred from point *i* to *j*;
- Q_{ij} - Reactive power transferred from point *i* to *j*;
- $\underline{V_i}$ – Complex Voltage of point *i*;
- $\underline{I_{ij}^*}$ - conjugated complex value of current that flows from point *i* to *j*;
- $\underline{V_j}$–Complex voltage of point *j*;

$\underline{Y_{ij}} = \frac{1}{\underline{Z_{ij}}}$ – Complex admittance between points *I* and *j*;
$\underline{Y_{0i}}$ – Complex parallel admittance placed at point *i*.

Power transferred from point *j* to *i* is calculated as:

$$\underline{S_{ji}} = P_{ji} + jQ_{ji} = \underline{V_j}\underline{I_{ji}^*} = \underline{V_j}\left[\left(\underline{V_j} - \underline{V_i}\right)\underline{Y_{ij}} + \underline{V_i}\underline{Y_{0j}}\right]^* \tag{3}$$

where:

$\underline{S_{ji}}$ - Total power transferred from point *j* to *i*;
$\underline{P_{ji}}$ - Active power transferred from point *j* to *i*;
$\underline{Q_{ji}}$ - Reactive power transferred from point *j* to *i*;
$\underline{Y_{0j}}$ – Complex parallel admittance placed at point *j*.
$\underline{I_{ji}^*}$ - conjugated complex value of current that flows from point *j* to *i*.

Generally speaking (for low voltage power grids), parallel admittances placed at point *i* and *j* are the same and can be calculated as:

$$\underline{Y_{0i}} = \underline{Y_{0j}} = j\frac{B}{2} = j\omega\frac{C}{2} = j2\pi f\frac{C}{2} = j\pi f C \tag{4}$$

By finding the sum of these two powers we can calculate power loss of power line modeled using π model.

$$\underline{\Delta S_{ij}} = \underline{S_{ij}} + \underline{S_{ji}} \tag{5}$$

In case of modeling with I model equations are analogue [1]. The only difference is that:

$$\underline{Y_{0i}} = \underline{Y_{0j}} = 0 \tag{6}$$

MODELING PARAMETERS

As was said before, in this article we used low voltage power grid modeled using both i and π models for overhead power lines. Modeling was done using EMTP/ATPDraw [4,5] and MATLAB [6] software applications. Parameters used for overhead power lines (Table 1) and for loads (Table 2) were taken from Faculty of technical sciences' archive.

Table 1. Overhead power lines parameters

q [mm^2]	*R* [Ω/km]	*L* [mH/km]	*C* [μF/km]
35	0.8353	1.013178243	0.011535883
25	1.2027	1.049642555	0.011115084
16	1.8792	1.094271265	0.010640062

Table 2. Load modeling parameters

S_n [kVA]	U_n[V]	$\cos\varphi$	*R* [Ω]	*L* [mH]
5	400	0.85	27.2	53.65751848
10			13.6	26.82875924
15			9.066666667	17.88583949
20			6.8	13.41437962
25			5.44	10.7315037

Figure 3 shows finished model for low voltage power grid.

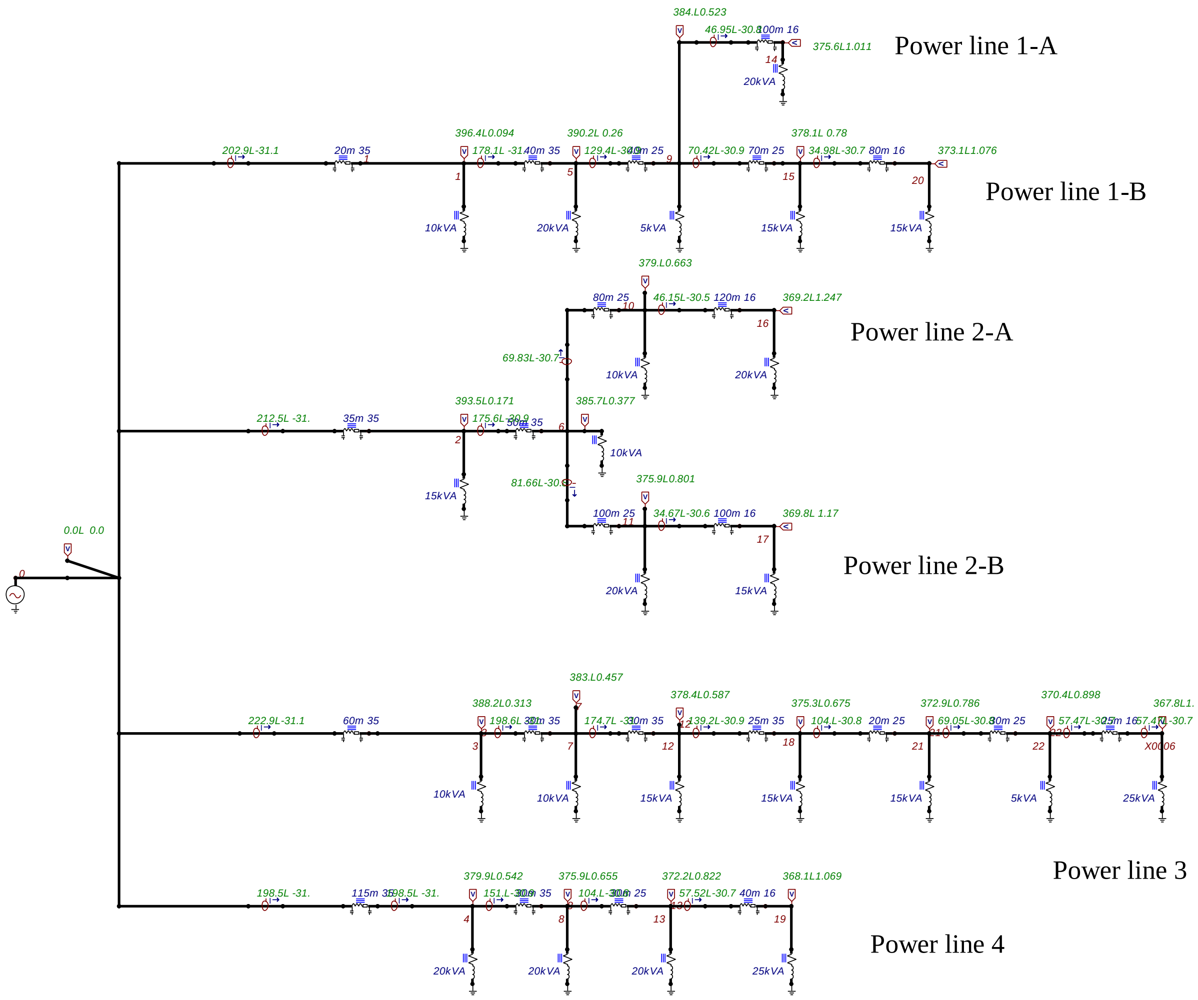


Figure 3. Low voltage power grid model in EMTP/ATPDraw

POWER FLOW RESULTS

Voltage deviation

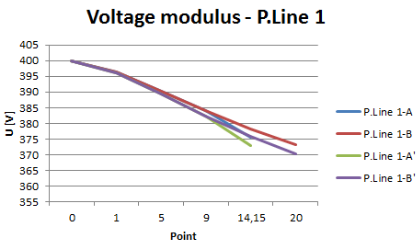
In order to better show the difference in modeling techniques we had used, we will compare calculated results using tables and graphic diagrams.

Table 3. Voltage deviation

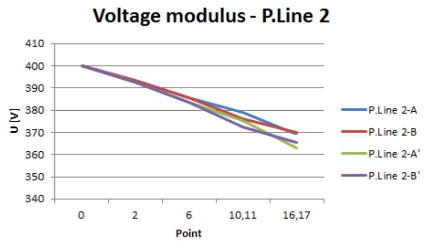
Point number	Π model		I model		Deviation	
	Modulus U [V]	Phase angle θ[°]	Modulus U [V]	Phase angle θ[°]	Modulus U [V]	Phase angle θ[°]
0	400.00	0.00	400.00	0.00	0.00	0.00
1	396.4305	0.09354	396.1161	0.10505	0.314369	-0.01151
2	393.457	0.170562	392.5366	0.237883	0.920369	-0.06732
3	388.2415	0.312547	386.7557	0.368507	1.485754	-0.05596
4	379.9275	0.54187	377.7211	0.625201	2.206447	-0.08333
5	390.1653	0.260443	389.2382	0.295767	0.927116	-0.03532
6	385.7339	0.376748	383.4981	0.540324	2.235849	-0.16358
7	383.0052	0.457257	380.8203	0.542259	2.184889	-0.085
8	375.9468	0.655466	372.5534	0.758976	3.393414	-0.10351
9	383.9595	0.522571	382.331	0.599801	1.628512	-0.07723
10	379.0339	0.663232	375.3248	1.028056	3.709116	-0.36482

11	375.949	0.801288	372.3341	1.043133	3.614872	-0.24185
12	378.4015	0.587306	375.5795	0.700815	2.821992	-0.11351
13	372.2096	0.62215	367.6223	0.958277	4.587292	-0.33613
14	375.5958	1.011378	372.771	1.160823	2.824751	-0.14945
15	378.0557	0.780185	375.8578	0.90595	2.197905	-0.12577
16	369.1663	1.247251	363.0466	2.111556	6.119701	-0.86431
17	369.7761	1.16991	365.3293	1.492683	4.446756	-0.32277
18	375.3452	0.674934	372.057	0.808039	3.288193	-0.13311
19	368.1145	1.069276	362.7142	1.258096	5.400288	-0.18882
20	373.0745	1.076071	370.3316	1.257405	2.742883	-0.18133
21	372.8552	0.786023	369.1467	0.94213	3.708485	-0.15611
22	370.3755	0.89761	366.1831	1.076592	4.192367	-0.17898
23	367.819	1.052689	363.1202	1.264504	4.698828	-0.21182

From the table above we can see that voltage modulus of all points in our grid are higher if π model is used. This can be explained by a simple fact that the capacitance, which we didn't exclude in this model, boosts voltage profile of a grid – this is the main principle of reactive power compensation. Also, since the phase angle is related to load nature, means that the said angle will be lower in case of π modeling because total reactive power is lover.
Graphic diagrams bellow (Figure 4) allow graphic interpretation of the power flow results.



a)



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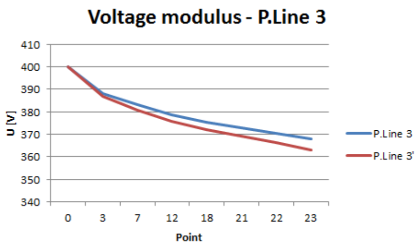

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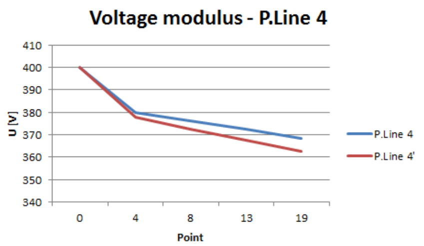

d)

Note Marker (') indicates take the results shown are calculated using I model.

Figure 4. Voltage modulus graphic diagrams

According to Figure 4, the further we are from the starting point (point 0) the greater the voltage deviation, which leads to the conclusion that the deviation has accumulative nature - which is correct. The further we are from the starting point the more capacitance we neglect resulting in greater deviation or results. In order to show that the deviation is cumulative we will draw deviation diagram (Figure 5). As we can see, deviation is almost linear if power lines with same cross-section are used.

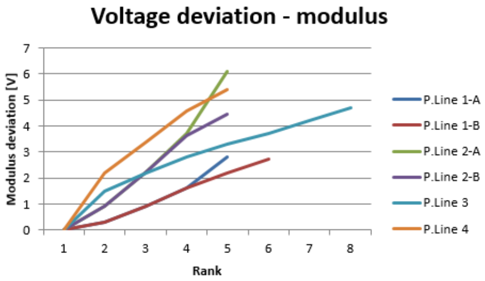

Figure 5. Voltage modulus deviation

Power loss deviation

Using the table 4 we will show estimated power losses between *i* and *j* points. Calculations were done according to equations shown in (1, 2, 3).

Table 4. Power loss deviation

Point		π model		I model		Deviation	
i	j	Active power loss ΔP_{ij} [W]	Reactive power loss ΔQ_{ij} [VAr]	Active power loss ΔP_{ij} [W]	Reactive power loss ΔQ_{ij} [VAr]	Active power loss ΔP_{ij} [W]	Reactive power loss ΔQ_{ij} [VAr]
0	1	687.9845	262.052	816.2879	311.0556	-128.303	-49.0036
1	5	1060.171	404.0438	1280.965	488.1257	-220.794	-84.0819
5	9	805.1434	220.7656	1003.388	275.1114	-198.244	-54.3458
9	14	414.2307	75.77976	540.951	98.95504	-126.72	-23.1753
9	15	417.4746	114.4544	508.243	139.3517	-90.7684	-24.8973
15	20	183.9081	33.64152	230.2698	42.12638	-46.3617	-8.48486
0	2	1320.189	502.977	1744.544	664.7754	-424.355	-161.798
2	6	1288.022	490.7674	1795.76	684.2939	-507.738	-193.527
6	10	469.2542	128.6508	746.5742	204.6988	-277.32	-76.0481
10	16	480.1941	87.84377	855.9521	156.5822	-375.758	-68.7384
6	11	801.9965	219.8798	1048.862	287.5725	-246.866	-67.6927
11	17	225.8332	41.31381	295.7708	54.10551	-69.9376	-12.7917
0	3	2489.386	948.557	3167.666	1207.066	-678.28	-258.508
3	7	988.4178	376.69	1274.799	485.7765	-286.381	-109.086
7	12	764.5006	291.3514	995.2474	379.2502	-230.747	-87.8988
12	18	404.5172	154.1678	539.3055	205.5073	-134.788	-51.3395
18	21	260.1225	71.3223	356.5839	97.76657	-96.4614	-26.4443
21	22	172.0056	47.16389	245.5916	67.33405	-73.586	-20.1702
22	23	155.1687	28.38805	222.6868	40.7397	-67.5181	-12.3517
0	4	3786.024	1442.749	4892.904	1819.058	-1106.88	-376.309
4	8	571.6818	217.8712	861.501	345.395	-289.819	-127.524
8	13	319.8303	222.2849	601.4131	182.6155	-281.583	39.66938
13	19	287.6615	-18.2666	357.098	65.32419	-69.4366	-83.5908
	Total:	18066.06	6382.715	24025.27	8237.262	5959.21	1854.548

As we can see, power losses are higher in case of I modeling.

CONCLUSION

Even though results are quite different in case of different modeling techniques, both models can be used depending on our needs. If we need more precise results it's recommended to use π modeling method but if that's not the case, less complex I model is better to use because of its simplicity. In case of low voltage power grid with many consumers it's better to use I model because in reality not all of the previously mention consumers will be operational simultaneously so it's better to predict higher power losses than they really are. Furthermore, if we neglect to incorporate the capacitance of overhead power lines we are consequentially improving the power factor even before using one of reactive power compensation methods.

ACKNOWLEDGMENT

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REFERENCES

[1] Milan S. Ćalović, Andrija G. Sarić, „Osnovi analize elektroenergetskih mreža i sistema“, Akademska misao, Beograd, Tehnički Fakultet, Čačak, 2004.
[2] https://repozitorij.etfos.hr/islandora/object/etfos:1421/preview
[3] Ranko Goić, Damir Jakus, „Distribucija elektrIčne energje“, Split, 2008.
[4] https://www.eeug.org/index.php/14-sample-data-articles/135-atp-load-flow-6-bus-example
[5] Thomas Degner, Alfred Engler, Oleg Osika Department Engineering and Power Electronics ISET e.V., Germany, “Modelling of Distributed Energy Resources with
[6] ATP-EMTP”, European ATP-EMTP Users Group Meeting and Conference, 12.-14. September 2005, Warsaw, Poland
[7] https://www.mathworks.com/matlabcentral/fileexchange/30272-power-flow-analysis-toolbox-pfatb

UV-VIS SPECTROSCOPY AND NEURAL NETWORKS IN DISTINGUISHING DIFFERENT TYPES OF HONEY

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Abstract: The aim of the article is to investigate the potential of honey discrimination (on the base of its botanical origins) by UV-Vis spectroscopy and neural networks. One hundred and eleven samples from three types of honey (acacia, linden, and honeydew) are measured by a spectrophotometer “Cary100” with recorded wavelength range of 190~900 nm. The samples are used as input data for two types of honey classifiers: the one is based on linear discriminant analysis (LDA), and the other uses an artificial neural network. The neural classifier is realized as a multilayered perceptron with Backpropagation learning algorithm. Principal components analysis (PCA) is used for reducing the number of inputs and for a proper visualization of the experimental results. The comparative analysis of the proposed classifiers is based on leave-one-out-cross validation test.
Key words: UV-Vis spectroscopy, honey discrimination, PCA, LDA, artificial neural network

INTRODUCTION

“Honey is the natural sweet substance, produced by honeybees from the nectar of flowers or from secretions of living parts of plants or excretions of plant sucking insects on the living parts of plants, which the bees collect, transform by combining with specific substances of their own, deposit, dehydrate, store and leave in honeycombs to ripen and mature” [1, 2]. Honey consists of sugars, water, amino acids, oil, mineral salts and especial enzymes produced by bees [3].
It is possible to determine the origin of specific samples of honey and the environmental pollution of a region from the quantitative and qualitative ratio of heavy and rare metals in honey [4]. Honey is proven to be a highly sensitive bioindicator for estimation of the environmental pollution with SO_2 [5]. It is possible to assume that honeybees (Apis mellifera L.) respond to changes in their environment and in particular to increased quantities of heavy metals in soil, air, plants. That makes them a reliable indicator and allows their use in biomonitoring of the environment [6].
Bee pollen appears to be safe for most people, but if someone has pollen allergies, bee pollen can cause a serious allergic reaction. Bee pollen is not safe for pregnant women and also may cause increased bleeding if taken with certain blood thinners [7]. Proteins derived from saliva of honeybee and pollen proteins contained in the honey cause allergic reactions to honey [8]. Different types of pollen (defining different floral origin of honey) can cause different allergic reactions in different people. Therefore it should be developed a means of distinguishing between different types of honey.
Several methods have been used for the determination of the floral origin of honey and among them the pollen recognition and sensory analysis are the most popular ones. However the technique of analysis of honey’s pollen content is tedious and has some limitations. The other methods are mainly based on the analysis of honey’s aroma compounds, sugar profile, flavonoid pattern, non-flavonoid phenolics, organic acids, isotopic relations, and protein and amino acid compositions and marker presence [9, 10]. But some of these methods are generally too time-consuming, complex, and labour intensive for routine quality control application or require very specialized personnel to interpret the results [11, 12].
In addition, most of the analytical techniques involve some kind of sample pre-treatment. The advantages of the technique of UV-visible (UV-Vis), infrared (IR) and fluorescence spectroscopy with respect to other analytical methods are the non-invasive approach, the relatively easy and quick data acquisition. Some authors [13, 14] have used the IR technique for qualification of adulterants in honey with good accuracy. Recently, both near infrared (NIR) and middle infrared (MIR) spectroscopy, were successfully used for classification of unifloral and multifloral honeys [15, 16, 17, 18]. Some authors have used Vis spectrometry for the same purpose [19, 20, 21], but there is almost no information on the use of UV for classification of honey according to its botanical origin [22].

The purpose of the paper is to investigate the possibility of honey discrimination (based on its botanical origin) using UV-Vis spectroscopy in absorbance mode. Spectroscopic data obtained undergo subsequent statistical processing including principal components analysis (PCA) for reducing the classifiers' number of inputs. An artificial neural network (ANN) with Backpropagation (BP) learning algorithm is proposed to classify honey in appropriate classes related to its floral origin. Another type of classifier is considered, which uses the popular linear discriminant analysis (LDA) to provide a basis for comparison of the results obtained. The performance of the two calibration models is confirmed by leave-one-out-cross validation test in MATLAB environment.

MATERIAL AND METHODS

Honey spectrum acquisition

One hundred and eleven samples of three different types of honey (acacia – 34 samples; linden – 46 samples; and honeydew – 31 samples) were purchased from supermarkets and from private producers. All samples of honey were diluted with distilled deionized water till 10% solution. The samples were annealed at room temperature (23-24^{0}C). The spectral characteristics of the honey were taken with a spectrophotometer Cary100 ranging from 190 to 900 nm at 1 nm sampling space.
Spectral readings of the three types of honey were treated by the PCA to reduce dimensionality of the input data, then they were classified using two classifiers – LDA and ANN based ones. In addition, the influence of the individual spectrum ranges - UV only, Vis only (plus very near infrared, i.e. Vis+), and the merging of both areas (UV and Vis +) on the classification result was investigated.

Principal Components Analysis [23, 24]

The aim of the method is to reduce the dimensionality of multivariate data (e.g., wavelengths) whilst preserving as much of the relevant information as possible. PCA is a linear transformation that transforms the data (observations of possibly correlated variables) to a new coordinate system such that the new set of variables, the principal components, are linear functions of the original variables. Principal components (PCs) are uncorrelated, and the greatest variance by any projection of the data comes to lie on the first coordinate, the second greatest variance on the second coordinate, and so on. This is achieved by computing the covariance matrix for the full data set. Then, the eigenvectors and eigenvalues of the covariance matrix are computed, and sorted according to decreasing eigenvalue [23, 24]. All the principal components are orthogonal to each other. The full set of principal components is as large as the original set of variables. Usually the sum of the variances of the first few principal components exceeds 80% of the total variance of the original data [25].

Linear Discriminant Analysis

Linear discriminant analysis (LDA) is a classic classifier, with, as its name suggests, a linear decision surface. The basic idea of LDA is to find a linear transformation, such that the ratio of the between-class scatter and the within-class scatter is maximized. Samples are projected to a new space with smallest within-class distance and largest inter-class distance [26]. Although LDA usually gives a good discrimination performance, it suffers from some deficiencies if variables are highly correlated or class boundaries are complex or nonlinear. To avoid such deficiencies, in the former case, variables are often transformed by correlation-reducing methods such as PCA, and in the latter case, LDA could be replaced by quadratic discriminant analysis or ANN.

Artificial neural network based classifier

It is well known that artificial neural networks with a feedforward multilayered structure are universal function approximators [27, 28]. One classification task can be easily reduced to a task for approximation. Let the classifier of honey be implemented as a neural network with a feedforward structure and Backpropagation (BP) learning algorithm. The neural network consists of $n = 2$ inputs (n is the number of PCs used by classifiers), 3 outputs and 2 hidden layers. The three outputs of the

network correspond to the three classes of honey: acacia, linden and honeydew honey. The two hidden layers contain neurons with 'tansigmoid' activation function (hyperbolic tangent), and the activation function of the three output neurons is 'logsigmoid' [29].
The method of the PCs is applied to UV and Vis+ spectra and total n = 2 PCs are used as input training samples for the neural network. The supervisor supplies the network's output with the following three combinations: '1 0 0', '0 1 0' or '0 0 1', depending on whether the input receives the data for the classes 'acacia', 'linden' or 'honeydew', respectively. BP is a gradient-based learning algorithm that minimizes the sum squared error between the real and required input of the ANN.

RESULTS AND DISCUSSION

Absorbance Spectra

After receiving the "raw" data from the measurements by spectroscopy, they are subject to pre-treatment. In order to remove some apparent interference received data are limited from above by a predetermined value. The resulting absorbance curves are smoothed by the method of creeping averaging, using the formula:

$$a_{i+l/2} = \frac{1}{l+1}\sum_{k=0}^{l} a_{i+k} \,, \tag{1}$$

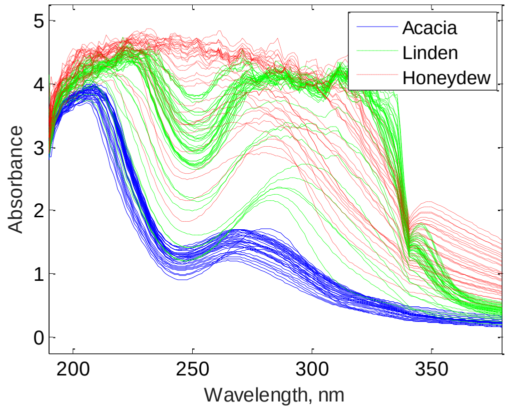
where l is the width of a linear filter accepting even-numbered values.
In the experiments shown below, three absorption spectra were used: (1) UV from 190 to 380 nm, (2) Vis^+ from 380 to 900 nm, and (3) UV-Vis^+ from 190 to 900 nm (Fig.1a,c,e). The PCA was applied to the spectral characteristics of the three ranges. The spectral dimensionality was reduced to a small number (two) of PCs using PCA. The scores scatter plots of the 1st and 2nd PCs are shown in Fig.1b,d,f, where samples from classes 'acacia', 'linden' and 'honeydew' are marked with circular, triangular and squared symbols, respectively. It is evident that the samples form three clusters, that with a few exceptions coincide with the three types of honey mentioned above. Here, determining the type of honey is based solely on the inscription on the label by the manufacturer, i.e. trusting the manufacturer. The first two PCs explain as high as: (a) 98.15 % of variance of the spectra (93.10 % for PC-1 and 5.06 % for PC-2) for UV region; (b) 99.89 % of variance of the spectra (99.41 % for PC-1 and 0.48 % for PC-2) for Vis^+ region; and (c) 97.89 % of variance of the spectra (91.83 % for PC-1 and 6.07 % for PC-2) for UV-Vis^+ one. The two PCs were chosen to develop the classification models.

LDA and ANN Based Honey Classifiers

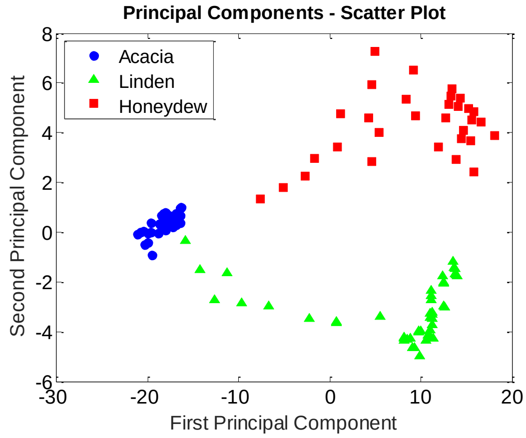
On the basis of these two PCs honey a few classifiers were developed using LDA and ANN. The prediction results of the honey's botanical origin made by the proposed classifiers, UV-LDA and UV-ANN, are shown in Fig. 2 and Table 1. The performance of the UV-ANN based model is better (96.4 % accuracy) than the UV-LDA based one (91.9 %) for honey discrimination. In the case of the better model (Table 1), 1 sample from observed class 'linden' was predicted wrong as 'acacia', while 3 samples from the same class 'linden' were predicted wrong as 'honeydew'. The model predicted 107 out of 111 samples correctly. The prediction accuracy 96.4 % was divided between the classes as follows: 91.3 % for class 'linden', and 100 % for the other two classes - 'acacia' and 'honeydew'.
The prediction results of the type of honey made by the Vis^+-LDA and Vis^+-ANN classifiers are shown in Fig. 3 and Table 2. Again, the ANN based classifier had better performance than the LDA based one - 93.7 % vs. 83.8 %. But the success rate was less than the result in UV domain. The Vis^+-ANN based classifier predicted wrong 3 samples from observed class 'acacia' as 'linden', 2 samples from class 'linden' as 'acacia', and 2 'honeydew' samples – as 'linden'. The model predicted 104 out of 111 samples correctly. The prediction accuracy of each of the three classes was: 91.2 % 'acacia', 95.7 % 'linden', and 93.5 % 'honeydew'.
After the combination of the two spectral regions UV and Vis^+ (Fig.4 and Table 3), the following prediction results were obtained: 99.1% accuracy for UV-Vis^+-ANN based classifier and 93.7% for UV-Vis^+-LDA based one. The ANN based model predicted 110 out of 111 samples correctly. Only 1

sample from observed class 'linden' was predicted wrong as 'acacia'. Thus the prediction accuracy of the classes 'acacia' and 'honeydew' was 100 %, while that of the class 'linden' - 97.8 %.

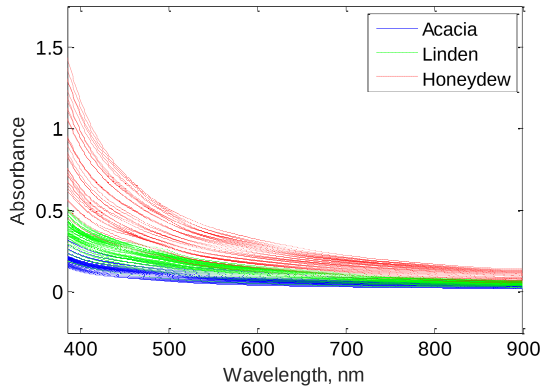
Table 4 summarizes the results of all honey classifications on the basis of botanical origin considered above. As seen the highest prediction results were obtained by using both UV and Vis+ regions in the classifier based on an artificial neural network.



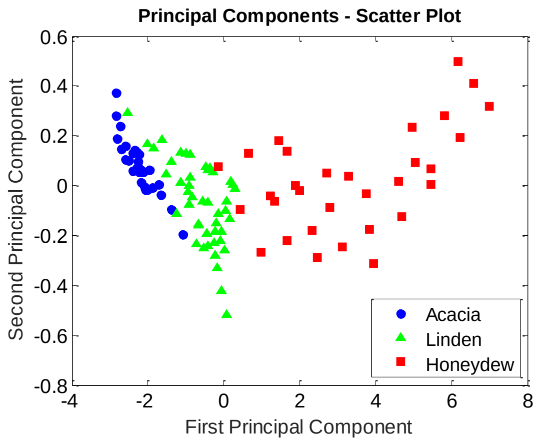
(a) UV



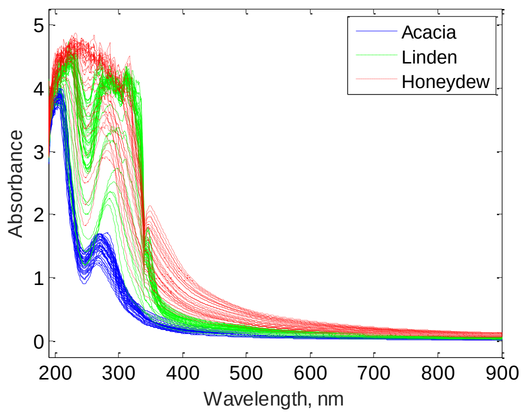
(b) PCA in UV



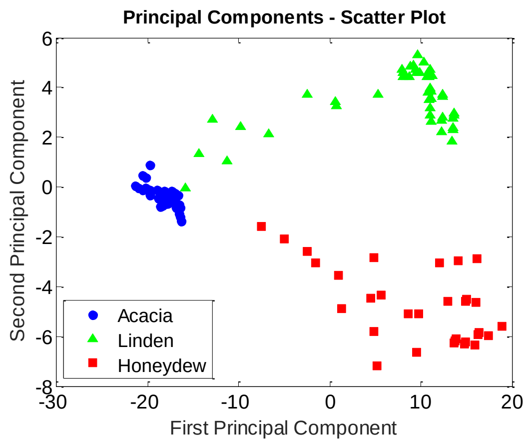
(c) Vis



(d) PCA in Vis

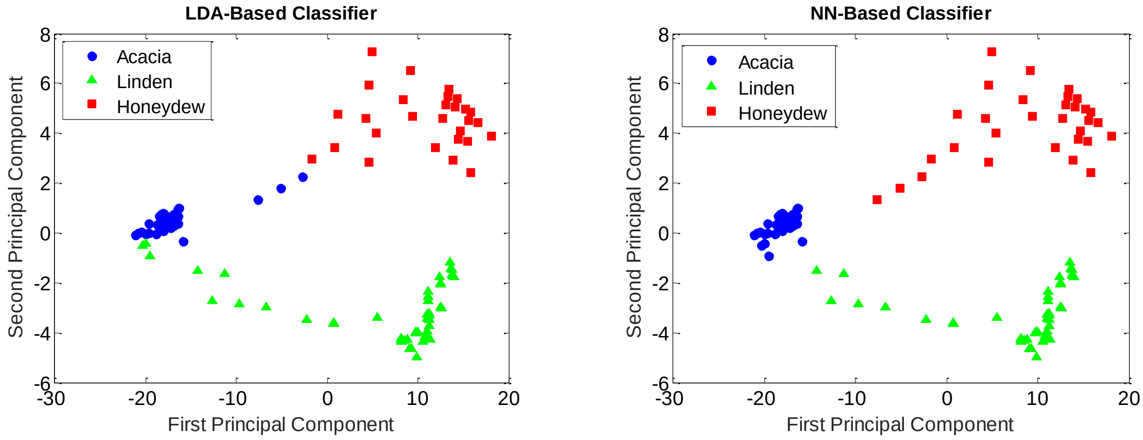


(e) UV-Vis



(f) PCA in UV-Vis

Figure 1. Absorbance spectra of honey in UV, Vis+, UV-Vis+ domains, and corresponding PCA scatter plots

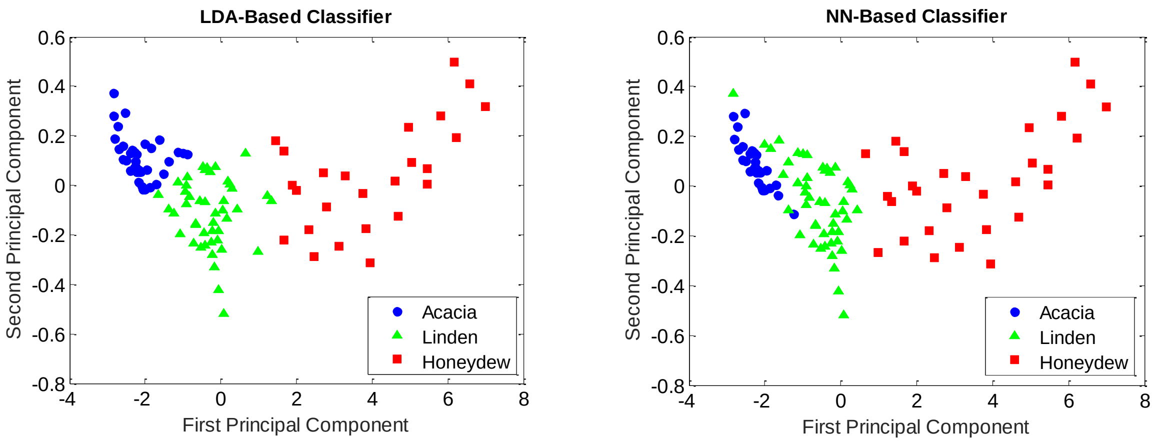


(a) (b)

Figure 2. UV-LDA and UV-ANN Based Honey Classifiers: (a) LDA-based classifier; (b) ANN-based one

Table 1. Discrimination accuracy of UV-LDA and UV-ANN based models

		Predicted Class by UV-LDA			←→	Predicted Class by UV-ANN		
		Acacia	Linden	Honeydew		Acacia	Linden	Honeydew
Observed Class	Acacia	34	0	0	34	34	0	0
	Linden	4	39	3	46	1	42	3
	Honeydew	2	0	29	31	0	0	31
		40	39	32	111	35	42	34
		Success = 91.8919 %				Success = 96.3964 %		

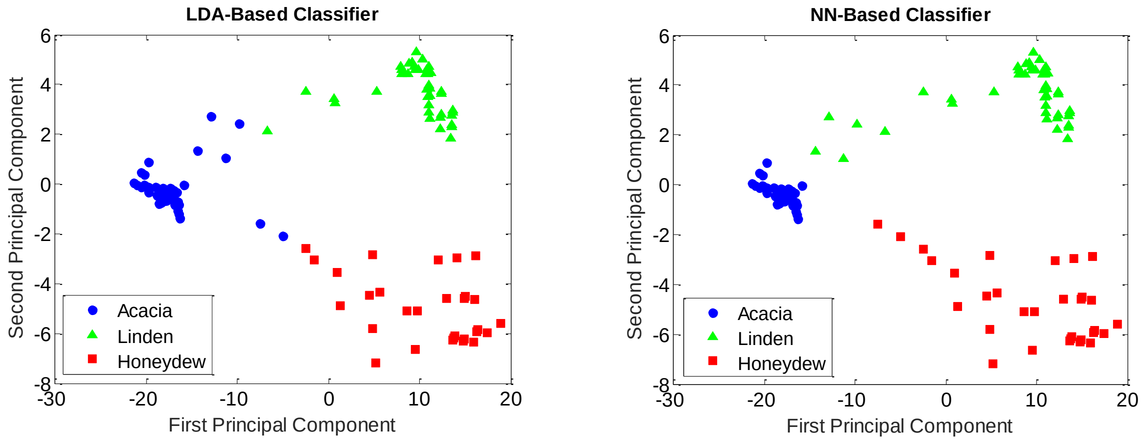


(a) (b)

Figure 3. Vis$^+$-LDA and Vis$^+$-ANN Based Honey Classifiers: (a) LDA-based classifier; (b) ANN-based one

Table 2. Discrimination accuracy of Vis$^+$-LDA and Vis$^+$-ANN based models

		Predicted Class by Vis$^+$-LDA			←→	Predicted Class by Vis$^+$-ANN		
		Acacia	Linden	Honeydew		Acacia	Linden	Honeydew
Observed Class	Acacia	31	3	0	34	31	3	0
	Linden	9	37	0	46	2	44	0
	Honeydew	0	6	25	31	0	2	29
		40	46	25	111	33	49	29
		Success = 83.7838 %				Success = 93.6937 %		



(a) (b)

Figure 4. UV-Vis+-LDA and UV-Vis+-ANN Based Honey Classifiers: (a) LDA-based classifier; (b) ANN-based one

Table 3. Discrimination accuracy of UV-Vis+-LDA and UV-Vis+-ANN based models

		Predicted Class by UV-Vis+-LDA				Predicted Class by UV-Vis+-ANN		
		Acacia	Linden	Honeydew	←→	Acacia	Linden	Honeydew
Observed Class	Acacia	34	0	0	34	34	0	0
	Linden	5	41	0	46	1	45	0
	Honeydew	2	0	29	31	0	0	31
		41	41	29	111	35	45	31
		Success = 93.6937 %				Success = 99.0991 %		

Table 4. Comparative analysis of LDA and ANN-based classifiers for all the ranges

No.	Spectral range	LDA-based classifier	ANN-based classifier
1	UV	91.9 %	96.4 %
2	Vis+	83.8 %	93.7 %
3	UV-Vis+	93.7 %	99.1 %

CONCLUSION

In this article the spectral properties of Bulgarian honey were investigated in regard to the potential of honey discrimination on the base of its botanical origin. The UV and Vis spectra separately and together were used for training two honey classifiers – LDA based classifier and ANN based one. By means of PCA the number of input data was reduced to only 2 PCs. The obtained advantages are the lack of correlation between the input data and also the ability to visualize the clusters formed by different types of honey. The ANN based classifier using wavelengths ranging from 190 to 900 nm (UV-Vis+ spectra) shows the best prediction accuracy, 99.1%, determined by the 111 leave-one-out-cross-validation tests.

Future work will include methods for distinguishing honey not only on the basis of its botanical origin but also on the basis of its geographical origin. Honey will be analyzed in areas around coal-fired power plants and fields contaminated with heavy metals.

REFERENCES

[1] Codex Alimentarius: Draft revised standard for honey (at step 10 of the Codex procedure). Alinorm 01/25, pp.19-26, 2001.

[2] EU Council: Council directive 2001/110/EC of 20 December 2001 relating to honey. Official Journal of the European Communities L10, pp.47–52, 2002.

[3] Boffo, E.F., L.A. Tavares, A.C.T. Tobias, M.M.C. Ferreira, A.G. Ferreira. Identification of components of Brazilian honey by 1H NMR and classification of its botanical origin by chemometric methods, LWT - Food Science and Technology, Vol.49, pp.55-63, 2012, www.elsevier.com/locate/lwt

[4] Birutė, S., M. Paulius, B. Rūta, Honey as an Indicator of Environmental Pollution. Environmental Research, Engineering & Management, Vol.36, No.2, pp.53-58, 2006.

[5] Ponikvar-Svet, M., J. Šnajder, B. Sedej, Honey as a bioindicator for environmental pollution with SO_2, Apidologie, Vol.36, No.3, 2005, DOI: 10.1051/apido:2005027

[6] Zhelyazkova, I., Honeybees – bioindicators for environmental quality, Bulgarian Journal of Agricultural Science, Vol.18, No 3, pp.435-442, 2012, Agricultural Academy, Bulgaria.

[7] Ratini, M., Bee Pollen Benefits and Side Effects, WebMD Medical Reference Reviewed by Melinda Ratini, DO, MS on January 26, 2018, https://www.webmd.com/balance/bee-pollen-benefits-and-side-effects

[8] Bauer, L., A. Kohlich, R. Hirschwehr, U. Siemann, H. Ebner, O. Scheiner, D. Kraft, C. Ebner, Food allergy to honey: Pollen or bee products? Characterization of allergenic proteins in honey by means of immunoblotting, The Journal of Allergy and Clinical Immunology, Vol. 97, No.1, pp. 65–73, 1996.

[9] Anklam E., A review of the analytical methods to determine the geographical and botanical origin of honey. Food Chem., Vol.63, pp.549-562, 1998.

[10] Hermosin, I., R.M. Chicon, M.D. Cabezudo. Free amino acid composition and botanical origin of honey, Food Chemistry, Vol.83, pp.263–268, 2003, www.elsevier.com/locate/foodchem

[11] Bogdanov S., P. Martin. Honey authenticity, Mitt. Geb. Lebensmittelunters Hyg., Vol.93, pp. 232–254, 2002.

[12] Benedetti, S., S. Mannino, A.G. Sabatini, G.L. Marcazzan. Electronic nose and neural network use for the classification of honey, Apidologie, Vol.35, pp.1–6, 2004, INRA/DIB-AGIB/ EDP Sciences, DOI: 10.1051/apido:2004025

[13] Gallardo-Velazquez, T., G. Osorio-Revilla, M.Z.D. Loa, Y. Rivera-Espinoza. Application of FTIR-HATR spectroscopy and multivariate analysis to the quantification of adulterants in Mexican honeys, Food Research International, Vol.42, No.3, pp.313–318, 2009.

[14] Zhu, X., S.Li, Y. Shan et al. Detection of adulterants such as sweeteners materials in honey using near-infrared spectroscopy and chemometrics, Journal of Food Engineering, Vol.101, No.1, pp. 92–97, 2010.

[15] Davies A., B. Radovic, T. Fearn, E. Anklam. A preliminary study on the characterisation of honey by near infrared spectroscopy, J. Near Infrared Spectrosc., Vol.10, pp.121–135, 2002.

[16] Ruoff K., W. Luginbühl, S. Bogdanov, B. Estermann, T. Ziolko, R. Amado. Potential of Near Infrared Spectroscopy for Authenticity Testing of Unifloral Honey, Eur. Congr. for Authenticity of Food, Nyon, Switzerland, 2003.

[17] Lichtenberg-Kraag B. Infrared spectroscopy: The quality assurance in honey analysis, Apidologie, Vol.34, pp. 479–480, 2003.

[18] Lekova, S., D. Tsankova, Determination of Botanical Origin of Honey by Mid Infrared Spectroscopy (Mid-FTIR), Colorimetry and Chemometric Analysis, Journal of Chemical Technology and Metallurgy (JCTM), Vol. 52, No. 1, pp. 52 - 57, 2017, University of Chemical Technology and Metallurgy, BG, http://dl.uctm.edu/journal/node/79

[19] Li, Y., H. Yang. Honey Discrimination Using Visible and Near-Infrared Spectroscopy, International Scholarly Research Network, ISRN Spectroscopy, Article ID 487040, 4 pages, 2012, doi:10.5402/2012/487040

[20] Tsankova, D., S. Lekova, Botanical Origin-Based Honey Discrimination Using Vis-NIR Spectroscopy and Statistical Cluster Analysis, Journal of Chemical Technology and Metallurgy (JCTM), Vol. 50, No. 5, pp. 638-642, 2015, University of Chemical Technology and Metallurgy, BG, http://dl.uctm.edu/journal/node/71

[21] Tsankova, D., S. Lekova, K. Nikolova, G. Terziyski, VIS Spectroscopy-Based Chemometric Analysis of Honey with Respect to Discrimination of Its Botanical Origin, Annals of Faculty Engineering Hunedoara – International Journal of Engineering, Romania, 2015, Vol. XIII, No.4, pp. 275-279, ISSN: 1584-2673 (CD edition, online).

[22] Tsankova, D., S. Lekova, UV-Vis Spectroscopy and Statistical Cluster Analysis in Distinguishing Different Types of Honey, International Conference "Automatics and Informatics'2015", Sofia, Bulgaria, 4 - 7 October 2015, pp.107-110.

[23] Hotelling, H., Analysis of a Complex of Statistical Variables into Principal Components. Journal of Educational Psychology, Vol.24, No.6 & 7, pp. 417–441 & pp. 498–520, 1933.

[24] Jolliffe, I. T., Principal Component Analysis. Second ed. Springer Series in Statistics. New York: Springer-Verlag New York, 2002.

[25] Statistics Toolbox™ User's Guide, R2014a, © COPYRIGHT 1993–2014 by The MathWorks, Inc.

[26] Kim, H., Drake, B. L., Park, H., Multiclass classifiers based on dimension reduction with generalized LDA, Pattern Recognition, Vol. 40, No. 11, pp. 2939–2945, 2007.

[27] Blum, E.K., Li, L.K., Approximation theory and feedforward networks, Neural Networks, Vol.4, pp.511-515, 1991.

[28] Hornik, K., Stinchcombe, M., White, H., Multilayer feedforward networks are universal approximators, Neural Networks, Vol.2, pp.359-366, 1989.

[29] Beale, M.H., Hagan, M.T., Demuth, H.B., Neural Network ToolboxTM, User's Guide, The MathWorks Inc., 1992-2015. https://www.mathworks.com/help/pdf_doc/nnet/nnet_ug.pdf

DETERMINATION OF THE RESISTANCE IN THE CUTTING ZONE FOR MACHINE PLASTIC PROCESSING

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Abstract: The following article examines the resistances that occur in the cutting zone when machining plastics is processed from a group of thermoplastic materials, and determines the main cutting resistance (F1) on the basis of the obtained experimental measurement results and the application of appropriate mathematical methods for their calculation. By varying the parameters of the cutting mode by applying the fuzzy logic controller, the passes and cuts are automatically optimized. In this way, the main cutting resistances can be defined to help define the other significant production parameters. At the end of the article is the graphical preview of the cutting resistance optimisation for a constant shaft speed, the cutting resistance optimisation for a constant cutting depth, and the cutting resistance optimisation for a constant step are shown.
Keywords: cutting resistances, machining, machine plastic.

INTRODUCTION

Thermoplastics are very suitable for producing prototype parts and devices that are in certain stages of a development. Substantially thermoplastics can be polished after various machining operations and lead to a very acceptable degree of surface roughness, so that the presented part is lovefuly appealing and clearly displayed. They are also suitable for making models with larger dimensions where the cost of making them is crucial. During the exploitation different operating temperature ranges of specific thermoplastics are visible to prevent overheating and loss of mechanical and other properties. Due to their predominantly poorer mechanical properties than metals, they are designed for machining with more intensive cutting modes [1, 2]. One of the very good features is the low thermal conductivity and in this case it is possible to heat intensely the surface layer while the inner layer stays cool. This is a very desirable feature in machining by cutting and it is necessary to find an adequate way for cooling the treated material's surface layer so that the chemical structure of the base material is not disturbed during the cooling and the workpiece is cooled to an adequate temperature. However, if there is more intense heating of the surface layer of the material the workpiece dimensions can be significantly disturbed and exceed the predicted tolerance values due to the high coefficient of thermal expansion. It can be essentially concluded that the machining of thermoplastic materials is very unpredictable and relatively more complex than metals [3, 4].

MATERIAL AND METHODS

Theoretical Research

The main cutting resistance during machining on a lathe (F1) depends directly on the cutting depth (a) and on the cutting steps (s) but also on the coefficients depending on the type of material processed. Other components of the cutting resistance force for the machining process are determined depending on the main cutting resistance (F1: F2: F3 = 5: 2: 1) [5-7] and are not the subject of consideration in this article. Generation of components F2 (penetration resistance) and F3 (auxiliary movement resistance) is justified when it is necessary to define specific machining parameters on the lathe, the accuracy and quality of the workpiece is checked by force F2, and the check of the drive and gear for auxiliary movement by force F3. Forces F1 and F3 are important for checking the resistance of the turning knifes handle.

The resulting cutting resistance force is shown as a function of all three components of the cutting resistance force (equation 1).

$$F_R = \sqrt{F_1^2 + F_2^2 + F_3^2} \tag{1}$$

Generation of main cutting resistance is possible by direct measurement through a dynamometer and transformation of the input pulses through the input port of the computer based on the defined parameters of the cutting mode registered by the controller. Another way to define it is by measuring electrical components and using the mathematical method to obtain the required sizes. Since the second way of generating the main cutting resistance is cheaper and simpler and less represented in practice, force generation will be performed in this way. The CNC machine with its technical characteristics enables the direct reading of electrical components (current strength primarily) which is registered on the controller and the scaling method gives the actual value used to define the force through the (equation 2).

$$F_1 = \frac{U \cdot I}{L \cdot \omega} \tag{2}$$

where are:

- U - voltage (constant value of 220 V)
- I - current (A)
- L - free knife handle length on the tool carrier (L = 0.020 m)
- ω - angular velocity (rev/sec) of the workpiece

The used equipment for performing the experiment permits the application of both methods of generating the main cutting resistance. Tests will be performed on a CNC machine because of the increased accuracy of movement and the stability of the processing process and the ability to apply an artificial intelligence system for machining ie. fuzzy logic.

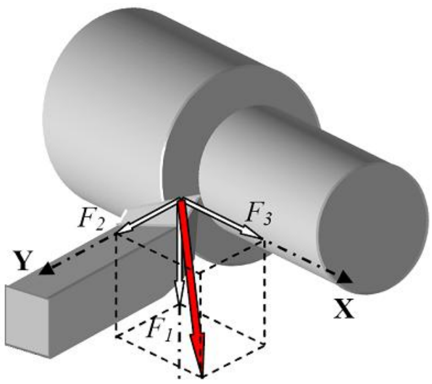

Figure 1. Components of the cutting force [8]

Measurement of the force in the cutting zone

Measurement of the cutting force is preasumed by generating electrical components that changes under certain conditions and depend on cutting parameters (such as current strength) and on the voltage which is assumed to be a constant value and will not change during the experiment. The direct measurement of the electric current, due to the input parameters of the cutting mode, is registered by the PLC controller, while on the other hand, the current value is read from the machine’s ampermeter. Due to the double detection of electric current strength, a correctional coefficient is established to filter the measured quantities. By a mathematical method, a given force pattern is generated by the computer based on measurable parameters defined in the eqations. The results of the measurement method are checked using the regression analysis method, in order to check the functionality of the measuring device and the principle of adequacy of the data generation method.

Technical preparation of the experiment

The measurement of the main cutting resistance (F1) was performed on a sample of a concrete workpiece made of polypropylene (PP) material. Due to the conditions of static and dynamic influence factors on the process flow, machining accuracy and other influences on cutting force, EMCO F5 CNC machine with an accuracy of 0.01mm was chosen. This machine has many comparative advantages but also some limitations, such as a limited range of step speeds (v_f), workpiece diameters, etc. The basic elements for performing the course of the experiment are: workpiece from PP material, machine on which processing is performed (CNC lathe), cutting tool and computer measuring system with accompanying equipment on which measurements were made.
The experimental method used in this article assumes the variation of cutting mode parameters (cutting speeds - v, step - and cutting depths) between min and max values, which are also one of the most influential factors in the development of cutting force and obtaining the required quality of the treated surfaces. The value of the current strength on the Ampermeter on the selected machine will also be monitored in order to calculate the factor of the current variation during the experiment (ks), which will perform the scaling of the PLC.
Measurement of the main cutting resistance was performed with a thermocouple connected to the controller which transmit the detected signal to the computer for processing, while the obtained data will be presented in tables and diagrams for ease of analysis and clarity.
In order to create an appropriate cutting modes and obtained values database for the main cutting resistance, an experiment was carried out on a material with a nominal diameter of Ǿ 40 mm, length L = 400mm. The working procedure on the basis of which the temperature was generated is at length L_1 = 50 millimeters. The tool with a hard metal plate (DIN 4976 1010 P10) is intended for an angle cutting with inclination of the blade of k = 45 ^{0}.

Computer measuring system

A computer measuring system for measuring the scraping force of machine plastic and the temperature of a turning knife and a workpiece is shown in figure 2. Slides 1 and 7 show's the photographs of a computer and a universal lathe with a lathe-operator. Photos of the Programmable Logic Controller (PLC) are shown on slides 2 and 3. Measuring forceps for single - phase engaging of the motor stator are given on slide 4. The tool carrier with a lathe blade in which the temperature sensor is located is shown on slide 5.

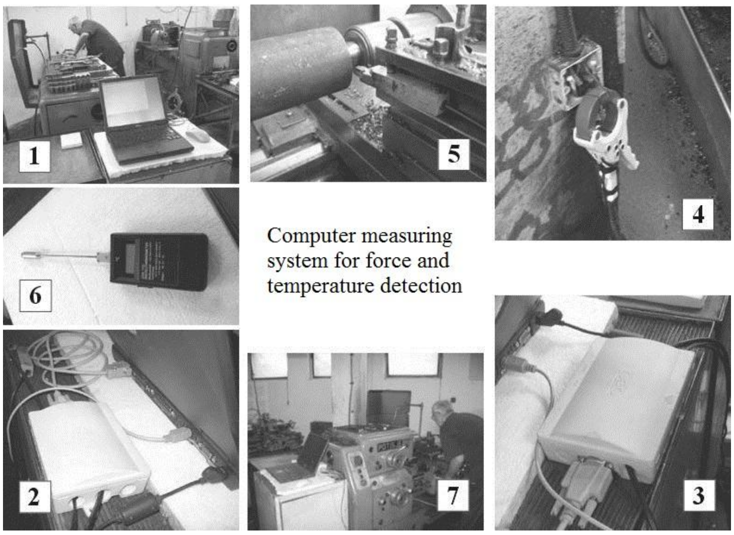

Figure 2. Computer measuring system for force and temperature detection

Slide 3 shows a photo of a computer power supply (1) with a mouse connector (2) as well as an RS232C connector (3), a PLC (4) whose PLC power is an AC / AC adapter (5) the power connector clamps (6) and finally the connector of the temperature sensor (7).

The PLS’s task is to translate the collected numerical valued data from the level 0-5 [V] from the temperature sensor (range 0 ^{0} – 150 ^{0} C) and current clamps into a binary code and send it to the computer for analysis and processing.
Measuring clamps are used to detect current through the power cord without interrupting the circuit. Basically the measuring clamp are a coil wound around a torus ferrite core that alignes the lines of magnetic induction forces. The transmission ratio is 1/1000 [A].

RESULTS AND DISCUSSION

Table 1 lists the limit values of the regime, the measured sizes, the scrapings of machine plastic shown as binary variables a, s, and n with binary values 0 and 1. It should be noted that the minimum value of the scrap mode is binary 0, while the maximum value is binary 1.

Table 1. Value of cutting mode parameters

	0	1
a (mm)	2	4
s (mm/min)	80	300
n (min^{-1})	600	1200

where the parameters a and s are defined in Chapter 2. and the parameter n [rpm] represents the speed of the machine's main spindle. According to Table 2, the parameter ω [rev/sec] is the angular velocity and is derived from the parameter n. The parameter s (shear) on the lathe is defined in mm/o and is derived from the value of shear rate (v_s) defined by the machine manufacturer in mm/min.
According to the same table, 8 measurements in the 0 to 7 mark will be realized based on combinations of binary values of the adopted logical variables (d, s, n).

Mathematical model for determining the force of the main cutting resistance

The analytical dependence of the plastic scraping mode can be represented by the formula

$$F_1 = C_{k1} \cdot \delta^{x_1} s^{y_1} \tag{3}$$

which are later logarithmed on the left and right side and transformed in the following equation

$$\ln F_1 = \ln C_{k1} + x_1 \ln \delta + y_1 \ln s \tag{4}$$

A system of linear algebraic equations can be written for one combination of the scraping mode in the following form:

$$\begin{aligned} \ln F_{1\max} - \ln C_{k1} &= x_1 \ln \delta_{\max} + y_1 \ln s_{\max} \\ \ln F_{1\min x} - \ln C_{k1} &= x_1 \ln \delta_{\min} + y_1 \ln s_{\min} \end{aligned} \tag{5}$$

According to the system of algebraic equations (4), their matrix form can be written and obtain the values in Table 2.

$$\begin{pmatrix} \ln F_{1\max} - \ln C_{k1} \\ \ln F_{1\min} - \ln C_{k1} \end{pmatrix} = \begin{pmatrix} \ln \delta_{\max} & \ln s_{\max} \\ \ln \delta_{\min} & \ln s_{\min} \end{pmatrix} \begin{pmatrix} x_1 \\ y_1 \end{pmatrix} \tag{6}$$

Table 2. Plan of performing the experiment and solving the system of equations (6)

		O measu-rement	1 measu-rement	2 measu-rement	3 measu-rement	4 measu-rement	5 measu-rement	6 measu-rement	7 measu-rement
a	(mm)	2	2	2	2	4	4	4	4
v_s	(mm/min)	80	80	300	300	80	80	300	300
$s = v_s/n$	(mm/rev)	0,133	0,067	0,500	0,250	0,133	0,067	0,500	0,250
n	(rev/min)	600	1200	600	1200	600	1200	600	1200
$\omega = \pi n/30$	(rev/s)	62,8	126	62,8	126	62,8	126	62,8	126
	F_{1max}	347	158	1585	262	122	73	982	
	F_{1min}	149	9	226	218	17	60	27	
	F_{1sr}	270	115	1309	237	83	66	721	

The actual value of the force F1, as mentioned, can be calculated according to Form 2, for all measurements, and based on the obtained values, F1max, F1min, F1avr is calculated.

For the form ($F_1 = \dfrac{U \cdot I}{L \cdot \omega}$) the electrical voltage is known and is U = 220V, as is the free knife length the imaginary bracket L = 0.02 m. Current I was calculated as the multiplied product of the correction factor value kavrg and the current measured by PLC by the formula $I = k_{avrg} \times I_{PLC}$

Optimization of Main Cutting Resistance

Optimization for the machine's main spindle's constant speed

Optimization of the main cutting resistance was performed for all three influencing factors of the cutting regime defined in the experiment. The first optimization was performed for a constant speed of the machines's main spindle, and the average value of the speed n = 900 rpm was taken.

Maximization of the main cutting resistance was performed due to the selected processing materials (thermoplastic materials), which have poorer mechanical properties compared to metals. For metals, it is more logical to minimize the main cutting resistance in order to define the minimum conditions for the scraping process. For thermoplastic materials, with increasing cutting forces, the temperatures of the workpiece and scrapings also increase, so it is necessary to see under what conditions (maximum) there will be no development of high cutting temperatures at the workpiece.

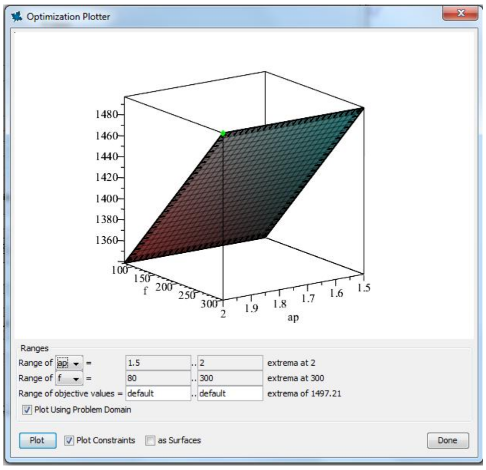

Figure 3. Graphical representation of the optimization with constant speed of the main spindle of the machine

According to the assumed optimization conditions of the main cutting resistance, it can be seen that the main cutting resistance is F1 = 1497.21 [N], for the influencing factors a_p = 2 [mm] and v_f = 300 [mm/min].

Optimization for constant cutting depth

Optimization for constant cutting depth and graphical solution is presented in Figure 4. Optimization was performed for constant average cutting depth of a_p = 1.75 [mm].

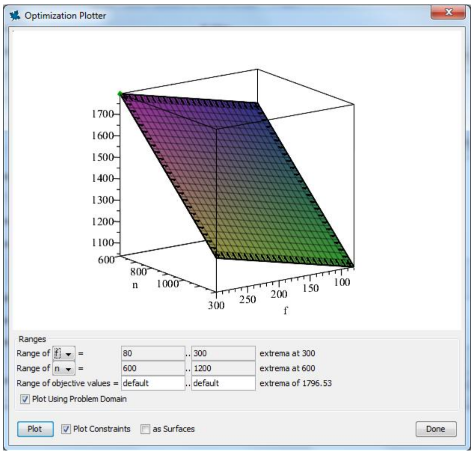

Figure 4. Graphic representation of the optimization with constant cutting depth

According to the assumed optimization conditions of the main cutting resistance, it is seen that the main cutting resistance is F1 = 1796,532 [N], for the influencing factors n = 600 [min^{-1}] and v_f = 300 [mm/min].

Optimization for a constant step

Optimization for constant step and the graphical solution is presented in Figure 5. Optimization was performed for a constant average step velocity of v_f = 190 [mm/min].

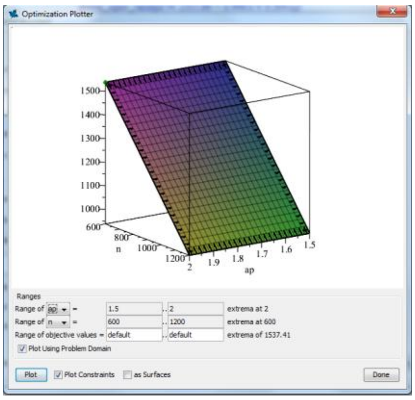

Figure 5. Graphic representation of the optimization with constant cutting depth

According to the assumed optimization conditions of the main cutting resistance, it can be seen that the main cutting resistance is F1 = 1537.41 [N], for the influencing factors n = 600 [min^{-1}] and a_p = 2 [mm].

CONCLUSION

By determining of the main cutting resistance (F1), one of the machining parameters that are manifested in the cutting zone when machining plastics from a group of thermoplastic materials, can significantly affect the economization of the process, given the anticipated production and use of selected materials and significant energy savings. By varying the parameters of the cutting mode using the fuzzy logic controller, the subjective influence of the technologist is completely eliminated and the passes and cuts are automatically optimized. In this way, the predicted limits of the generated sizes can be maintained in the predicted zones and the actual main cutting resistances can be defined in order to define other significant production parameters based on them [5,7]. The test results will greatly accelerate the production processes of the materials for which no relevant data exist to this date.

REFERENCES

[1] Caprino G., Langella A., Analysing cutting forces in machining processes for polymer-based composites, Machining Technology for Composite Materials, pp.75-115, 2012.
[2] www. Ensiger-inc.com 2016.
[3] Karania, R., Kazmer,D., Low volume plastics manufacturing strategies, American Society of Mechanical Engineers, Design Engineering Division, 118A, pp. 265-274, 2005.
[4] Latha,B., Senthilkumar, V.S., Palanikumar, K., Machining science and technology, Taipei, pp.172-191, 2011.
[5] Filipović L., Priručnik za projektovanje i pripremu tehnoloških postupaka pri obradi metala rezanjem, ZUNS, Beograd[Manual for Design and Preparation of Technological Procedures for Metal Cutting, ZUNS, Belgrade], 1999.
[6] Sredanović B., Razvoj modela za definisanje univerzalne obradivosti na osnovu parametara procesa rezanja, Magistarski rad, Univerzitet u Banja Luci, Banja Luka [Development of a model for defining universal workability based on cutting process parameters, Master's thesis, University of Banja Luka, Banja Luka], 2012.
[7] Nedić B, Lazić M., Proizvodne tehnologije, Obrada metala rezanjem, Mašinski fakultet, Kragujevac [Production Technologies, Metal Cutting, Faculty of Mechanical Engineering, Kragujevac], 2007.
[8] Tanovic, Lj, Petrakov, J., Teorija i simulacija procesa obrade, Masinski fakultet Beograd [Processing Theory and Simulation, Faculty of Mechanical Engineering, Belgrade], 2007.

DEVELOPMENT AND MASTERING OF PRODUCTION OF COATED ELECTRODES FOR CUTTING AND GOUGING METAL MATERIALS

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Abstract: This paper presents the results of mastering the composition of coatings and production technology of two metallurgical quality coated electrodes for metal cutting and gouging. Experimental work has included designing coating formulas based of manganese ore for one type of electrode and hematite based for the second electrode type. Mastered was the production technology using the experimental equipment according to the designed formula for two types of coated electrodes intended for cutting and gouging.
Preliminary electric arc cutting and gouging of steel and gray cast iron with two quality produced coated electrodes was carried out in the laboratory of the Research and Development Center in Belgrade during mastering of production. Experimental electric arc cutting and gouging of steel and cast iron with two produced qualities of the coated electrodes was performed in the IHIS RDC laboratory and a gray iron foundry.
Key words: coated electrode, electric arc metal cutting, metal gouging

INTRODUCTION

Because In cast iron and steel foundries as well as mounting conditions outdoors in hard to reach places and in many other cases manual metal electric arc cutting and gouging with special coated electrodes is applicable. This method of cutting with respect to the use of the gas cutting process with acetylene and oxygen does not require special preparation or a compressed air supply to the cutting site as well as special training of workers [1-3,7].

Development and mastering of the formula of coating was done for a certain quality of the steel core and the selected metallurgical quality of the electrode intended for cutting and gouging metal. Mastering production technology of designed quality electrodes for metal cutting was carried out on experimental equipment which is located in the Research and Development Center in Belgrade.

The coated electrode for cutting consists of a metal steel core which is uniformly coated with a formulated compound, and which consists of milled metallic and nonmetallic powders mixed with a suitable binder. When using a specially coated electrode the coating provides a stable electric arc and a high heat value when using the appropriate amperage and voltage of the electric arc. The coating should ensure high fire resistance and provide oxidation of the liquid metal for its easier removal from the location of cutting or gouging.

By using the coated electrodes the cutting speed of cast iron and cast steel is 1.5-2.0 times greater than when using a carbon electrode in the same mode in air-electric arc cutting [1, 3, 5-7]. Using the coated electrodes yielded a clean, cut surface covered with oxides.

MATERIAL AND METHODS

Experimental production of coated electrodes for metal cutting and gouging

The desire Based on literature and practical knowledge a coating formula was made for the development and mastering of production of two types of electrodes for cutting and gouging of metal materials.

a) Electrodes of IHIS SR 2B quality have a basic coating based on hematite and quartz (classification according to standard EN 499, DIN 1913 AWS A-5.1). Thick coated electrodes are designed for cutting, gouging parts made of steel, cast iron, copper alloys. Application of the electrodes is possible to remove defective weld metals, cracks, inlet systems, etc. The grooves are uniform and smooth and do not require additional processing of the cut surfaces.
b) Electrodes of IHIS SZ MN quality (classification according to standard EN 499, DIN 1913-AWS A 5.1) have an acidic coating with the base consisting of manganese ore. Thick coated electrodes are designed for cutting, grooving and cutting of all metal materials. The coated electrode can be used in all positions for cutting except vertically upwards. The grooves are uniform and smooth and do not require additional processing of the cut surfaces.

The mastered metallurgical quality of electrodes are intended for manual electric arc cutting and gouging of all metals except magnesium, and are particularly suitable for gouging cracks during repair welding of gray cast iron. Suitable also for application during assembly and repair of metal structures in installation conditions in open space and in hard to reach places.

For preparing the core of the electrode selected were steel rods 3.25 mm in diameter and standard length of 350 mm, and a rod a diameter of 5.0 mm, length 450 mm, they are made by the technological process of flattening and cutting from solid drawn steel wire produced by multistage drawing.

View of produced coated electrodes for cutting and gouging metal material internal code: IHIS SZ MN, Figure 1a, and view of produced coated electrodes internal code: IHIS SR-2B, Figure 1b.

Figure 1. Produced coated electrodes, a diameter of 3.25mm and 5.0mm for cutting and gouging of metal materials, internal codes: IHIS SZ MN (a) and IHIS SZ-2B (b)

Experimental electric arc cutting with produced coated electrodes

With produced coated electrodes, internal code: IHIS SZ-MN and IHIS SZ-2B, with a diameter of 3.25mm and 5.0mm preliminarily and then experimental electric arc cutting and gouging were performed. For the purpose of comparison of properties and quality of the cut obtained were SEKATOR 1 and SEKATOR 2B electrodes (manufacturer Jesenice).

The preliminary cutting and gouging using the two produced qualities of coated electrodes IHIS SZ-MN and IHIS SZ-2B, was done by MEA procedure with parameters given in Table 1.

Table 1. Cutting and gouging parameters using the MEA method

Electrode	d [mm]	Cutting parameters	Gouging parameters
		Welding current, I, [A]	Welding current, I, [A]
IHIS SŽ-2B IHIS SŽ-2M	3.25	110-200	140-300
	5.0	250-350	350-450

Based on comparison of the quality of cutting and gouging with two mastered qualities of the coated electrodes IHIS SZ-MN and IHIS SZ-2B and purchased two types of electrodes (SEKATOR 1 and SEKATOR 2B) of the well-known electrodes manufacturer -Jesenice established was:

- That the electrode IHIS SZ-2B showed very good results for cutting and gouging operations of steel materials and cast iron, similar to electrode SEKATOR 2B (Jesenice).
- That the electrode IHIS SZ-MN showed satisfactory properties in cutting and gouging operations of steel materials and cast iron similar to electrode SEKATOR 1 (Jesenice).

Based on the results of comparison of quality in the preliminary cutting and gouging with the two produced coated electrodes IHIS SZ-MN and IHIS SZ-2B, and based on the indicators of health safety of welders, it was concluded that the applied electrode marked IHIS SZ-2B has the advantage in relation to the electrode marked: IHIS SZ-MN.

Experimental arc cutting was performed with the selected coated electrode IHIS SZ-2B, a diameter of 3.25 mm and 5.0 mm, under laboratory conditions at IHIS RDC and industrial conditions at MIN foundry in NIS, Figure 2 (a-c), Figure 3 (d-f). In the photographs in Figure 2 (a, b, c) shown are electric arc cutting and gouging of steel samples using the produced electrode IHIS SZ-2B, with a diameter of 3.25 mm. In the photographs in Figure 3 (d-f) shown is electric arc cutting of gray cast iron with the electrode IHIS SZ-2B, with a diameter of 5 mm.

a) b) c)

Figure 2. Experimental electric arc gouging (ab) and cutting (c) of steel samples with the electrode IHIS SZ-2B, with a diameter of 3.25 mm.

a) b) c)

Figure 3. Experimental electric arc cutting (a-c) of gray cast iron with the electrode IHIS SZ-2B, with a diameter of 5 mm.

CONCLUSION

On the basis of the comparative results obtained with experimental electric arc gouging and cutting of steel and gray cast iron with the electrode IHIS SZ-2B and electrode SEKATOR 2B (manufacturer Jesenice) concluded was:

- that the new electrode IHIS SZ-2B showed very good results for cutting and gouging operations of steel materials and gray cast iron,
- that from the aspect of hygienic-sanitary point of view the applied electrode IHIS SZ-2B has an advantage compared to the similar electrode IHIS SZ-MN,
- that the above mentioned metallurgical quality of the coated electrode can be recommended for industrial applications.

ACKNOWLEDGEMENTS

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REFERENCES

[1] N.N. Potapov, D. N. Baranov, O. S. Kakovkin, D. B. Vitman i dr.:ISBN 5-217-01236-8., Moskva, Masinostrenie, 1993.
[2] B.D. Maliseva: Svarka i rezka v promislenom stroiteljstve, ISBN 5-274-00854-2, Tim I, Moskva 1989.
[3] Dodatni materijali za zavarivanje-katalog, Elektrode Jesenice
[4] Nikola S. Bajić, Monografija: ISBN 978-86-89775-00-6, COBISS.SR-ID 204235020, (2013)
[5] Nikola Bajić, Darko Veljić, Marko Rakin, Slobodan Stojadinović, Jasmina Pekez, Mihailo Mrdak: Welding&Welded Structures, LVIII, UDK/UDC:621.791.04, ISN 0354-7965, COBISS.SR-ID 105396743, No 4/2013, I-deo.p.157-161.
[6] Welding and cutting: Selection of stick electrodes (part 1) welding and cuting. Vol.123, No4, 2013.
[7] M.Bogner, M. Borisavljevic, V. Matovic, M.M. Bogner: Zavarivanje, ISBN 978-86-85361-14-2, 2007.

CONTROL OF TIME-DELAY PROCESSES USING CONTROLLER DESIGNED BASED ON POLE PLACEMENT METHOD

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Abstract: Due to many problems in the system control caused by time delay present paper, like many others, deals with such a kind of processes. Approximation and reduction of mathematical model of process have been carried out, in order to adapt it for controller design according pole placement method. Proposed procedure was researched and proven on the two different processes. First, single-input single-output (SISO) process and the other multivariable process with two-inputs and two-outputs (TITO), both with time delay. Investigation has been carried out using simulations.
Key words: time-delay processes, model approximation, PI controller, pole placement method

INTRODUCTION

Processes with time delay are very common in the many areas of life. Due to that, interest in their control is very frequent. Regardless whether time delay is caused by process nature or delay of measurement signal, it makes troubles in process control. A lot of researches and publications are referred to time-delay systems and its control, like in [1-4]. Various methods for analysis and design of controller for this kind of processes were presented herein. Pole placement method is very useful approach for controller design, because few parameters is used in defining of controller's terms (proportional, integral and/or derivative) and therefore system dynamical behavior. There is a lot of literature for this method, too. Some of them are presented in [5-8]. Taking into account general expressions of the pole placement method, it is evidently, that mathematical models of many processes have to be adjusted for applying of this method. Many types of approximations are available from literature but Padé approximation, presented in [9], has been used in this investigation. Therefore, procedure of PI controller design, using pole placement method, for time-delay processes control has been suggested here. The paper is organized in the following way. Short literature overview of thematic area and paper content are given in this chapter. Chapter *Controller design* contain explanation of pole placement method and preconditions for its application. Representative processes (SISO and TITO) are simulated in the chapter *Examples*. Chapter *Conclusions* gives some notes and guidelines about presented procedure. *References* are listed in the last chapter.

CONTROLLER DESIGN

Pole placement method

Among numerous literature sources that deal with pole placement method for PI controller design, this investigation is based on [10]. Initially for PID controller design, process transfer function $G(s)$ has to be in the form (1):

$$G(s)=\frac{K}{(T_1 s+1)(T_2 s+1)} \tag{1}$$

where are K – process gain, T_1 and T_2 – time constants.

Controller's $G_c(s)$ general form is presented by (2). The meaning of the parameters is: K_p, K_i and K_d – proportional, integral and derivative gain, respectively, T_i and T_d – integral and derivative time constant.

$$G_c(s) = K_p\left(1 + \frac{1}{T_i s} + T_d s\right) = K_p + \frac{K_i}{s} + K_d s \tag{2}$$

Taking into account well known transfer function of the closed loop and roots of the characteristic equation (poles of the system), desired system behavior is described by the following equation (3):

$$(s + \alpha\omega_n)\left(s^2 + 2\xi\omega_n s + \omega_n^2\right) = 0 \tag{3}$$

where are ω_n – natural frequency of the process, ξ – damping degree, $-\alpha\omega_n$ – real pole whose real part should be several times larger than two dominant poles. Parameter α serve for controller adjusting.
According [10] expressions for PID controller's parameters are:

$$\begin{aligned} K_p &= \frac{T_1T_2\omega_n^2(1+2\xi\alpha)-1}{K} \\ T_i &= \frac{T_1T_2\omega_n^2(1+2\xi\alpha)-1}{T_1T_2\alpha\omega_n^3} \\ T_d &= \frac{T_1T_2\omega_n(\alpha+2\xi)-T_1-T_2}{\omega_n^2T_1T_2(1+2\xi\alpha)-1} \end{aligned} \tag{4}$$

Model approximation and reduction

As it can be seen in previous subchapter, procedure for PID controller design according pole placement method is pretty simple. The problem is that many processes cannot be described in form (1), which means that they have zeros and/or they are not of the second order. In order to apply above presented pole placement method process transfer function should be approximated and even reduced its order. In doing so, care must be taken to ensure that deviations in system responses are acceptable, i.e. it mustn't disturb controller design. Transfer function of the time-delay system $G(s)$ is product of rational and exponential term (5). Obviously, exponential term, that represents time delay, should be approximated. Padé approximation of degree 1 is used here (6), in order to avoid order rising of entire system.

$$G(s) = \frac{K}{Ts+1}e^{-Ls} \tag{5}$$

$$e^{-Ls} = \frac{2-(Ls)}{2+(Ls)} \tag{6}$$

where is L – time delay.
If process transfer function is second or higher order, after approximation we get transfer function of the entire system which is third order or higher. In that case model reduction must be carried out. It can be done in the software Matlab.

EXAMPLES

Two different time-delay processes were simulated in order to prove possibilities for applying proposed procedure. One single-input single-output (SISO) process and the other multivariable two-input two-output (TITO) were deliberately tested, with a view to show diversity and effectiveness of procedure in the case when mutual coupling is present.

First example

In this example direct heat exchanger was taken into consideration. Voltage drop $U(t)$ is manipulated variable, while liquid temperature $\vartheta(t)$ is controlled variable (response) of the system. It was modeled as time-delay process in [11] and its transfer function is shown by (7).

$$G(s)=\frac{2,38}{50,264s+1}e^{-10s} \tag{7}$$

After Padé approximation (6) and algebraic transformations transfer function becomes (8).

$$G(s)=\frac{-11,75s+2,25}{(5s+1)(50s+1)} \tag{8}$$

Model reduction (9) was allowed, because neglection of right half plane zero didn't significantly distorted compared step responses of the process, as it can be seen in Fig. 1. Now, process transfer function is:

$$G(s)=\frac{2,25}{(5s+1)(50s+1)} \tag{9}$$

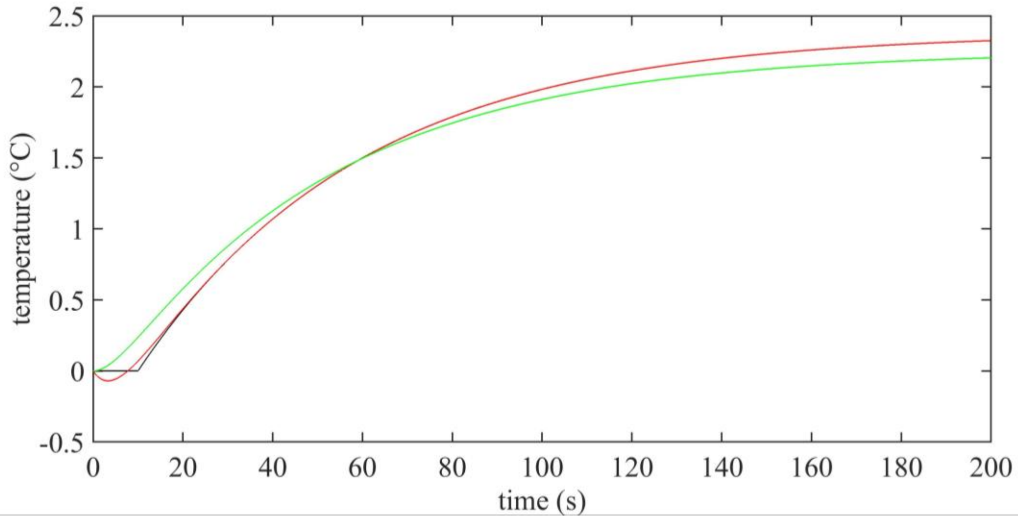

Figure 1. Comparative display of three stage of process transfer function presented by equations: ____ (7), ____ (8) and ____ (9)

According equations (1) and (9) following parameters are obtained: K=2,25 ; T_1=5 s ; T_2=50 s ; ω_n=0,02 rad/s ; ξ=1. Parametar α has been chosen as α=12 to place non-dominant pole far enough from the origin. Parameters of PID controller $G_c(s)$ calculated from (4) are: K_p=0,667 ; K_i=0,011; K_d=6,667. They were applied in configuration shown in Fig 2, where: r – reference value (It was set as r=20 °C), u – manipulative value and y – proces response (output).

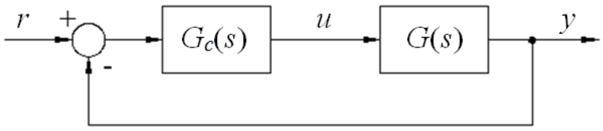

Figure 2. Configuration for testing (SISO) process

After perform simulations in Matlab software, it was noticeable that derivative term causes needless dynamic in the process response. Therefore, derivative term was dismissed, and PI controller has been used for process control. It enables pretty good response (shown in Fig. 3), because there is no overshoot while response speed is acceptable.

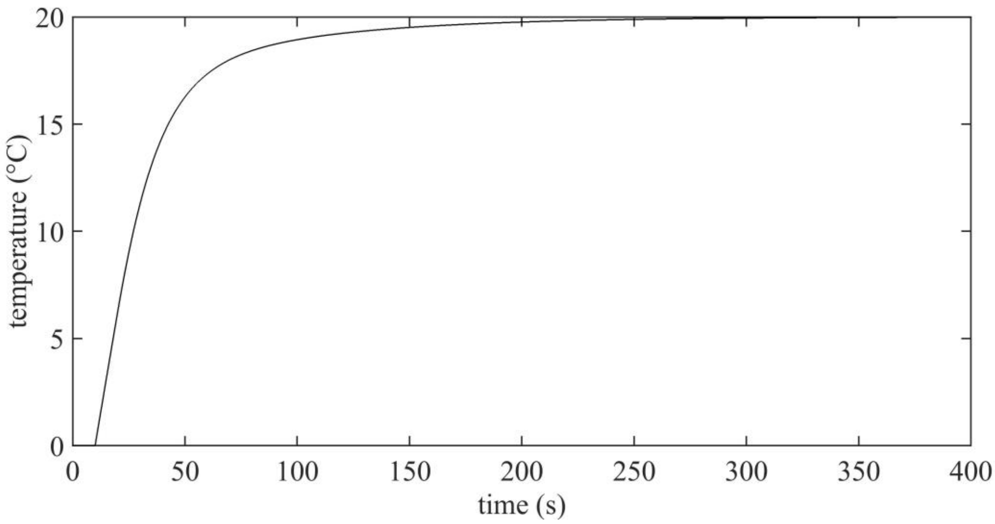

Figure 3. Response of the direct heat exchanger

Second example

Binary distillation column (water-methanol) has been frequently used as object for testing various control algorithms. Its mathematical model (10) was formed in [12]. Controlled variables are: $X_D(s)$ – percentage of methanol in the distillate, $X_B(s)$ – percentage of methanol in the bottom products, and manipulated variables are: $R(s)$ – reflux flow rate and $S(s)$ – steam flow rate in the reboiler.

$$\begin{bmatrix} X_D(s) \\ X_B(s) \end{bmatrix} = G(s) \times \begin{bmatrix} R(s) \\ S(s) \end{bmatrix}$$

$$G(s) = \begin{bmatrix} g_{11}(s) & g_{12}(s) \\ g_{21}(s) & g_{22}(s) \end{bmatrix} = \begin{bmatrix} \dfrac{12,8}{16,7s+1}e^{-s} & \dfrac{-18,9}{21s+1}e^{-3s} \\ \dfrac{6,6}{10,9s+1}e^{-7s} & \dfrac{-19,4}{14,4s+1}e^{-3s} \end{bmatrix} \tag{10}$$

In order to compensate influence of mutual coupling and in that way, enable proper controller design, this multivariable process has been decoupled using simplified decoupling procedure (11) and (12). It was done in [13]. Where $d_{12}(s)$ and $d_{21}(s)$ are terms of decoupler $D(s)$.

$$D(s)=\begin{bmatrix}1 & d_{12}(s)\\ d_{21}(s) & 1\end{bmatrix}=\begin{bmatrix}1 & \dfrac{-g_{12}(s)}{g_{11}(s)}\\ \dfrac{-g_{21}(s)}{g_{22}(s)} & 1\end{bmatrix} \tag{11}$$

$$d_{12}(s)=1{,}47\frac{16{,}7s+1}{21s+1}e^{-2s}, \qquad d_{21}(s)=0{,}34\frac{14{,}4s+1}{10{,}9s+1}e^{-4s} \tag{12}$$

After decoupling, following diagonal transfer matrix of the process was obtained. It is presented by (13) and (14) [13]:

$$Q=\begin{bmatrix}g_{11} & g_{12}\\ g_{21} & g_{22}\end{bmatrix}\cdot\begin{bmatrix}d_{11} & d_{12}\\ d_{21} & d_{22}\end{bmatrix}=\begin{bmatrix}g_{11}d_{11}+g_{12}d_{21} & g_{11}d_{12}+g_{12}d_{22}\\ g_{21}d_{11}+g_{22}d_{21} & g_{21}d_{12}+g_{22}d_{22}\end{bmatrix}=\begin{bmatrix}q_1 & 0\\ 0 & q_2\end{bmatrix} \tag{13}$$

In the (13) Laplace operator s was omitted because of shorter writing.

$$Q(s)=\begin{bmatrix}\dfrac{12{,}8\cdot e^{-s}}{16{,}7s+1}-\dfrac{6{,}4(14{,}4s+1)\cdot e^{-7s}}{228{,}9s^2+31{,}9s+1} & 0\\ 0 & -\dfrac{19{,}4\cdot e^{-3s}}{14{,}4s+1}+\dfrac{9{,}7(16{,}7s+1)\cdot e^{-9s}}{228{,}9s^2+31{,}9s+1}\end{bmatrix} \tag{14}$$

Having in mind (10), (13), (14) and (1) it is obvious that terms q_1 and q_2 are not in appropriate form for controller design according pole placement method. So, both of them were subjected to Padé approximation and reduction of model order using Matlab software. Hence:

$$q_1(s)=\frac{-0{,}5644s^2+0{,}9406s+0.1892}{s^2+0{,}4785s+0{,}02957} \tag{15}$$

$$q_2(s)=\frac{-0{,}4384s^2+2{,}647s-2{,}909}{s^2+2{,}975s+0{,}2999} \tag{16}$$

Neglecting of one right half plane zero and one left half plane zero in q_1, and two right half plane zero in q_2 leads to following forms (17) and (18).

$$q_1(s)=\frac{6.307}{(2{,}463s+1)(13{,}699s+1)} \tag{17}$$

$$q_2(s)=\frac{-9{,}729}{(0{,}348s+1)(9.615s+1)} \tag{18}$$

This reductions (17) and (18) are allowed because deletion of mentioned zeros didn't significantly distorted process step responses, as it can be seen in Fig. 4 and 5.

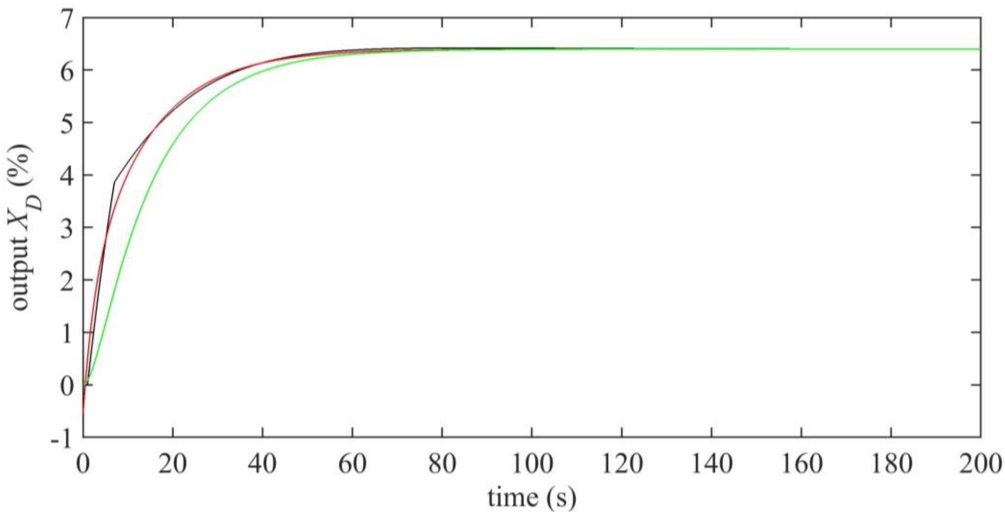

Figure 4. Comparative display of three stage of process transfer function presented by equations: ____ q_1(14), ____ (15) and ____ (17)

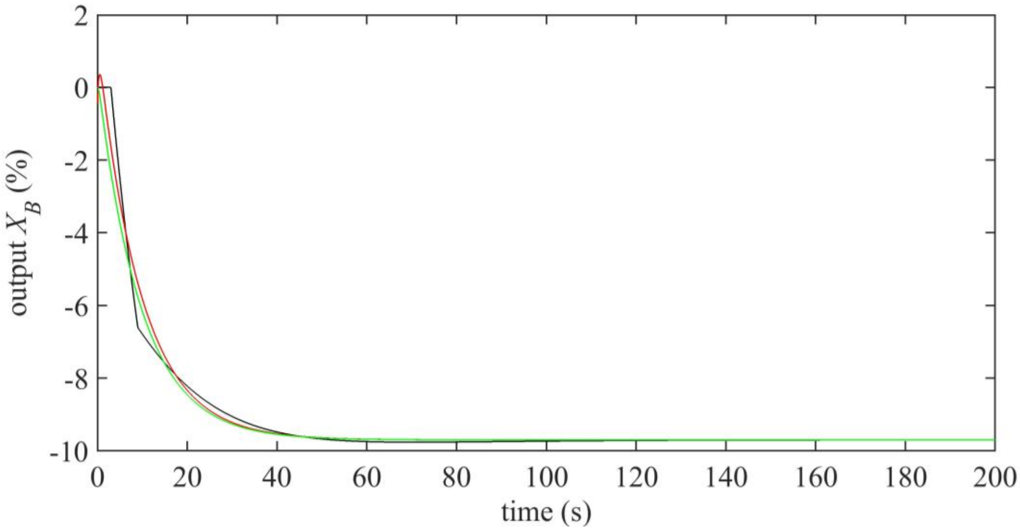

Figure 5. Comparative display of three stage of process transfer function presented by equations: ____ q_2(14), ____ (16) and ____ (18)

Equations (1) and (17) give following parameters (for the first loop): K=6,307 ; T_1=2,463 s ; T_2=13,699 s ; ω_n=0,073 rad/s ; ξ=1. Parametar α has been chosen as α=6 to place non-dominant pole far enough from the origin. Parameters of PID controller G_{c1} calculated from (4) are: K_p=0,2121 ; K_i=0,0125; K_d=0,5617.

On the same way, equations (1) and (18) give following parameters (for the second loop): K=-9,729 ; T_1=0,348 s ; T_2=9,615 s ; ω_n=0,104 rad/s ; ξ=1. Parametar α has been chosen as α=18 to place non-dominant pole far enough from the origin. Parameters of PID controller G_{c2} calculated from (4) are: K_p=-0,0348 ; K_i=-0,007; K_d=0,3087.

All of these parameters were applied in configuration shown in Fig. 6, where: r_1 and r_2 – reference values (set as 1), e_1 and e_2 – errors of controlled variables, v_1 and v_2 – outputs of controllers, u_1 and u_2 – manipulative values and y_1 and y_2 – process responses (outputs).

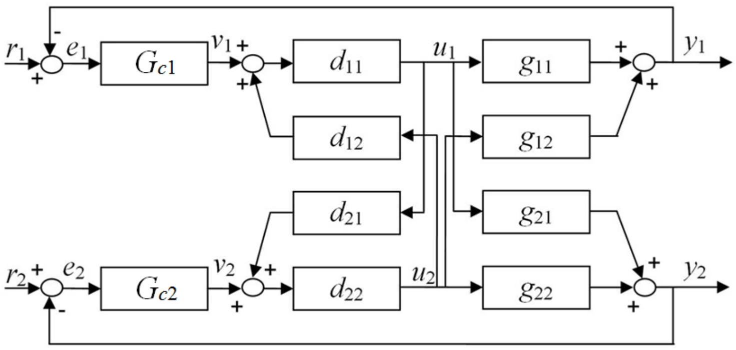

Figure 6. Configuration for testing multivariable process

In the Fig. 6 Laplace operator s was omitted to make it simpler.
Simulations carried out in Matlab software give process responses shown in Fig.7. Derivative term in this process introduce needless dynamic in the process response. Due to that, it was dismissed and therefore PI controller has been used for process control. Fig. 7 shows that PI controller gives first output without overshoot and the second one with a little bit of overshoot. Speed of both responses is good enough.

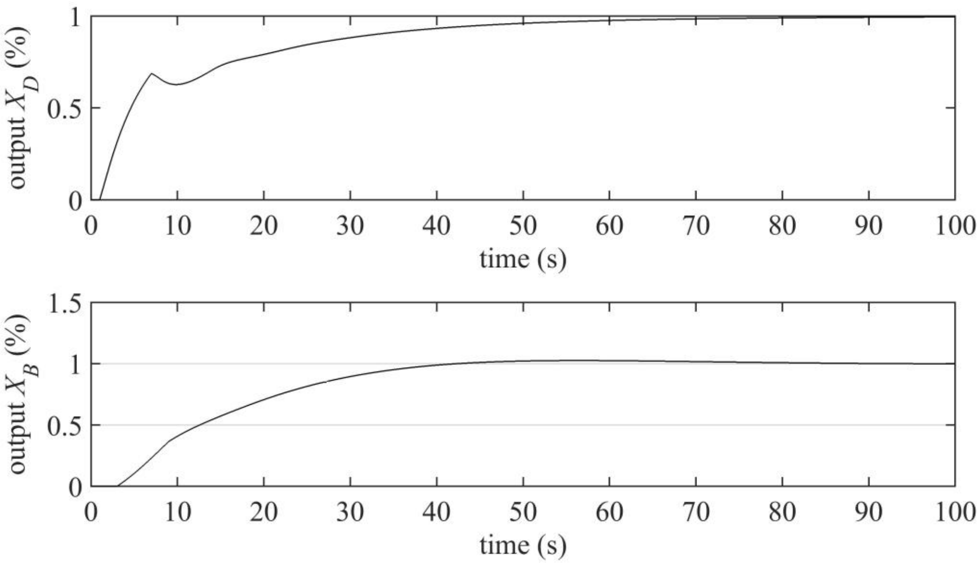

Figure 7. Responses of the binary distillation column (water-methanol)

CONCLUSION

One more procedure for controller design and activities preceding it is presented here. It is proved and emphasized that proper approximation and reduction of model, if they are necessary, contribute to successful controller design. In the case of multivariable systems, there are more phases of approximation and reduction. Pole placement method in the combination with above mentioned steps gives controller that enables pretty good process responses. Depending on the particular process, parameter α, that define non-dominant pole, can be placed on the various distance from the origin in order to obtain good behavior of the entire control system. Despite the defined calculation, if any of the controller parameters impair the response quality (often derivative term), it should not be used like in presented examples where PI controllers were utilized.

REFERENCES

[1] Dugard, L., Verriest, E.I. (Eds.): Stability and Control of Time-delay Systems, Springer-Verlag, London, 1998.

[2] Zhong, Q.-C.: Robust Control of Time-delay Systems, Springer-Verlag, London, 2006.

[3] Vu, T.N.L., Lee, M.: Multi-loop PI controller design based on the direct synthesis for interacting multi-time delay processes, ISA Trans., 49, pp. 79 – 86, 2010.

[4] Hu, Z.R., Li, D.H., Wang, J., Xue, F.: Analytical Design of PID Decoupling Control for TITO Processes with Time Delays, J. Computers, 6, pp. 1064–1070, 2011.

[5] Matejičková, K., Bakošová, M.: Robust PI controller desing for a time-delay process, International Conference on Process Control (PC), pp. 480 – 485, Štrbské Pleso, Slovakia, 2013.

[6] Cîrtoaje, V., Baiesu, A.S.: Two Design Procedures for a Time-Delay Control System, Control Engineering and Applied Informatics, Vol.12, No.4, pp. 3 – 9, 2010.

[7] Michiels, W., Vyhlídal, T., Zítek, P.: Control design for time-delay systems based on quasi-direct pole placement, Journal of Process Control, Vol.20, pp. 337–343, 2010.

[8] Wang, Q.-G., Liu, M., Hang, C.C.: Approximate Pole Placement with Dominance for Continuous Delay Systems by PID Controllers, The Canadian Journal of Chemical Engineering, Vol.85, pp. 549–557, 2007.

[9] Hanta, V., Procházka, A.: Rational Approximation of Time Delay, 2009.

[10] Filipović, V. Ž., Nedić, N. N.: PID Controllers, University of Kragujevac, Faculty of Mechanical Engineering, Kraljevo, 2008.

[11] Sabljo, R.: Dead-time Influence on Control Quality, Final work, University of Josipa Jurja Strossmayera in Osijek, Faculty of Electrical Engineering, 2016.

[12] Wood, R.K., Berry, M.W.: Terminal composition control of binary distillation column, Chem. Eng. Sci. Vol. 28, pp. 1707–1717, 1973.

[13] Prodanović, S.Lj., Nedić, N.N., Filipović, V.Ž., Dubonjić, Lj.M.: Modified approach to distillation column control, Hem. Ind., vol. 71, no 3, pp. 183–193, 2017.

USING CAD FOR PRODUCT DEVELOPMENT ON THE INTERNET

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Abstract: Nowadays, it has become more important than ever to establish a successful online branding strategy. The company visually presents itself through a wide variety of elements: corporate name, logo of many other elements in order to present the company and its products and services, and a very important website - online branding. Companies of all types and sizes are increasingly becoming part of the web, not only to create their own websites, but also to expand their presence on secondary sites, social networks or company blogs. At this stage of web development, it has become more important than ever to establish a successful online branding strategy where graphical presentation using Cad software is very important.
Key words: product, online branding, Cad software

INTRODUCTION

Companies of all kinds and sizes are now more than ever expanding their business to the internet, not only to create their own sites but also in order to expand their influence on social networks and company blogs. In today's world it is extremely important for companies to have a successful online branding and marketing strategy [1].

COMPANY IDENTITY AND IMAGE

Corporate identity is a company portrait, everything customers use to identify a certain company, starting from it's philosophy, history, culture, strategy, management style, and all the way to it's design and employee behavior.
Corporate image is how the general public sees a certain company. It's the impression the company leaves on everyone it works with.
In order for a company to be well known and easily recognised, it needs to have a clear and recognisable identity.

Visual presentation of a company

A company presents itself visually through a wide spectre of many elements:

- company name,
- logo,
- emblem or a symbol,
- company's color scheme,
- uniforms and badges,
- company products' labels,
- architectural style of factories, offices, vehicles and other equipment,
- signs,
- leaflets,
- company stands,
- multimedia material,
- internet presentation.[2]

Branding in a digital world

Internet has opened up a way for small companies and startups to get brand recognition that was completely out of their reach without it. Today even independent professionals have a chance of branding themselves with almost the same opportunities as multinational companies.

Visual branding

Visual branding doesn‘t consist solely of the company logo, but it certainly is a central aspect of it. But a logo isn‘t the only element of visual communication. In reality, thanks to the popularity of social media platforms, there now exist alternative, but equally as recognizable logo designs (Skype logo and Skype logo on Tweeter).
A great majority of companies that already have a developed brand should create alternative versions of their logos for use on social media platforms.

Branding on social networks

Thanks to the rise of social media, users can interact with brands they like in ways that were not possible before. This type of direct communication opens up an opportunity for companies to gain more loyal customers. This is achieved using all kinds of regular blog posts, status updates, or tweets.
Can you imagine this type of interaction without the internet?

Branding ideas

Branding is most effective when you succeed in making an association between the product and popular ideas.
For example, Aston Martin successfully connected their brand with the movie character of James Bond, but the main benefits of this lie in the ideas associated with the character by the oublic, as are action, adventure and success.
Many other brands have done the same, and sometimes in a way more abstract way, for example *Nike with it’s „Just Do It“ campaign, Adidas with „Greatness“ or Apple with „Think different“, L’Oreal with „Because You’re Worth It“; De Beers with „A diamond is forever“; McDonald’s with „I’m lovin’ it“; Old Spice with „Believe in your Smellf“.*

MARKETING OF NEW PRODUCTS

Marketing mix is one of the keys to modern business conception. Elements of marketing mix are usually classified as the 4P’s:

- product,
- price,
- place,
- promotion.
-

But today the 4P’s are more and more expanded to 7P’s which also contain: people, process and physical environment.

How elements of 4P affect the desired market

Ways in which products affect the desired market are: quality, characteristics, possibilities, style, product name, brand, packaging, service, warranty and profit per unit sold.
Distribution affects the desired market by distribution channels, coverage, location, supply i transport.
Promotional activity affects the desired market by advertising, personal selling, sales promotion and public marketing.

Figure 1. Elements of marketing mix [2]

Product and marketing mix

Marketing mix quality

Marketing mix quality is influenced by many external factors. Especially important to consider are economic capabilities of the country, competitors influence, business partner influence.
Marketing mix is considered a marketing instrument which has two main objectives:
The communication objective is to create such conditions that the product easily attracts customers.
The operating objective is to create optimal conditions for the transaction.
Both have three main goals:

1. Informing the buyer about the product
2. Getting the buyer to want to buy the product
3. Balancing supply and demand for the product

The product as an instrument of marketing mix

A product includes it's physical appearance, ideas and services that it provides.
Product characteristics are:

- Physical – shape and look
- Functional – utility
- Symbolic – design, packaging

Product

There are three important product levels:

- product idea
- material product
- customer service. [3]

EXAMPLE OF STUDENTS WORK

Following is an example of a students work focused around an energy drink. Students were given the task of creating a marketing mix, as well as developing a complete graphical solution for the product. This project demonstrates many complex skills students acquired within the program industrial product design at The Higher Technical Education School of Professional Studies in Novi Sad.

In presenting the graphical design of the product students used skills acquired from programs of Computer graphics and Computer animations within which students used CAD software.
The presented product is an energy drink. This type of drink has become one of the most recognizable in the modern world which is characterized by the constant need to be fully concentrated and engaged in what you are doing, and the evrgrowing demands businesses give their employees.
The presented product comes in three innovative flavors - orange, lemon, and blackberry, which gave inspiration for the colors used in product design.

Product name

The name of this product is Nott. Given that the consummation of energy drinks is mostly associated with nighttime, the product was named after the Nordic goddess Nott who is the goddess of night in Norse mythology. In Norse mythology, the goddess was given a carriage by other gods which was then put to the sky to fly over the Earth. Notts carriage was towed by a horse name Hrimfaxi, which every day covered the Earth in morning dew.

Product design

The buyers attention is attracted by attractive design which incorporated appropriate vibrant colors, as well as the quality and size and shape of the packaging. Choosing right colors is an extremely important factor in product design. Especially important in to make sure all elements fit together in the desired way.

Color

Color is one of the most important elements in establishing a brand. Every color evokes a different feeling and people associate them with different things. Choice of colors and color combinations for a certain brand or product are what gets customers to associate the product with desired feelings. Three colors used for designing this product are:
Red is an emotionally intensive color. It enhances human metabolism, speeds up breathing and raises blood pressure. It is very easily spotted.
Blue is the color of the sky and sea. It symbolizes stability trust, wisdom, intelligence, heaven...
Green is the color of nature and as such it symbolizes growth, freshness and unison. It has an intense emotional connection with security and is the color that calms. [5], [6]

Figure 2. Product design [4]

Determining the target market

In the last ten or so years many similar products have come to market, which indicates buyers have an interest for such products. The target market for this product would be Serbia. There exist some already well-established brands competing in that market already, with their popular and recognizable products. The most important thing about this kind of product is an original design solution which will be instantly recognizable. The product can also be adjusted for foreign markets, thanks to it's modern design and innovative flavors. [6], [7]

Determining the target demographic

The product is aimed at young people as it's main demographic. As an energy drink with high caffeine and sugar content, it is not suited for underage individuals, individuals with heart problems, pregnant women and athletes. It is mostly aimed at younger individuals such as students, because it helps them stay awake while studying at night.

Promotional campaigns

One of the best ways of promoting a product is at a company stand at large conventions, where people can easily discover it. Also, a company can advertise themselves and their products by sponsoring certain events, such as the Olympic games for example.
The product would also be advertised using the internet – advertisements on YouTube videos and social networks are a great advertising platform this, due to their recent spike in popularity.

Figure 3. Product billboard design [4]

Slogans proposed for the product:

- I'm NOTT sleeping tonight.
- NOTT sleeping. [4]

CONCLUSION

The importance of design, product presentation and customer service is of great importance for promoting a company. The days when buyers exclusively relied on magazines and newspaper in order to find products and services are long gone. Today, internet is the first place they look at to find more information about products and services they require, and that is where companies build their brands. It is often people say that **if you can't be found, you don't exist.**

REFERENCES

[1] https://www.popwebdesign.net/index_eng.html
[2] https://www.popwebdesign.net/popart_blog/2012/12/kako-da-unapredite-vas-online-branding/
[3] http://edukacija.rs/poslovne-vestine/marketing/marketing-miks-i-marketing-novih-proizvoda
[4] Milica ilić, Students work, Design ambalage, at The Higher Technical Education School of Professional Studies in Novi Sad 2018.
[5] http://healthclub.rs/zdrav-zivot/energetska-pica-sastav-i-delovanje
[6] http://opusteno.rs/dizajn-f128/znacenje-boja-zelena-t17404.html
[7] file:///C:/Users/User/Downloads/03%20-%20Dizajn%20pakovanja.pdf

A BRIEF INTRODUCTION TO PROCESS PLANNING OPTIMIZATION

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Abstract: Process planning optimization (PPO) belongs to the group of non-deterministic polynomial (NP) hard optimization problems according to the theory of complexity. Two main components of the PPO problem are operation sequencing and selection of machines, cutting tools and tool approach directions (TADs) for each operation. The dimensions of the problem increase with the number of operations and its resources. Also, adequate precedence constraints and flexibilities have to be taken into account in order to obtain feasible process plans. To test the validity of process plans, manufacturing cost and manufacturing time are mostly adopted as optimization criteria. Most effective methods for solving the PPO problem are metaheuristic algorithms which have been thoroughly studied in recent years. This study provides the brief background of the PPO problem, flexibilities, criteria and gives short insight into biologically-inspired metaheuristic algorithms.
Key words: process planning, optimization, metaheuristic algorithms

INTRODUCTION

Optimization represents the collection of mathematical principles and techniques aimed at finding the most suitable solution regarding predetermined conditions. When it comes to techno-economical optimization, it considers the task whose goal is to meet technical requirements of product quality on one side such as functionality, reliability, manufacturability, lifetime, shape, machining accuracy or product design and economical requirements on the other side, such as productivity, manufacturing time and cost, price and market life [1]. Using appropriate objective function (optimization criterion), optimization task is focused on evaluation of obtained results. This paper is focused on process planning optimization problem as a part of techno-economical optimization. The following chapters will introduce the main characteristics of this problem, constraints that affect feasibility of process plans, optimization criteria as well as modern metaheuristic algorithms which are used for finding optimal process plans.

OPTIMIZATION OF PROCESS PLANNING

Process plans are characterized with multiple variants which occur in almost all planning stages. Variants of process plans are mostly influenced by type of raw material, machining processes, operation type and operation sequence, manufacturing resources as well as techno-economical effects [2]. Adopting these variants have enabled decomposition of a process plan to outer and inner optimization, where outer optimization focuses on the selection of optimal elements of process plans at the macro level while the inner optimization emphasizes the selection of optimal elements of process plans at the micro level [1,3].

The process planning optimization (PPO) problem is built up of two parts: the first is the problem of operation sequencing and the other is the optimal selection of appropriate machine, cutting tool and tool approach direction for each operation [4,5,6]. The PPO problem is an NP hard combinatorial problem which, besides integer programming, belong to the branch of discrete optimization. The main characteristic of discrete optimization problems (here, combinatorial) is the search for solution within a discrete or finite set of possible alternatives. On the other side, taking into account the mentioned complexity of the PPO problem, high demands in computational resources (space complexity) and an amount of time an algorithms needs to solve the problem (time complexity) emerge as two important resources when approaching to solve an NP hard problem [7]. High dimensionality of the PPO is reflected in the increase in the number of operations, machines, tools and/or TADs which also affect the increase in space and time complexity.

FLEXIBILITIES AND OPTIMIZATION CRITERIA

Constraints and flexibilities in process planning optimization

The existence of precedence constraints based on the precedence relationships among features and operations is one of the crucial components of process planning optimization problem. These constraints are important in generating feasible and at the same time economical and technological sequence of operations [8,9,10]. They are most frequently represented using matrices and graphs while some authors adopted so called AND/OR networks which cover all process plan flexibilities [11,12].
For the purpose of defining the process planning optimization problem, different types of flexibilities occur. In the literature five different flexibilities are most popular [13]:

1. Process/Processing flexibility – possibility of machining the same feature by using different operations or different sequences of operations;
2. Machine flexibility – possibility of machining the same feature on different machines
3. Tool flexibility – possibility of machining the same feature using different cutting tools;
4. TAD flexibility – possibility of machining the same feature by using different tool approach directions;
5. Sequence flexibility – possibility of using different operation sequences for machining an observed part.

Optimization criteria in process planning

Main optimization criteria for the evaluation of process plans are manufacturing cost and manufacturing time [14]. As far as the first criterion is concerned, total manufacturing cost of a single part conists of five elements: machine cost, cutting tool cost, machine change cost, tool change cost and setup change cost[15,13]. Some authors [13,17] have adopted weight coefficients in order to conduct experiments in various conditions. Each of these elements of manufacturing costs can be expressed with the following equations:

- Machine cost (MC):

$$\mathrm{MC} = \sum_{i=1}^{n} \mathrm{MCI}_i \tag{1}$$

n is the total number of operations, and MCI_i is cost index of a machine i.

- Cutting tool cost (TC):

$$\mathrm{TC} = \sum_{i=1}^{n} \mathrm{TCI}_i \tag{2}$$

where TCI_i stands for cost index of a cutting tool i.

- Machine change cost (MCC):

$$\mathrm{MCC} = \mathrm{MCCI} \times \sum_{i=1}^{n} \Omega\,(\mathrm{M}_{i+1} - \mathrm{M}_i) \tag{3}$$

where MCCI stands for machine change cost index.

- Cutting tool change cost (TCC):

$$\mathrm{TCC} = \mathrm{TCCI} \times \sum_{i=1}^{n-1} \Omega_2\,(\Omega_1(\mathrm{M}_i - \mathrm{M}_{i+1}) - \Omega_1\,(\mathrm{T}_i - \mathrm{T}_{i+1})) \tag{4}$$

$$\Omega_1(X-Y)=\begin{cases}1, \text{if } X\neq Y\\ 0, \text{if } X=Y\end{cases} \qquad \Omega_2(X-Y)=\begin{cases}0, \text{if } X=Y=0\\ 1, \quad \text{otherwise}\end{cases}$$

where TCCI represents cutting tool change cost index.

- Setup change cost (SCC):

$$SCC = SCCI \times \sum_{i=1}^{n-1} \Omega_2\left(\Omega_1(M_i - M_{i+1}) - \Omega_1(PPA_i - PPA_{i+1})\right) \tag{5}$$

where SCCI represents setup change cost index.

Total manufacturing cost with appropriate weight coefficients for each cost element can be calculated as:

$$TWC = w_1 \cdot MC + w_2 \cdot TC + w_3 \cdot SCC + w_4 \cdot MCC + w_5 \cdot TCC \tag{6}$$

The second most popular optimization criterion for process planning optimization is the total manufacturing time that consists of total working time, total transportation time, tool change time and setup change time. The equations are given bellow.

- Total working time (TW):

$$TW = \sum_{i=1}^{n} TWI(i,j,k) \tag{7}$$

where n stands for the total number of operations, TWI(i,j,k) is the total time need for operation i on alternative machine j using alternative cutting tool k.

- Total transportation time (TT):

$$TT = \sum_{i=1}^{n-1} TTI((i,j_1),(i+1,j_2)) \tag{8}$$

where $TTI((i,j_1),(i+1,j_2))$ represents the transportation time between alternative machines j_1 i j_2.

- Total cutting tool change time (TCT):

$$TCT = TCTI \sum_{i=1}^{n-1} \Omega_2\left(\Omega_1(M_i - M_{i+1}) - \Omega_1(T_i - T_{i+1})\right) \tag{9}$$

$$\Omega_1(X-Y)=\begin{cases}1, \text{if } X\neq Y\\ 0, \text{if } X=Y\end{cases} \qquad \Omega_2(X-Y)=\begin{cases}0, \text{if } X=Y=0\\ 1, \quad \text{otherwise}\end{cases}$$

where T_i stands for a cutting tool used for operation i, and $TCTI_i$ is cutting tool change time.

- Total setup change time (SCT):

$$SCT = SCTI \sum_{i=1}^{n-1} \Omega_2\left(\Omega_1(M_i - M_{i+1}) - \Omega_1(PPA_i - PPA_{i+1})\right) \tag{10}$$

where PPA_i stands for tool orientation for operation i, and $SCTI_i$ is setup change time.

Finally, the total manufacturing time is calculated using the following expression:

$$PT = TW + TT + TCT + SCT \tag{11}$$

METAHEURISTIC ALGORITHMS IN PROCESS PLANNING OPTIMIZATION

According to the aforementioned, process planning optimization problem can be solved by adopting methauristic approach. Metaheuristics represent stochastic methods based on which the exploration of search space of possible solutions can be performed and "good" solutions can be found in a reasonable time period [18,19]. These "good" solutions are considered to be those solutions which cannot equal optimal but near optimal solutions and there is no guarantee that the found result really is optimal. Therefore, metaheuristics have the role of a tool that helps to successfully solve hard optimization problems or at least find the solution that will to some extent meet predefined criterion. Metaheuristics are characterized with universality, simplicity and stochasticity and their main task is to achieve balance between local and global search. In other words, they tend to intensify their search process towards local optima (intensification), and to involve the element of randomness in order to explore unexplored regions of search space (diversification) [18].

Metaheuristics are implemented in the form of algorithms and most of them are based on intelligent social as well as biological process that can be found in real environment. The area of artificial intelligence that deals with these algorithms is known as the swarm intelligence [20,21]. It has gained much popularity and expansion in scientific community in recent years. Nature is enriched with individuals that live in groups such as fish, bees, wolves or ants. Their complex mutual interaction aimed at acquiring local information for the group is a result of the emergence of social intelligence which reflects in foraging behavior (fish or ants), hunting behavior (wolves or whales), food pillaging (crows) and many other collective intelligent mechanisms in the nature. All these natural mechanisms have inspired a number of authors to develop computer algorithms that will be capable of solving various optimization problems [22-25].

The search process of biologically-inspired metaheuristic algorithms (also nature-inspired) is based on a randomly generated population of individuals (search agents) whether they are ants, fish, birds or some other living organisms. Dynamics of these algorithms is mostly determined by the set of expressions that characterize certain biological process based on which the population itself may evolve. In other words, population individuals are evaluated using predetermined optimization criterion/criteria and the process of evolution of individuals is repeated through previously defined number of iterations. As mentioned before, balancing between local and global search is primarily emphasized which requires adequate adjustments of input parameters and, in some cases, improvement of algorithm performances by modifying their structure or by hybridization with other algorithms.

CONCLUSION

This paper gave a brief introduction to process planning optimization. After short background of techno-economical optimization, main components of process planning problem were discussed and the complexity of this combinatorial optimization problem was expressed. To ensure feasibility of process plans, one must take into account precedence constraints and flexibilities that occur when generating process plans. Five main types of flexibilities were introduced, such as machine flexibility, tool flexibility, TAD flexibility, process flexibility and sequence flexibility. Objective functions, or optimization criteria were discussed in more detail. Basic elements of manufacturing cost and manufacturing time functions were given. Lastly, short review of metaheuristic algorithms was proposed emphasizing their background and pointing out biologically-inspired metaheuristics as modern methods for addressing the process planning optimization problem.

REFERENCES

[1] Todić, V., Penezić, N., Lukić, D., Milošević, M.: Tehnološka logistika i preduzetništvo, Fakultet tehničkih nauka, Novi Sad, 2011, ISBN 978-86-7892-368-5.

[2] Lukić, D., Milošević, M., Todić, V.: Integrisani CAPP sistemi i tehnološka baza podataka (Modul Integrisani CAPP sistemi), skripta sa predavanja, Fakultet tehničkih nauka, Novi Sad, 2013.

[3] Todić, V.: Projektovanje tehnoloških procesa, Fakultet tehničkih nauka, Novi Sad, 2004, ISBN 86-80249-93-9.

[4] Jun, W., Kuslak, A.: Computational Intelligence in Manufacturing Handbook, CRC Press LLC, USA, 2001, ISBN 0-8493-0592-6.

[5] Li, W. D., Ong, S. K., Nee, A.Y.C.: Integrated and Collaborative Product Development Environment – Technologies and Implementations, Series on Manufacturing Systems and Technology Vol.2, World Scientific Publishing Co. Pte. Ltd., Singapore, 2006, ISBN 981-256-680-5.

[6] Đurđev, M., Milošević, M., Lukić, D., Desnica, E., Todić, V., Kurić, I.: Modified Particle Swarm Optimization with Chaotic Maps for Process Planning Optimization, 13. International Scientific Conference "Flexible Technologies" - MMA, University of Novi Sad: Faculty of Technical Science, 28-29th September, Novi Sad, 2018, pp. 183-186.

[7] Rothlauf, F.: Optimization Problems in: Design of Modern Heuristics, Natural Computing Series, Springer, Berlin, Heidelberg, 2011, ISBN 978-3-540-72961-7.

[8] Faheem, W., Hayes, C.C., Castano,J.F., Gaines, D.M.: What is Manufacturing Interaction?, Proceedings of DETC'98, 1998 ASME Design Engineering Technical Conferences, September 13-16, 1998, Atlanta, Georgia, USA.

[9] Lukić, D., Milošević, M., Erić, M., Đurđev, M., Vukman, J., Antić, A.: Improving Manufacturing Process Planning Through the Optimization of Operation Sequencing, Machine Design, Vol. 9, No. 4, 2017, pp. 123-132.

[10] Wang, J., Kusiak, A.: Computational Intelligence in Manufacturing Handbook, CRC Press, 2001, ISBN-13: 978-0849305924.

[11] Lian, K., Zhang, C., Shao, X.: Optimization of process planning with various flexibilities using an imperialist competitive algorithm, International Journal of Advanced Manufacturing Technology, Springer-Verlag London Limited, 2011, Vol. 59, pp. 815-828.

[12] Petrovic, M., Mitic, M., Vukovic, N., Miljkovic, Z.: Chaotic particle swarm optimization algorithm for flexible process planning, International Journal of Advanced Manufacturing Technologies, Vol. 85, pp. 2535-2555, November 2015.

[13] Lian, K., Zhang, C., Shao, X.: Optimization of process planning with various flexibilities using an imperialist competitive algorithm, International Journal of Advanced Manufacturing Technology, Springer-Verlag London Limited, 2011, Vol. 59, pp. 815-828.

[14] Petrović, M., Mitić, M., Vuković, N., Miljković, Z.: Optimizacija fleksibilnih tehnoloških procesa primenom algoritma baziranog na inteligenciji roja i teoriji haosa, 39. Jupiter konferencija, 35. Simpozijum, Beograd, 2014.

[15] Huang, W., Hu, Y., Cai, L.: An effective hybrid graph and genetic algorithm approach to process planning optimization for prismatic parts, International Journal of Advanced Manufacturing Technology, Springer-Verlag London Ltd., 2011, Vol. 62, No. 9, pp. 1219-1232, ISSN 1433-3015.

[16] Salehi, M., Tavakkoli-Moghaddam, R.: Application of genetic algorithm to computer-aided process planning in preliminary and detailed planning, Engineering Applications of Artificial Intelligence, Elsevier, 2009, Vol. 22, pp. 1179-1187.

[17] Wen, X., Li, X., Gao, L., Sang, H.: Honey bees mating optimization algorithm for process planning problem, Journal of Intelligent Manufacturing, Springer Science+Business Media, 2012, Vol. 25, pp. 459-472.

[18] Talbi, E.G.: Metaheuristics: From Design to Implementation, Wiley, 2009, ISBN: 978-0-470-27858-1.

[19] Yang, X.-S.: Engineering Optimization: An Introduction with Metaheuristics Applications, Wiley, 2010, ISBN: 978-0-470-58246-6.

[20] Panigrahi, B.K., Shi, Y., Lim, M-H.: Handbook of Swarm Intelligence, Concepts, Principles and Applications, Springer-Verlag Berlin Heidelberg, 2011, ISBN 978-3-642-17389-9.
[21] Yang, X.-S., Deb, S., Zhao, Y.X., Fong, S., He, X.: Swarm intelligence: past, present and future, Soft Computing, Vol. 22, No. 18, pp. 5923-5933, DOI 10.1007/s00500-017-2810-5.
[22] Mirjalili, S.: Grey Wolf Optimizer, Advances in Engineering Software, Vol. 69, p.p. 46-61, 2014.
[23] Mirjalili, S.: The Whale Optimization Algorithm, Advances in Engineering Sofware, Vol. 95, p.p. 51-67, 2016.
[24] Mirjalili, S., Grasshopper Optimisation Algorithm: Theory and application, Advances in Engineering Software, Vol. 105, pp. 30-47, 2017.
[25] Yang, X.-S.: Nature-Inspired Metaheuristic Algorithms, Luniver Press, 2008, ISBN: 1905986106 9781905986101.

SESSION 2. ENERGETICS AND PROCESS TECHNIQUE

ENERGY PERFORMANCE OF AACTIVE SOLAR WALL WITH CENTRAL CHANNEL

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Abstract: This study analyzes the energy of an active solar wall with a central channel and forced convection. The analyzed system comprises a double glass glazing and a massive wall with an opening and central channel in it. To increase efficiency, a fan is provided at the bottom vent of the wall. The active solar wall with z a central channel is more advanced as compared with simple Trombe solar wall with a relatively low thermal resistance. This paper presents the one-dimensional steady-state mathematical model for simplified analysis of the efficiency of the active solar wall air heating system. The obtained results were analysed to predict the effects of operating and environmental parameter variations on thermal efficiency.
Key words: solar energy, solar air heating, energy efficiency

INTRODUCTION

Traditionally, there have been two approaches to the application of solar energy to building space heat: an active system which uses an array of solar collectors and passive systems which capture solar energy using building design. A solar wall is essentially a thermal system comprising a glazing panel and a high thermal-mass wall, separated by an air cavity. The most popular concept for air heating is to use solar walls which transfers heat to the room space by radiation and convection. Solar wall operates at lower temperatures due to the large surface area for heat transfer. Different purpose solar space heating systems are based on the use of massive solar walls that are covered with transparent covers, the irradiated surface with good absorption characteristics and the massive wall which has the significant thermal-accumulation capacity.
In this paper, the active solar wall, representing a modified Trombe wall with a central channel, used for space heating applications was investigated. Subject to the position of the valve, the modified Trombe wall ensures the following operating regimes: A – room heating by hot air circulation from the entrance zone in the adjacent room; B– heat storage, partly by the direct absorption and conduction, and partly by hot air circulation from the entrance duct into the channel space; C – room heating and heat storage by simultaneous air circulation from the entrance duct into the room and the channel space; D – room heating when the wall is not exposed to the solar radiation activity, the room is heated by both radiation and natural convection from the inside wall, and hot air circulation from the central channel.

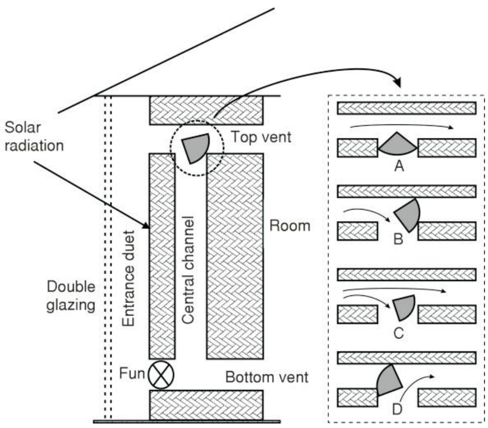


Figure 1. Operating regimes of the active solar wall system

The solar walls have been the subject of numerous experiments and investigations. Many theoretical and experimental studies have shown that indoor comfort is improved due to well-designed solar walls [1-3]. Due to the increasing actualization of the use of massive solar walls for space heating purposes, it is necessary to carry out tests that will result in optimal parameters of the wall to achieve higher energy efficiency. This paper presents the effect of operating and environmental parameters on the thermal efficiency of the analyzed solar heating system with a massive wall and central channel.

MATERIAL AND METHODS

Heat transfer analysis

The heat transfer mechanism for model C from Fig. 1 is the following: heated air from the entrance duct to the central channel of the wall and towards the heated room. Depending on the valve position, heated air is divided into two parts. One part goes directly into the room and warms the air in it. The second part of the heated airflow to the central channel of the wall, where part of the heat is transferred by convection to the inner part of the wall where is accumulating in it and partly transfer by conduction through the wall and heat the room air. The rest of the heat back to the entrance duct through the lower wall shaft.

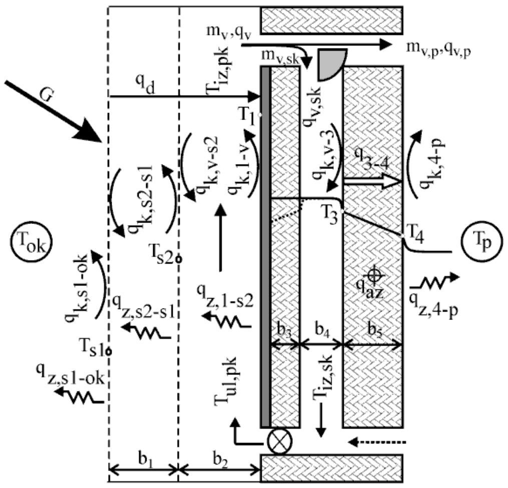


Figure 2. Heat transfer mechanisms for the solarwall with central channel for the operating regime C

In this investigation, the following simplified assumptions have been made: the model is steady-state, heat transfer through the system is one-dimensional, different layers of wall are at uniform temperature at any given time, thermo physical properties of air and all materials involved constant and independent of temperature, the resistance of conduction heat exchange through glazing is neglected, air is considered as a nonparticipating medium in radiation heat exchange, the entire system is well insulated so there are no heat lateral losses, two horizontal boundaries are adiabatic, the temperature of the adjacent room is constant. As in all steady-state methods, the role of the storage capacity of the massive wall was not considered. Return air energy is insignificant compared to the energy of air that circulates between the absorbing surface and the glass covers of the wall, and heat flux of the return air could be ignored in the energy balances. According to these assumptions, the mathematical model of the wall is developed.

Mathematical model

A mathematical model is developed for the case when the air temperature in the heating room is below a specified level, so it is necessary to achieve the circulation of heated air to the room. In this case, the fan is turned on and the valve takes the position as shown in Fig. 2.
The geometrical, thermo-physical and operational parameters of the system are:

1. Double glass glazing unit: $b_1=b_2=10$ cm;
2. Solar wall: $\rho_z=2400$ kg/m^3, H=2.7 m, Y=3 m, $\lambda_z=0.9$ W/mK, $b_3=b_4=5$ cm, $b_5=10$ cm;
3. Outside conditions: $t_{ok}=0$ °C, $w_v=0$ m/s;

Heat flux that is transferred to the air in the heated room, ignoring the useful accumulating thermal flux in the inner part of the wall is given as:

$$q_{v,gp} = q_{v,p} + q_{z,4-p} + q_{k,4-p} \qquad (1)$$

where:
- $q_{v,gp}$total flux entering the heated room, $[\frac{W}{m^2}]$;
- $q_{v,p}$ heat flux from the entrance duct to the air in the heated room, $[\frac{W}{m^2}]$;
- $q_{z,4-p}$radiant heat flux from the internal surface of the wall to air in the room, $[\frac{W}{m^2}]$;
- $q_{k,4-p}$conduction heat flux from the internal surface to air in the room, $[\frac{W}{m^2}]$.

Mass and energy balances for the given model are:

$$m_v = m_{v,p} + m_{v,sk} \qquad (2)$$

$$m_{v,p} = \xi \cdot m_v \qquad (3)$$

$$m_v = 2/3 \cdot w_o \cdot \rho_v \cdot b_2 \cdot Y \qquad (4)$$

$$m_{v,sk} = (1-\xi) \cdot m_v = w_{sk} \cdot \rho_v \cdot b_4 \cdot Y \qquad (5)$$

$$q_v = q_{v,p} + q_{v,sk} \qquad (6)$$

$$q_{v,p} = \xi \cdot q_v \qquad (7)$$

$$q_{v,sk} = (1-\xi) \cdot q_v \qquad (8)$$

where:
- *$\xi \in$ (0-1)* the air flow ratio coefficient that defines the air mass flow rate from the entrance duct to the heated room;
- $m_v$air mass flow rate through the entrance duct of the wall, $[\frac{kg}{m^3}]$;
- $m_{v,p}$ air mass flow rate from the entrance duct to the heated room, $[\frac{kg}{m^3}]$;
- $m_{v,sk}$ air mass flow rate from the entrance duct to the central channel, $[\frac{kg}{m^3}]$;
- ρ_v air density, $[\frac{kg}{m^3}]$;
- w_o air velocity at the inlet of the to the entrance duct, $[\frac{m}{s}]$;
- w_{sk} air velocity at the central channel, $[\frac{m}{s}]$;
- $q_{v,sk}$heat flux from the entrance duct to the central channel of the wall, $[\frac{W}{m^2}]$.

The heat flux that the heated air takes from the entrance duct can be calculated from the following equation:

$$q_v = h_{pk} \cdot (T_1 + T_{s2} - T_{ul,pk} - T_{iz,pk}) = h_{pk} \cdot \left\{ \left[\frac{1}{2} \cdot (T_1 + T_{s2}) - T_{ul,pk} \right] \cdot \left(1 + e^{-\frac{3 \cdot h_{pk} \cdot H}{c_p \cdot \rho_v \cdot w_o \cdot b_2}} \right) \right\} \qquad (9)$$

The energy balance for the circulating air through the central channel of the wall is given as:

$$(1-\xi) \cdot \frac{2}{3} \cdot w_o \cdot \rho_v \cdot b_2 \cdot Y \cdot c_p \cdot (T_{ul,sk} - T_{iz,sk}) = \left[\frac{\lambda_z}{b_5} \cdot (T_3 - T_4) + \frac{\rho_z \cdot c_z \cdot b_5}{\tau} \cdot \left(\frac{T_3 + T_4}{2} - T_{\tau o}\right) \right] \cdot Y \cdot Z \qquad (10)$$

The heat transfer coefficients by convection in the entrance duct and central channel, are calculated by the following equations [4]:

$$h_{pk} = 2{,}27 \cdot \left(\frac{w_o}{b_2} \right)^{0{,}5} \tag{11}$$

$$h_{sk} = 3{,}02 \cdot \frac{w_{sk}^{0.83}}{b_4^{0.17}} \tag{12}$$

The thermal efficiency of the analyzed air solar heating system with a central channel in the case of simultaneous heating and accumulating is given as:

$$\eta = \frac{q_{v,gp}}{q_u} = \frac{q_{v,p} + q_{4-p}}{q_d + \varepsilon_v} = \frac{\xi \cdot q_v + q_{z,4-p} + q_{k,4-p}}{q_d + \varepsilon_v} \tag{13}$$

where:
q_d - solar heat flux at the collector surface
ε_v - electricity usage for the fan operation.

On the basis of the mathematical model given in [5], which was developed for the case when the heated air is discharged directly into the heated room, and the equations (1-13) that take into account the analyzed case when the air is discharged into the heated room and the central duct a series of numerical calculations have been done for the evaluation of the efficiency of the analyzed heating system.

RESULTS AND DISCUSSION

The thermal analysis of such system is very complicated, because of possible variations of constructive, operating and environmental parameters. Therefore, in the efficiency studies conducted for modified Trombe wall certain parameters are considered as constant, while the influence of two parameters was analyzed. While the air velocity at the entrance duct increases, the coefficient of heat transfer by convection from the air to the inside part of the active solar wall in the central channel increases, (Fig.3). When the air mass flow from the entrance duct to the heated room decreases, the mass air flow from the entrance duct to the central channel increases, which causes the increase of the air velocity through the central channel of the wall as well as the coefficient of heat transfer by convection from the air to the wall. The correlation of the heat transfer coefficient by convection with the air velocity at the inlet of the entrance duct can be represented by the linear function given in Table 1.

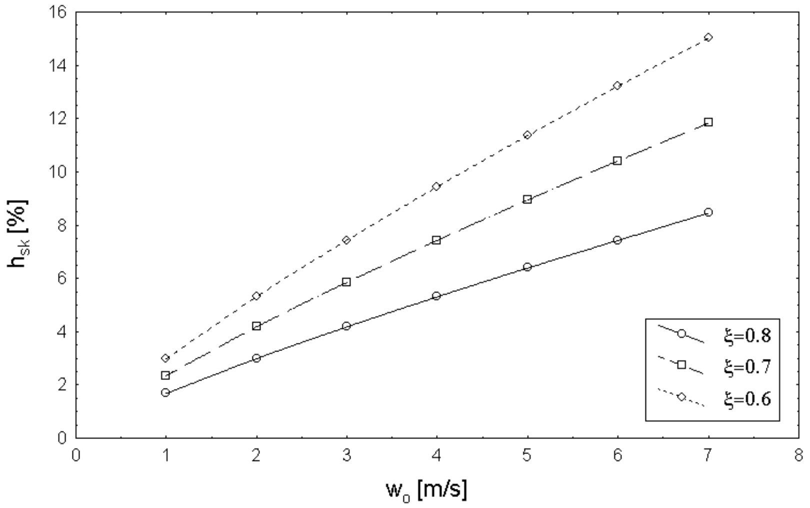
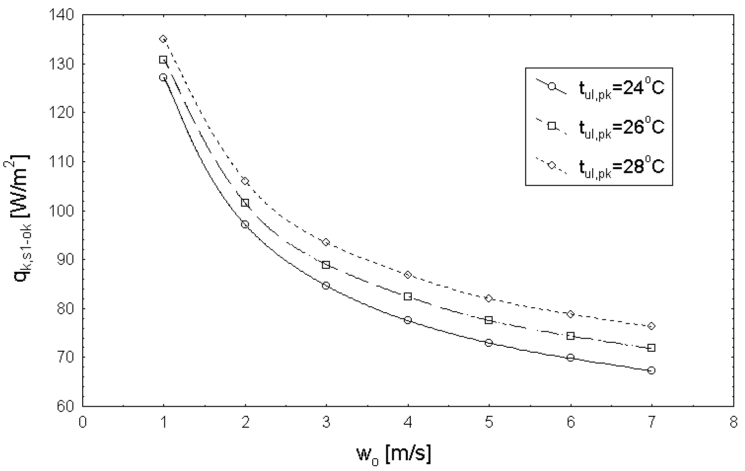


Figure 3. The heat transfer coefficient by convection in the central channel of the wall, G=1000 W/m²

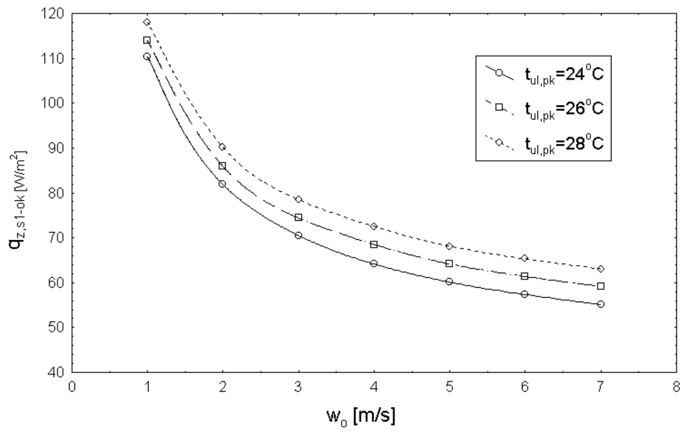
Table 1. The correlation of the heat transfer coefficient by convection with the air velocity at the inlet of the entrance duct

$\mathbf{h_{sk} = A_o + A_1 w_o \left[\frac{W}{m^2K}\right]}$		
ξ	$\mathbf{A_o}$	$\mathbf{A_1}$
0.8	0.72	1.121
0.7	1.00	1.571
0.6	1.27	1.995

Diagrams from Fig. 4 show that the convective heat losses and radiative heat losses from the outside glass cover to the environment decrease as the air velocity at the inlet to the entrance duct increases, for all analyzed inlet air temperatures in the entrance duct of the wall. With the increase of the air velocity at the inlet of the to the entrance duct, heat transfer from the zone where losses occur intensify, whereby the efficiency increases.



a. Convective heat losses $q_{k,s1-ok}$



b. Radiative heat losses $q_{z,s1\text{-}ok}$

Figure 4. The heat losses from the outside glass cover to the environment, G=1000 W/m^2

As the air temperature at the inlet of the entrance duct of the wall increases, the efficiency decreases, for the analyzed mass flows of heated air which circulate from the entrance to the heated room (Fig. 5). The efficiency increases as the mass flow of heated air circulating from the entrance duct to the heated room increases, for the constant air temperature at the inlet to the entrance duct of the wall.

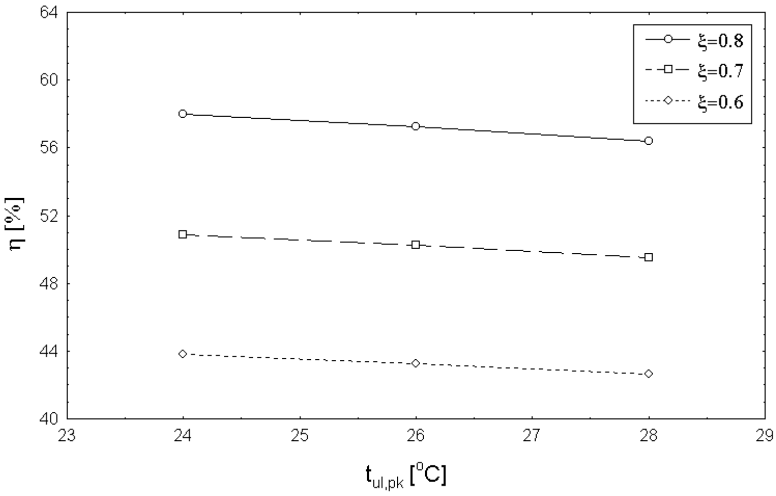


Figure 5. Variation of the thermal efficiency η with the inlet air temperatures in the entrance duct $t_{ul,pk}$ G=1000 W/m^2, w_o=1 m/s

The diagrams from Fig. 6 show that the coefficient of efficiency increases with the increase in global solar radiation for all analyzed mass airflows from the entrance duct to the heated room. When the air temperature at the inlet of the entrance duct is lower, the efficiency is higher, and vice versa.

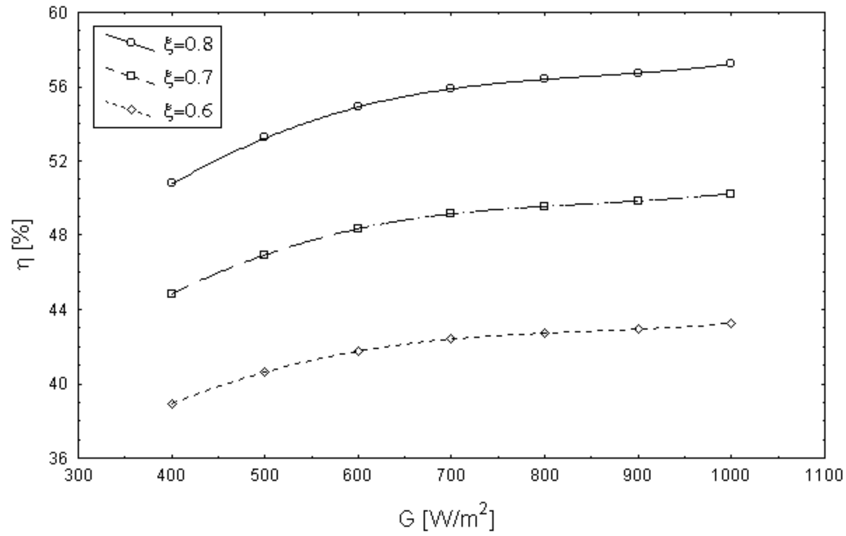


Figure 6. Variation of the thermal efficiency η with the solar global radiation G
w_o=1 m/s, $t_{ul,pk}$=26°C

CONCLUSION

The data from this investigation yield some insights into the efficiency of the air heating by an active solar wall with central channel, by varying the operating and environmental conditions. The analyzed model of active solar wall is used to heat the room while simultaneously accumulating energy during the days when the wall is exposed to the sun's radiation. The results of the optimization of the model of active solar wall were obtained in the case when the air temperature was maintained in the heated room at 20°C. The results show that increase of the inlet air velocity at the entrance duct causes an increase in the efficiency: for air velocities up to 4 m/s the efficiency increases significantly, after which efficiency is approximately constant. Efficiency increase when the inlet air temperature at the entrance duct decrease: for analyzed parameters when this temperature decreases from 28 °C to 24 °C the efficiency increases up to 18%. Increase of global solar radiation causes an increase in the efficiency and heat that accumulates in the inner layers of the wall. The results show that the efficiency increases significantly with increasing of solar radiation from 100 to 600 W/m^2.
This analysis enables users to evaluate the efficiency of the solar wall air heating system for a number of options, and to make comparison and predictions of thermal behaviour of the presented solar wall under various conditions.

ACKNOWLEDGEMENT

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REFERENCES

[1] Dimassi, N., Dehmani, L., Thermal Efficiency of a Solar Wall in Tunisia, ISRN Renewable Energy, Article ID 465249, 8 pages, 2012.
[2] Jie, J., Hua, Y., Gang, P., Jianping, L., Study of PV-Trombe wall installed in a fenestrated room with heat storage, Applied Thermal Engineering, No. 27, pp. 1507-1515, 2007.
[3] Briga-Sa, A., Boaventura-Cunha, J.,Lanzinha, J.C., Paiva, A., Experimental and analytical approach on the Trombe wall thermal performance parameters characterization, Energy and Buildings, Volume 150, pp. 262-280, September 2017.

[4] Lambic, M. Solar walls – The Passive solar heating, 2nd edition, University of Novi Sad, Technical faculty "M. Pupin" Zrenjanin, Serbia, 2000.

[5] Dragicevic, S., Lambic, M., Radosavljevic, J., Raos, M., Estimation of The Effect of Environmental Conditions on The Efficiency of Active Solar Wall Air Heating System, Journal of Energy Engineering, Vol. 141, No. 3, doi: 10.1061/(ASCE)EY.1943-7897.0000156, 2015.

IMPLEMENTATION OF ENERGY RENOVATION OF BUILDINGS IN THE FIVE COUNTIES OF EASTERN CROATIA

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Abstract: This paper analyzes the final results of residential and public buildings energy renovation on the area of the Osijek-Baranja County as well as the beginning of energy renovation of residential and public buildings in the five counties of Eastern Croatia based on of signed contracts for energy renovation. The structure of purpose of public buildings by cities and settlements is presented an overview of the contracted projects with the number of funds for energy renovation of multi-residential buildings is given. The conclusion emphasizes the importance of energy renovation of buildings in terms of reducing energy consumption and reducing energy imports and emphasizes that energy distributors in the five counties of Eastern Croatia need to coordinate their business procurement plans for energy delivery.
Key words: building energy consumption, energy renovation of buildings, public buildings, region of Slavonia, residential buildings

INTRODUCTION

Buildings consume more than 42.3% of total energy consumption, and in the last 30 years (due to rising standards) this share has been increasing. Most buildings in Croatia were built by the end of the 1980's and have little or no thermal insulation; such buildings consume 5 times more energy than buildings rated with energy class B, [1] [2].
The European Parliament and the Council adopted Directive 2012/27 / EU on energy efficiency [3]. Chapter 2 (Energy Efficiency) of the section 'Renovation of buildings' (Article 4) states: 'Member States shall establish a long-term strategy to encourage investment in the reconstruction of the national housing and commercial buildings, public and private (The first version of the strategy shall be published by 30 April 2014 and subsequently updated every three years and forwarded to the Commission as part of national energy efficiency action plans). In Art.5. "Public authority buildings as a model" points out "EU Member States are obliged to rebuild 3% of the total floor area of heated and / or cooled buildings owned and used by the central government under Directive 2012/27 / EU as of 1 January 2014. "The goal is to encourage the renovation of energy-efficient publicly owned buildings to reduce the cost of maintaining them and at the same time to give an example to citizens that energy renovation results not only in energy and financial savings but also in better quality of space use. [3].
Pursuant to the said directive, the Government of the Republic of Croatia adopted: "Public Sector Buildings Energy Recovery Program 2014-2015" [4], Multifamily Buildings Energy Renovation Program 2014-2020 [5] and Public Sector Buildings Energy Recovery Program for the period 2016-2020 [6] and the Environmental and Energy Efficiency Fund and the Ministry of Construction and Physical Planning have been designated as implementing bodies.
According to data from the National Energy Management Information System (ISGE), in 2010, the Republic of Croatia recorded 13.8 million m2 of usable floor space of public sector buildings; and 43.9% of the surface is in heating mode. The implementation of energy efficiency measures, ie energy renovation, plans to reduce energy consumption in public sector buildings by 30 to 60%, ie to 150 kWh/m^2 per year and reduce CO2 emissions by about 20,500 tons per year [7]. In 2017, the call 'Energy renovation of buildings and use of renewable energy sources in public sector buildings' was opened, which provided HRK 380 million for the energy renovation of public sector buildings. The minimum grant awarded to finance eligible project costs was 10,806 € and a maximum of 5.4 mil. €. The grants were awarded through an open grant procedure in a permanent call modality.

ENERGY RENOVATION OF BUILDINGS IN OSIJEK-BARANJA COUNTY

Public buildings

Public buildings include public buildings - performing activities in the field of social activities (education, education, science, culture, sports, health and social care), work of state bodies and organizations, bodies and organizations of local and regional self-government, legal entities with public authority, banks, savings banks and other financial organizations, international institutions, chambers of commerce and industry and other associations, religious communities, passengers in public transport and users of postal and electronic communications services.

- Within the Call 4c1.2 - Pilot project "Energy renovation of buildings and use of renewable energy sources in public institutions engaged in education" - one project "Energy renovation of Primary School building" was completed in the territory of Osijek-Baranja County (OBZ). Vladimir Nazor ", Đakovo [9].

- Under Call 4c1.3. - “Energy renovation of buildings and use of renewable energy sources in public institutions engaged in education” [10] - 24 projects were implemented in the area of OBŽ; thus, the buildings of three kindergartens (Belišće, Đakovo, Našice), 11 primary school buildings (2x Čepin, Dalj, Feričanci, Koška, Ladimirevci, 2x Osijek, Semeljci, Valpovo and Vuka) and six regional school buildings (Črnkovci, Kapelna, Kotlina, Kozarac, Novi Bezdan and Petlovac) and four high school buildings (Beli Manastir, Đakovo, Našice and Osijek). The annual heat demand for heating per unit area of the useful floor building area- QH,nd [kWh/(m^{2}a)] - before construction works was 7,150 MWh per year in these buildings, and the projected future consumption will be 2,067 MWh per year - which makes projected savings of 71%.

- The annual primary energy consuption per useful floor area unit of the building Eprim [kWh/(m^2/a)] before reconstruction works was 10,848 MWh, and the projected future consumption will be 4,237 MWh per year (Annual primary energy per unit area of the useful floor space of an Eprim building [kWh/(m^{2}a)] includes all energy before transformation used for heating, cooling, ventilation and domestic hot water preparation.) Fig. 1.

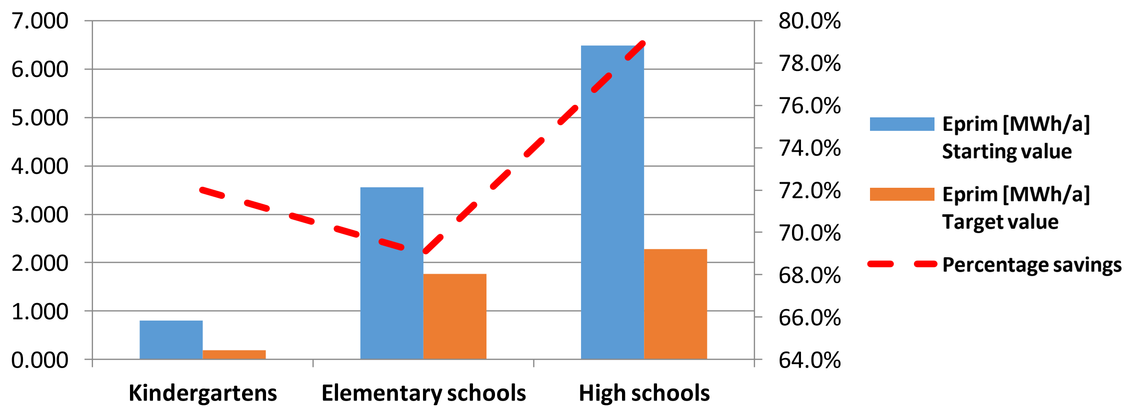

Figure 1. Required energy for heating per unit area of usable building area in energy renovated public buildings in Osijek-Baranja County [11]

- Under Call 4c1.4. (Energy Renewal and Use of Renewable Energy Sources in Public Sector Buildings) There are 11 projects in the area of OBŽ in which works have been started (in 8 settlements) or construction works have been completed (in 3 settlements). It is about energy renewal and use of renewable energy sources in buildings of voluntary fire companies (5), buildings of sports facilities (3), community center (1), kindergarten (1) and administrative building of the local authority units (JLS) (1). The annual heat demand for heating per unit area of the useful floor area of the building - QH, nd [kWh/(m^2/a)] - before construction works amounted to 1,147 MWh per year in these facilities, and the projected future consumption will be 341 MWh per year - which makes projected savings of 70.3%

ENERGY RENEWAL CONTRACTS OF BUILDINGS IN THE AREA OF EASTERN CROATIA

Energy renovation of apartment buildings

At the invitation of the Ministry of Construction and Physical Planning for the energy renovation of multi-residential buildings from the Slavonia region (five counties of Eastern Croatia; Fig. 2), over 100 projects (buildings) were submitted, of which 112 were accepted (from 20 settlements) for a total amount of 11.6 mil. € (Out of 648 submitted projects, 596 projects were accepted from all counties in the Republic of Croatia.) Fig. 3. The average value of the projects is 103,800 €.

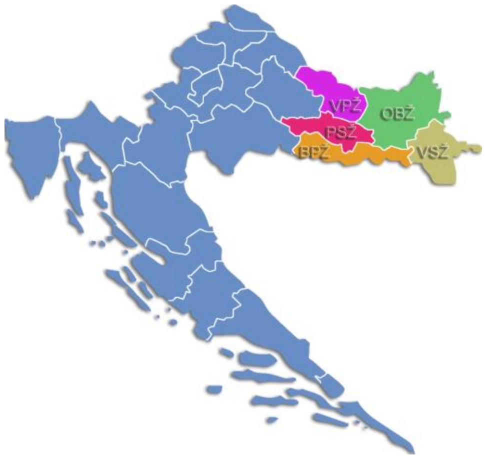

Figure 2. The five counties of Eastern Croatia

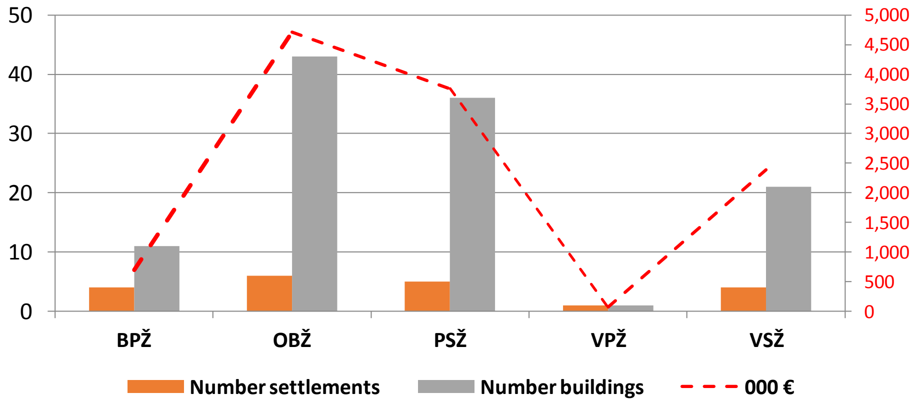

Figure 3. Number of settlements, number of buildings and amount of funds for energy renovation of multifamily buildings in the five counties of Eastern Croatia [9]; Legend: BPŽ = Slavonski Brod county; OBŽ = Osječko-baranjska county; PSŽ = Požega county; VPŽ = Virovica county; VSŽ = Vukovar county;

In the case of energy renovation of multifamily buildings, construction works are undertaken to improve the thermal protection of the building envelope and to replace the exterior joinery; the projected savings for these projects are between 50% and 70% of the heating/cooling energy per building. Table 1 shows the number of settlements and the number of apartments buildings in energy renovation by county.

Table 1. Number of settlements and number of multi-dwelling buildings under energy renovation in the five counties of Eastern Croatia, suource [9]

	BPŽ	OBŽ	PSŽ	VPŽ	VSŽ
Nº buildings	4	6	5	1	4
Nº settlements	11	44	35	1	21

Energy renovation of public buildings

At the invitation of the Ministry of Construction and Physical Planning for the Energy Renovation of Public Buildings from the Five Counties of Eastern Croatia, over two hundred projects were submitted, of which 195 were accepted (out of 92 settlements) for a total amount of 49.6 mil. €. The average value of projects is 253,934 €, Fig. 4.

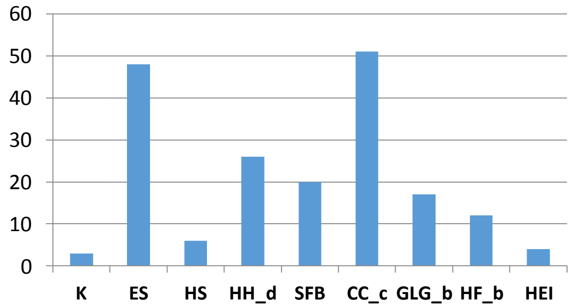

Figure 5. Number of public buildings by purpose to energy renovation on area of five counties of Eastern Croatia [9] [10];

Legend:
K= kindergarten;
E_s = elementary School;
H_s = high school;
HH_d = hospitals, health centers, dispensaries;
SFB = sports facilities buildings;
CC_C = community centers, culture centers, reading rooms;
GLG_b = government and local government buildings;
HF_b = homes of fire companies;
HEI = homes for elderly and infirm

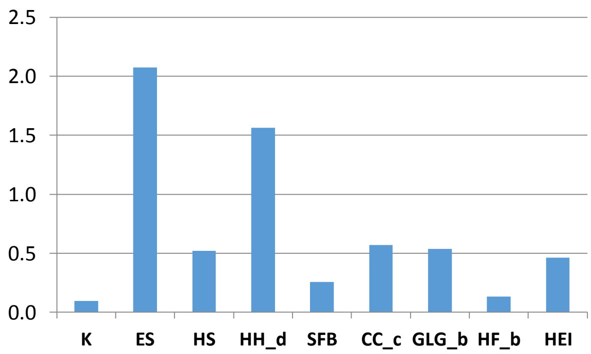

Figure 6. The value of the investment in energy renovation of public buildings by purpose in the five counties of Eastern Croatia (mil. €) [9] [10];

National currency average exchange rate for 1 € [13]
Croatia = 7.4035 kuna;
Bosnia and Herzegovina = 1.95583 convertible mark;
Bulgaria = 1.9558 lev;
Hungaria = 330.26 forint;
Macedonia = 61.4893 denar;
Romania = 4.7271 leu;
Serbia = 117.8172 dinar;
Turkey = 6.4594 lira

Base on the invitation from the Ministry of Construction and Physical Planning for the energy renovation the total contracted funding for energy renovation projects for apartments buildings and public buildings in the five counties of Eastern Croatia is shown in Fig. 7.

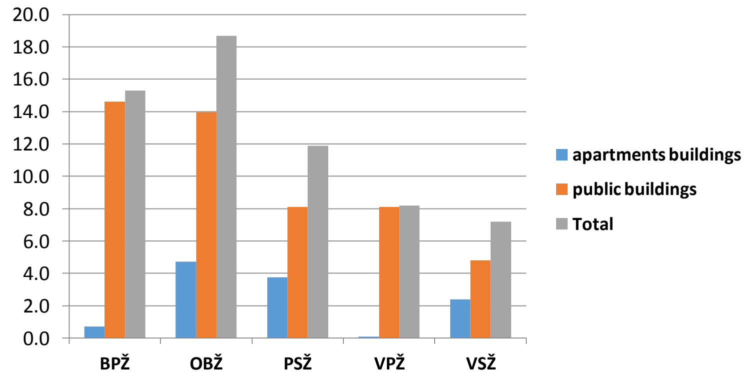

Figure 7. Total contracted funds for apartments buildings and public buildings to energy renovation projects in the five counties of Eastern Croatia (mil.€) [9] [10]

CONCLUSION

Following the adoption of national programs for the energy renovation of public and apartments buildings in the Republic of Croatia, grants from EU funds were secured in the preparatory phase for 3 years in the period from 2017 to 2019. Four public calls for energy renovation of public and apartments buildings were made. Within the framework of these public calls, local self-government units, counties, state bodies and public institutions (for public buildings) as building managers (for multi-residential buildings) from the five counties of Eastern Croatia applied over three hundred projects, of which 195 were accepted for public buildings in totaling € 49.6 million and 112 for apartment buildings totaling € 11.6 million. Therefore, at this stage of energy renovation of buildings in the five counties of Eastern Croatia, an energy renovation of 307 public-purpose and apartments buildings with a total value of € 61.2 million was agreed.
Most of these projects were implemented at the end of July and the rest will be completed by the end of 2019. According to projections from the contracted projects, the consumption of energy for heating/cooling will be reduced in the range from 52 to 81% for individual buildings.
The implementation of these projects is significant for several reasons:

a) Energy consumption per unit of housing and business is reduced - which will have a positive impact on reducing the costs of family budgets and budgets of local and regional self-government units and state bodies.
b) Imports of energy (natural gas, petroleum products, and electricity) to Croatia are decreasing - which contributes to improving the country's trade balance.
c) CO_2 emissions are reduced - which contributes to the fulfillment of Croatia's obligations under the Kyoto Protocol, that is, to preserve the planet's climate regime.
d) Local labor is employed in the construction sector - contributing to a reduction in unemployment and an increase in GDP in Croatia.

With regard to all of the above, we warn fuel distributors and central heating systems in the five counties of Eastern Croatia of the need for a more detailed reference to energy renovation projects for buildings to harmonize their business procurement plans for energy delivery on time [12].

REFERENCES

[1] Ivanović, Milan; Blažević, Damir; Glavaš, Hrvoje. The Structure of Electricity Consumption and its Utilisation Efficiency in European Transition Countries //IJECES – Interna-tional Journal of Electrical and Computer Engineering Systems; (2011.) Vol.1, No.2; pp 18 -32 (ISSN 1847-6996)

[2] Glavaš, Hrvoje; Ivanović, Milan; Blažević, Damir. Program of Efficient Use of Energy in Final Energy Consumption on the Area of Eastern Croatia, 1st International scientific conference „Economy of Easter Croatia“, Osijek, May 20, 2012; Proceedings, pp 54 – 64 (ISBN 978-953-253-106-0)

[3] DIRECTIVE 2012/27/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 25 October 2012 on energy efficiency. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32012L0027&from=EN
[4] Government of the Republic of Croatia. Energy renovation program of buildings of the public sector 2014 - 2015 .; Zagreb, 31 October 2013
[5] Government of Republic Croatia, Apartments building renovation program for 2014-2020 with a detailed plan for 2014-2016. Official Gazette of the Republic of Croatia 78/2014
[6] Government of Republic Croatia. Public Buildings Energy Renovation Program 2016-2020. Official Gazette of the Republic of Croatia 22/17
[7] The Environmental Protection and Energy Efficiency Fund. Energy renovation of public buildings http://www.fzoeu.hr/hr/energetska_ucinkovitost/enu_u_zgradarstvu/energetska_obnova_javnih_zgrada/
[8] The Environmental Protection and Energy Efficiency Fund. Energy efficiency of buildings, http://www.fzoeu.hr/hr/energetska_ucinkovitost/enu_u_zgradarstvu/energetska_obnova_visestambenih_zgrada/
[9] Ministry of Construction and Physical Planning. Review of signed contracts - Invitation "Invitation 'Energy renovation of multi-residential buildings'"; Reference number: KK.04.2.2.01 https://mgipu.gov.hr/UserDocsImages/EUFondovi/...2/KK.04.2.2.01.ugovori.pdf
[10] Ministry of Construction and Physical Planning. Review of signed contracts - Invitation "Energy renewal and use of renewable energy sources in public sector buildings", Reference number: KK.04.2.1.04 https://mgipu.gov.hr/UserDocsImages/EUFondovi/...2/KK.04.2.2.01.ugovori.pdf
[11] Dvoržak, Domagoj; Ivanović, Milan; Glavaš Hrvoje. Results of energy renovation of buildings in Osijek-Baranja County. Proceedings of the PLIN 2019 - 17th Meeting on Natural Gas, Heat and Water Conferece 10th International Natural Gas, Heat and Water Conference, Osijek, 25 to 28 September 2019
[12] Ivanovic, M., Tonkovic, Z., Use of natural gas in Slavonia and Baranja from 1972 to 2014, Proceedings of the PLIN 2015 - 13 conferences on natural gas, heat and water / Pero Raos, editor (s). (ISSN 1849-0638). Faculty of Mechanical Engineering in Slavonski Brod, Osijek, October 26-28, 2015 pp. 165–182
[13] Currency Exchange Rate https://ec.europa.eu/budget/graphs/inforeuro.html

THERMOGRAVIMETRIC ANALYSIS OF OAK TREE – THE INFLUENCE OF HEATING RATE ON THE PYROLYSIS

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Abstract: Thermogravimetry is a valuable tool in evaluating the pyrolysis of biomass samples on a small (mg) scale. Herein, we performed a thermogravimetric analysis of an oak tree in an inert (nitrogen) atmosphere at three different heating rates. The shape of the TGA curve indicated that there were three stages of mass loss during the thermal treatment of oak tree ((1) dehydration and light volatiles evaporation, (2) active and (3) passive pyrolysis). The temperature ranges of stages depended on the heating rates. The start and end temperatures of each stage increased as the heating rate increased, but the heating rate did not affected the total weight loss at any stage. This may be due to the heat transfer limitations, because with an increase in the heating rate longer time may be required for the purging gas to reach the equilibrium. Moreover, the amount of pyrolytic residue decreased as the heating rate decreased.
Keywords: thermogravimetric analysis, biomass, oak tree, pyrolysis, heating rate

INTRODUCTION

Global energy consumption rises every year. In 2018 it increased by 2.3% and that was the greatest rise in a decade [1]. According to International Energy Agency – IEA [2] this rise was driven by a robust global economy and stronger heating and cooling needs in some regions. Unfortunately, energy rise is directly linked to environmental issues. Despite the green movement actions and aggressive media campaigns fossil fuels still dominate in the global energy mix. Fossil fuel contribution in global final energy consumption is still enormous and in 2017 it was nearly 80% [3]. It is remarkable that fossil fuel subsidies still exist and that they even increased by 11% from 2017[3]. This influenced global energy-related carbon dioxide (CO_2) emissions which rose by an estimated 1.7% in 2018 [3]. Unfortunately, it seems that we are far away from achieving targets set down in Paris Agreement or of Sustainable Development Goal 7 and urgent actions are needed. However, the encouraging fact is that the global market for renewable energy technologies is stable and experience a steady rise. This particularly pertains to solar and wind energy. These technologies are mature and from year to year, due to strong competition, prices for installed kilowatt are decreasing. This particularly pertains to power generation. In 2018 almost 100 GW of solar photovoltaics (PV) and 51 GW of wind power installations were added globally [3]. One of the main drawbacks of these two technologies is their inherent intermittence. Technologies based on biomass utilization for energy production are a perfect match for solving the intermitance issues. In 2017, modern bioenergy provided an estimated 5% of global final energy consumption, nearly half of the entire contribution of renewable energy [3].
Different chemical, biological, thermal and mechanical processes can be used for the conversion of biomass in a final, usable form. Pyrolysis is one of the mature thermochemical decomposition technologies which converts biomass into a range of useful products, either in the total absence of oxidizing agents or with a limited supply that does not permit gasification to an appreciable extent [4]. During the biomass pyrolysis process complex, bio-polymeric pseudo components degrade into simpler compounds that may be in the solid, liquid or gaseous state. Understanding the pyrolysis process is indispensable for process design, feasibility assessment and scaling-up in industrial applications.
Thermogavimetry is a valuable tool for obtaining appropriate biomass thermal-degradational data. Although the TGA analysis is usually performed on a small-scale (the mass of the samples is usually up to 20 mg) the results are crucial for understanding the fundamentals of the pyrolysis of the analyzed material. During the experiments, samples are exposed to the controlled temperature program and controlled atmosphere while the mass loss of the sample is continuously measured and recorded. From obtained TGA signal important thermal events can be isolated directly or after analysis of the

derivative signal. In this work, a biomass (oak tree) samples, were exposed to predefined temperature programs. Four different heating rates were used in order to analyze the effect of heating rate on the degradation process.

MATERIAL AND METHODS

Sample preparation

The oak tree samples were prepared according to ICTAC recommendations [5] and EN ISO 14780:2017 Standard [6]. After drying at 105 °C to constant mass the samples were pulverized using mortar grinder Fritsch Pulverisette 2 (Fritsch GmbH, Weimar, Germany) and then sieved using vibratory sieve shaker Fritsch Analysette 3 Spartan (Fritsch GmbH, Weimar, Germany). Finally, particle sizes of less than 100 μm were used for TGA experiments.

TGA experiments

Thermogravimetric experiments were conducted using Perkin-Elmer Thermogravimetric Analyzer TGA 4000 (Norwalk, CT, USA). Prior to the analysis, the calibration of the instrument (temperature, furnace, and weight calibration) was performed according to the manufacturer's recommendation. The temperature calibration was done according to the Curie points of alumel, perkalloy, and iron. The experiments were conducted with approximately 10 mg of samples placed in the ceramic crucible. The same crucible was used for all experiments. After each experiment crucible was heated and hold at 900 °C for 1 h in order to eliminate impurities. The temperature regime was as follows: the samples were held isothermally at 30 °C for 5 min, heated from 30 to 900 °C at four different heating rates (1, 2, 5 and 10 °C/min) and then again held isothermally at 900 °C. Nitrogen, at a flow rate of 20 ml/min, was used as a purge gas. The collected data were processed using Pyris™ Software (PerkinElmer, Norwalk, CT, USA).

RESULTS AND DISCUSSION

The thermal behavior of an oak tree, a high-quality biomass sample, was evaluated in this study. The samples of an oak tree were subjected to thermogravimetric analysis, in an inert (nitrogen) atmosphere, at four different heating rates. The characteristic TGA curve and a corresponding derivative plot (DTG) obtained at a heating rate of 5 °C/min are shown in Fig. 1.

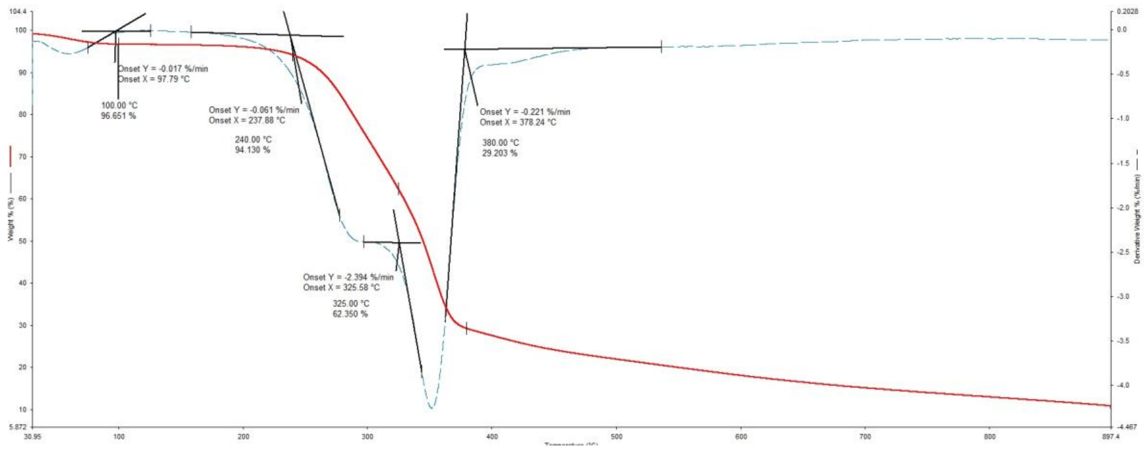


Figure 1. TGA (red line) -DTG (blue line) output for the decomposition of oak tree under inert (nitrogen) conditions obtained at a heating rate of 5 °C/min.

The shape of the TGA curve indicated that there were three stages of mass loss during the thermal treatment of the oak tree, as it is usually the case with woody biomass samples. This was even more evident from the DTG curve which was used for the determination of the temperature ranges of the steps. As it is depicted in Fig. 1, the start and the end temperature of each step were determined by the intersection of tangents from the linear part and the descending parts of the peak of the DTG curve [7]. The temperature ranges of the steps and the weight losses during these steps are summarized in Table 1.

Table 1. Temperature ranges and weight losses during the thermolysis of the oak tree.

	1 °C/min		**2 °C/min**		**5 °C/min**		**10 °C/min**	
	t (°C)	**Wt (%)**	**t (°C)**	**Wt (%)**	**t (°C)**	**Wt (%)**	**t (°C)**	**Wt (%)**
Stage I (Moisture and light volatiles evaporation)	30	100	30	100	30	100	30	100
	75	97.91	80	96.82	100	96.65	120	95.84
Stage II (Active pyrolysis)	220	95.13	230	93.94	240	94.13	245	93.94
	305	60.21	315	60.05	325	62.35	330	66.08
	345	31.90	360	30.38	380	29.20	405	28.06
Stage III (Passive pyrolysis)	345	31.90	360	30.38	380	29.20	405	28.06
	900	0.05	900	5.08	900	10.90	900	14.65

The first step of mass loss starts at 30 and ends at 75 – 120 °C depending on the heating rate. This step corresponds to moisture and light-volatiles evaporation and low weight loss during it (less than 5%) indicates the low moisture and light volatiles content in the sample. The second stage occurs in the temperature range from 220 – 245 to 345 – 405 °C, corresponding to the highest weight loss during the analysis (ca. 65 %). Immediately after the second stage, the third one begins with the weight loss of ca. 30%. The weight loss between the first and the second stage was insignificant (ca. 0.5%).
The temperature ranges of stages depended on the heating rates (Fig. 2). The start and end temperatures of each stage increase as the heating rate increases [8]. This may be due to the heat transfer limitations because with an increase in heating rate longer time may be required for the purge gas to reach equilibrium with the temperature of the furnace or the sample [7]. However, the heating rate did not affect the total weight loss at any stage.

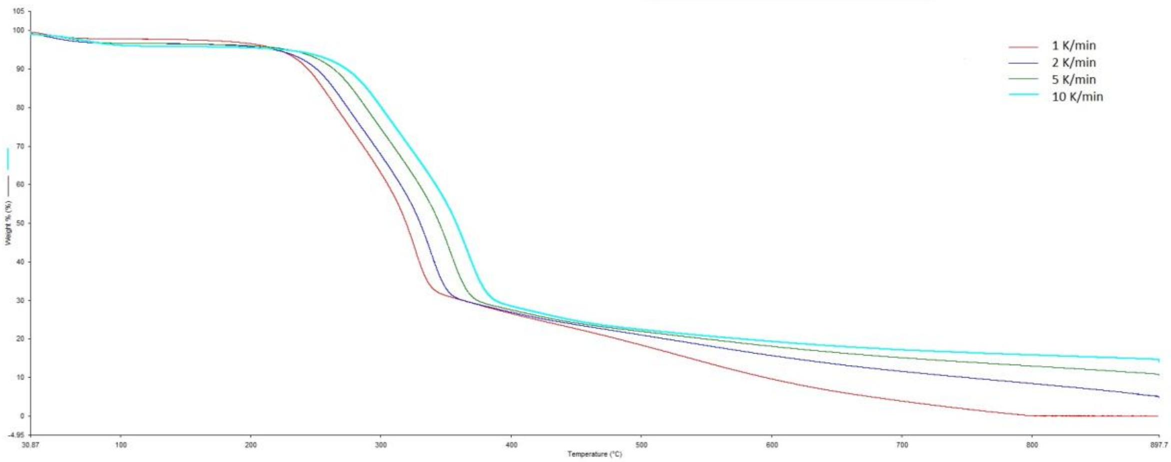
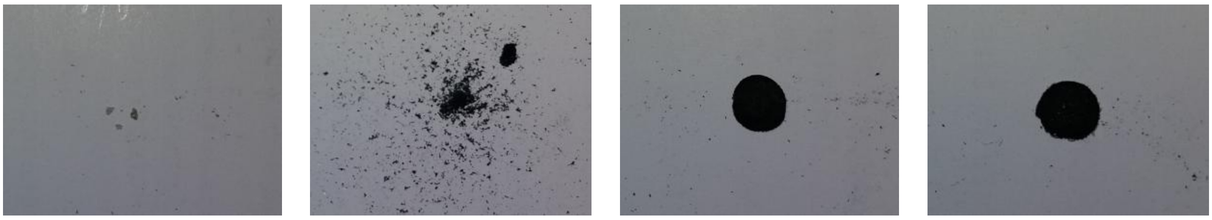


Figure 2. TGA output for the decomposition of oak tree under inert (nitrogen) conditions obtained at the heating rates of 1, 2, 5 and 10 °C/min.

Oak tree, like other woods, is classified as lignocellulosic biomass that is composed of cellulose (ca. 55%), hemicellulose (ca. 25%) and lignin (ca. 20%) [9]. Cellulose and hemicellulose are high molecular weight polysaccharide polymers that form chains and fibers that constitute the cell wall with lignin acting as an adhesive binding them all together. Yang and co-workers [10] conducted a thermogravimetric analysis of these three components and concluded that decomposition of hemicellulose starts first and it is then overlapped with the loss of cellulose, while the loss of lignin is slow and occurs over a wide range of temperatures. Generally, cellulose and lignin are the main combustible component in wood composition [9].

Our TGA results are generally in accordance with [10]. During the second and the third stage the decomposition of lingo-cellulose components occurs. The highest mass loss of ca. 65 % occurring during the second stage corresponds to the decomposition of cellulose and hemicellulose. This zone is designated as the zone of active pyrolysis. Immediately after the second stage the third one, with the weight loss of ca. 30%, begins. Slow and continuous loss of mass in the third stage corresponds to the continuation of lignin and/or the decomposition of complex high-molecular-weight components. This is the zone of passive pyrolysis.

The pyrolytic residue, generally comprised of mineral constituents and chemically bound carbon was in the range from 0.05 to 14.65% (Table 1). Such a low value was in accordance with the fact that the biomass belongs to a group of high volatile fuels. The amount of residue depends on the heating rate (Fig. 3). The decrease in the amount of residue with the decrease in the heating rate indicates that at low rates there was enough time for the degradation of organic compounds (Fig. 3).



1 °C/min 2 °C/min 5 °C/min 10 °C/min

Figure 3. Pyrolytic residue after the pyrolysis of the oak tree at different heating rates

CONCLUSION

The results of TGA indicated that there were three stages of mass loss during the thermal treatment of oak tree ((1) dehydration and light volatiles evaporation, (2) active and (3) passive pyrolysis). The temperature ranges of stages depended on the heating rates. The start and end temperatures of each stage increased with the heating rate, but the heating rate did not affect the total weight loss at any stage. Moreover, the amount of pyrolytic residue decreased with the decrease in heating rate.

Generally, TGA in an inert atmosphere is a valuable tool and provides interesting insights into degradation mechanisms. Although the results can not be directly applied to practice they can be used as a guidance for the proper understanding of the pyrolysis mechanism for particular biomass species, as well as for preparing a proper design of process equipment. The results obtained herein indicate that the heating rate has a profound effect on the degradation process. The content of biomass pseudo-components influences the reaction conversion rate. Further work will be directed in uncovering these mechanisms.

REFERENCES

[1] OECD/IEA, “Global Energy and CO_2 Status Report”, https://www.iea.org/geco/.
[2] IEA, https://www.iea.org/newsroom/news/2019/march/global-energy-demand-rose-by-23-in-2018-its-fastest-pace-in-the-last-decade.html
[3] Murdock, H. E., Gibb, D., André, T., Appavou, F., Brown, A., Epp, B., Sawin, J. L. (2019). Renewables 2019 Global Status Report
[4] Basu, Prabir. Biomass gasification and pyrolysis: practical design and theory. Academic press, 2010
[5] Vyazovkin, S., Chrissafis, K., Di Lorenzo, M. L., Koga, N., Pijolat, M., Roduit, B., ... & Suñol, J. J. (2014). ICTAC Kinetics Committee recommendations for collecting experimental thermal analysis data for kinetic computations. *Thermochimica Acta, 590*, 1-23
[6] ISO 14780:2017, Solid biofuels — Sample preparation

[7] Kumar, A., Wang, L., Dzenis, Y.A., Jones, D.D., Hanna, M.A., Thermogravimetric characterization of corn stover as gasification and pyrolysis feedstock, Biomass and Bioenergy, Vol.32, pp. 460 – 467, 2008.

[8] Protić, M., Miltojević, A., Raos, M., Đorđević, A., Golubović, T., Vukadinović, A., Thermogravimetric analysis of biomass and sub-bituminous coal, Proceedings of VIII International Conference Industrial Engineering and Environmental Protection 2018 (IIZS 2018), pp. 368 – 373, October 11-12th, 2018, Zrenjanin, Serbia.

[9] Abdoli, M.A, Golzary, A, Hosseini, A. i Sadeghi, P., Wood pellet as a renewable source of energy – From production to consumption, Springer International Publishig, Cham, Switzerland, (2018).

[10] Yang, H., Yan, R., Chen, H., Lee, D. H., Zheng, C., Characteristics of hemicellulose, cellulose and lignin pyrolysis, Fuel, Vol.86, pp. 1781 – 1788, 2007.

ATTITUDES TOWARDS ENERGY CONSUMPTION FROM THE PERSPECTIVE OF EMPLOYEES IN REPUBLIC OF SRPSKA

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Abstract: Energy consumption represents a significant part of the total costs for companies, with the dominant usage of electrical energy. The study is based on the attitudes of the employees of companies towards energy consumption and it involves raising awareness regarding the usage of alternative energy sources such as energy from agricultural activities (biogas, biodiesel ...). The analysis has been performed considering the EU standards, since the Republic of Srpska is an official candidate to enter the European Union. The survey examined the attitudes toward other sources of energy, as well as energy from renewable sources of energy as a supplement and replacement for electrical energy. The conducted study involved 150 respondents (employees) from different companies and their opinions on the importance of various activities in production for energy consumption in the industry. This paper demonstrates the relationship between the level of awareness on different sources of energy and a company (employees) with a higher energy cost.
Key words:

INTRODUCTION

The survey "Renewable Energy Sources" was conducted on a sample of 150 respondents. The survey consisted of questions about personal data and opinion on efficient consumption and renewable energy sources (1. Competitiveness and consumer energy, 2. Energy sources). Each of the questions asked consisted of a response with a scale of 5 offered responses: A - insignificant, B - less significant, C - medium, D - very significant, E - extremely important.
We will consider the criterion question:
Electricity consumption has a significant share in the total cost of the company.

The answer to this criterion question provides insight into respondent attitude on the matter of electricity consumption within his company. Depending on the answer to the given criterion question, the entire sample is split into 5 groups:
A - Insignificant (0 respondents), B - less significant (4 subjects), C - intermediate (36 subjects), D - very significant (69 respondents) and E - extremely significant (41 subjects).

Based on the distribution of the answers to the criterion question, we excluded the group A from the future consideration, since there were no respondents. Also, the respondent group B, although provides a small number of respondents, it is still not relevant result for being taken into consideration. So, this study focuses on the difference in attitudes between groups: C - medium significant (36 subjects), D - very significant (69 respondents) and E - extremely significant (41 respondents).

The answer to this criterion question shows us how the respondent looks at the consumption of electricity within the work he deals with. Since this is the criterion question, it means that the entire sample is divided into 5 groups depending on their answers to it:
A - Insignificant (0 respondents), B - less significant (4 subjects), C - intermediate (36 subjects), D - very significant (69 respondents) and E - extremely significant (41 subjects).
Based on the distribution of the answers to the criterion question, we see that the group A is minimal, we will not use it in the future because there are no respondents, while the results of group B are less significantly taken with the reserve because the group has a small number of respondents, so we can not consider the result as relevant. So our focus will be on the difference in attitudes between groups: C - medium significant (36 subjects), D - very significant (69 respondents) and E - extremely significant (41 respondents).

METHODOLOGY

Our goal is to determine whether there are differences and on which questions differences exist between the 4 groups mentioned. That is, among the respondents who consider that electricity consumption has a significant share in the total costs of the company. We will test hypotheses:

H1 – Groups defined by criteria question (CQ) have different opinion (answer) on the question *"The competitiveness among electricity suppliers in the market is expressed through possibility to choose between different suppliers."*

H2 - Groups defined by criteria question have different opinion (answer) on the question *"I think over a need to save energy."*

H3 - Groups defined by criteria question have different opinion (answer) on the question *"I think over economic development in accordance with environmental principles, as well as replacing energy sources that are environmentally harmful."*

H4 - Groups defined by criteria question have different opinion (answer) on the question *"Economy notably affects an increase in the number of greenhouse gases in the atmosphere. "*.

H5 - Groups defined by criteria question have different opinion (answer) on the question *"The use of alternative energy sources reduces environmental pollution. "*.

In this study, MANOVA and ANOVA analysis will be performed. The analysis was done with R-project. First, the MANOVA analysis was done where we tested whether there was a difference on all groups. If there is the difference as a result of MANOVA, later ANOVA analysis was conducted to test between which groups differences exists.

RESULTS

First test was done on the first question in relation to the criterion question:

1. Groups defined by criteria question (CQ) have different opinion (answer) on the question *"The competitiveness among electricity suppliers in the market is expressed through possibility to choose between different suppliers."*
0. Electricity consumption has a significant share in the total cost of the company. (criterion question, CQ)

MANOVA results are shown in the table bellow.

Table 1. MANOVA

	Df	**Sum Sq**	**Mean Sq**	**F value**	**Pr (>F)**
data1$pt3aa	3	13.95	4.65	3.651	0.0141
Residuals	146	185.94	1.274		

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

The test shows that is statistically significant difference, between some groups, so hypothesis H1 is proven

Next analysis, ANOVA, was performed on following questions:

1. The competitiveness among electricity suppliers in the market is expressed through possibility to choose between different suppliers
0. Electricity consumption has a significant share in the total cost of the company. (criterion question, CQ)

Table 2. ANOVA

Groups defined by criteria question	Diff	lwr	Upr	p adj
(C - intermediate)- (B - less significant)	-1.92683	-3.46316	-0.3905	0.00751
(D - very significant) - (B - less significant)	-0.31572	-0.98561	0.354169	0.612116
(E - extremely significant) - (B - less significant)	-0.23118	-0.80951	0.347158	0.726931
(D - very significant) - (C - medium significant)	1.611111	0.065329	3.156893	0.037525
(E - extremely significant) - (C - intermediate)	1.695652	0.187287	3.204017	0.020822
(E - extremely significant) - (D - very significant)	0.084541	-0.51846	0.687543	0.983397

There was a significant difference between the groups (D - very significant) - (C - medium significant) with p = 0.00751,
D - very significant) - (C - medium significant) p= 0.037525
(E - extremely significant) - (C - intermediate) p= 0.020822

In other case there is no statistically significant difference.

Second test was done on the third question in relation to the criterion question

2. I think over a need to save energy

0 Electricity consumption has a significant share in the total cost of the company. (Criterion question, CQ)

Table 3. ANOVA

	Df	Sum Sq	Mean Sq	F value	Pr (>F)
data1$pt3aa	3	2.64	0.8797	0.743	0.528
Residuals	146	172.75	1.1832		

The test MANOVA shows that is no statistically significant difference (p = 0.528), that means that we rejects the hypothesis H5

Table 4. ANOVA

Groups defined by criteria question	Diff	lwr	upr	p adj
(B - less significant) - (E - extremely significant)	0.243902	-1.23693	1.724736	0.973588
(C - intermediate) - (E - extremely significant)	-0.14499	-0.79068	0.500704	0.936899
(D - very significant) - (E - extremely significant)	0.171439	-0.38601	0.728883	0.854654
(C - intermediate) - (B - less significant)	-0.38889	-1.87884	1.101057	0.905177
(D - very significant) - (B - less significant)	-0.07246	-1.52634	1.381417	0.99922
(D - very significant) - (C - intermediate)	0.316425	-0.2648	0.897645	0.492137

In all case there is no statistically significant difference.

Third test was done on the third question in relation to the criterion question

3. I think over economic development in accordance with environmental principles, as well as replacing energy sources that are environmentally harmful

0. Electricity consumption has a significant share in the total cost of the company. (criterion question, CQ)

Table 5. MANOVA

	Df	Sum Sq	Mean Sq	F value	Pr (>F)
data1$pt3aa	3	12.18	4.062	5.083	0.00224
Residuals	146	116.65	0.799		

The test shows that is statistically significant difference, between some groups, so hypothesis H3 is proven

Table 6. ANOVA

Groups defined by criteria question	Diff	lwr	upr	p adj
(B - less significant) - (E - extremely significant)	-1.79878	-3.01562	-0.58194	0.001033
(C - intermediate) - (E - extremely significant)	-0.29878	-0.82936	0.231798	0.462217
(D - very significant) - (E - extremely significant)	-0.2082	-0.66627	0.249865	0.639644
(C - intermediate) - (B - less significant)	1.5	0.275676	2.724324	0.009512
(D - very significant) - (B - less significant)	1.59058	0.395892	2.785268	0.003912
(D - very significant) - (C - intermediate)	0.09058	-0.38702	0.568182	0.96057

There was a significant difference between the groups (B - less significant) - (E - extremely significant) with p = 0.001033,
(C - intermediate) - (B - less significant) with p = 0.009512,
(D - very significant) - (C - intermediate) with p= 0.003912

In other case there is no statistically significant difference.
Fourth test was done on the third question in relation to the criterion question

4. I think over economic development in accordance with environmental principles, as well as replacing energy sources that are environmentally harmful

0. Electricity consumption has a significant share in the total cost of the company. (criterion question, CQ)

Table 7. MANOVA

	Df	Sum Sq	Mean Sq	F value	Pr (>F)
data1$pt3aa	3	9.77	3.257	4.838	0.00307
Residuals	146	98.29	0.673		

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

There is a statistically significant difference but on level 0.05. In the next table analyze ANOVA shows there is no statistically significant difference, with level 0.05, that means that we accept the hypothesis H4.
ANOVA will show is there some difference or not.

Table 8. ANOVA

Groups defined by criteria question	Diff	lwr	upr	p adj
(B - less significant) - (E - extremely significant)	-0.2378	-1.35478	0.87917	0.945523
(C - intermediate) - (E - extremely significant)	-0.71003	-1.19706	-0.22299	0.001252
(D - very significant) - (E - extremely significant)	-0.37186	-0.79234	0.048611	0.103103
(C - intermediate) - (B - less significant)	-0.47222	-1.59607	0.651626	0.694984
(D - very significant) - (B - less significant)	-0.13406	-1.2307	0.962587	0.988861
(D - very significant) - (C - intermediate)	0.338164	-0.10024	0.776572	0.191004

ANOVA shows there is statistically significant difference, with level 0.05 between the groups (C - intermediate) - (E - extremely significant) with p=0.001252.

Fifth test was done on the third question in relation to the criterion question

5 The use of alternative energy sources reduces environmental pollution

0 Electricity consumption has a significant share in the total cost of the company. (criterion question, CQ)

Table 9. MANOVA

	Df	**Sum Sq**	**Mean Sq**	**F value**	**Pr (>F)**
data1$pt3aa	3	7.93	2.6427	2.781	0.0432
Residuals	146	138.75	0.9503		

There is statistically significant difference, with level 0.05, so hypothesis H5 is proven

Table 10. ANOVA

Groups defined by criteria question	**Diff**	**lwr**	**upr**	**p adj**
(B - less significant) - (E - extremely significant)	-0.56707	-1.89416	0.760018	0.683656
(C - intermediate) - (E - extremely significant)	-0.62263	-1.20128	-0.04398	0.029595
(D - very significant) - (E - extremely significant)	-0.23012	-0.72969	0.269453	0.629649
(C - intermediate) - (B - less significant)	-0.05556	-1.39081	1.279703	0.999546
(D - very significant) - (B - less significant)	0.336957	-0.96598	1.639893	0.907478
(D - very significant) - (C - intermediate)	0.392512	-0.12837	0.913389	0.208675

ANOVA shows there is statistically significant difference, with level 0.05 between the groups (C - intermediate) - (E - extremely significant) with p=0.029595.

DISCUSSION

Based on the results, we can conclude that groups (C – intermediate significant) and (E - extremely significant) defined on question "Electricity consumption has a significant share in the total cost of the company" (criterion question, CQ) have different opinion on question *The competitiveness among electricity suppliers in the market is expressed through possibility to choose between different suppliers, Economy notably affects an increase in the number of greenhouse gases in the atmosphere* and *The use of alternative energy sources reduces environmental pollution*.

Employees awareness about the impact of economy on the increase in the number of greenhouse gases in the atmosphere, and the fact that the use of alternative energy sources reduces environmental pollution, affect the choice of electricity suppliers in the market.

Reason is given by the fact that they do not feel pressure with high costs of electric energy, and so their interests for the other source of energy are small.

Respondents from the companies where costs for electric energy are intermediate didn't show any interest in the other sources of energy besides electrical energy.

On the other hand, respondents from companies with high electric energy costs, have shown more interest for the renewable sources of energy.

CONCLUSION

1. For hypothesis H2 results indicated that there is no significant differences between criteria groups with analyses MANOVA and ANOVA.
2. For hypothesis H1 we get different results with MANOVA and ANOVA analysis.
3. For hypothesis H1, H3, H4 and H5, we get there is significant differences on level of significance 0.05.

This means that the group of respondents who think that electricity consumption has significant share in the total cost of the company (answer E on the CQ), have different opinion (answer) on question *The competitiveness among electricity suppliers in the market is expressed through possibility to choose between different suppliers,* there is difference between the groups
(C - intermediate) - (B - less significant), (D very significant) - (C - intermediate), (C - intermediate) - (E - extremely significant);
I think over economic development in accordance with environmental principles, as well as replacing energy sources that are environmentally harmful, there is difference between the groups
(B - less significant) - (E - extremely significant), (C - intermediate) - (B - less significant), (D - very significant) - (B - less significant);
Economy notably affects an increase in the number of greenhouse gases in the atmosphere, there is difference between the groups
(C - intermediate) - (E - extremely significant);
The use of alternative energy sources reduces environmental pollution, there is difference between the groups
(C - intermediate) - (E - extremely significant)

ACKNOWLEDGEMENTS

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REFERENCES

[1] Balat, M., An Overview of Biofuels and Policies in the European Union, Energy Sources, Part B: Economics, Planning, and Policy, No.2, pp.67 – 181, 2007.
[2] Best, G., Alternative energy crops for agricultural machinery biofuels – focus on biodiesel, Agricultural Engineering International: the CIGR E-journal, Vol. 8, 2006.
[3] Brkić, M., Skala, D., Mulić, R., Marić, M., Technology production of biodiesel - Biodiesel and ecological alternative to liquid fuel, Contemporary Agricultural Engineering, Vol.30, pp.73-105, 2005.
[4] Brkić, M., Skala, D., Mulić, R., Marić, M., Technology production of biodiesel - Biodiesel and ecological alternative to liquid fuel, Contemporary Agricultural Engineering, Vol.30, pp.73-105, 2005.
[5] Martin Kaltschmitt, Wolfgang Streicher, Andreas Wiese (ed): Renewable energy. Technology, economics and environment, Springer, Berlin/Heidelberg. 2007.
[6] Demirbas A., The Importance of Bioethanol and Biodiesel from Biomass. Energy Sources, Part B: Economics Planning and Policy, No.3., pp. 177 – 185, 2008.

RENEWABLE ENERGY SOURCES AS A SUSTAINABLE DEVELOPMENT FACTOR

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Abstract: The achievement of the long-term goals of sustainable development involves renewable energy sources, which is directly affect the preservation and protection of the environment, and indirectly for quality of life and the growth of the living standard. The use of renewable energy sources enables the rational use of natural resources, therefore, the potential of renewable energy sources such as biomass, hydro, solar, wind and geothermal energy is analyzed. A long-term policy of efficient environmental protection and efficient use of renewable energy sources creates the necessary preconditions for a sustainable life in the future.
Key words: renewable energy sources, sustainable development, environment, natural resources

INTRODUCTION

Today, humanity is confronted with a multitude of existential crises, among which the ecological crisis holds a special place, because nature expensively punishes man's faults that disrupt the global natural balance. Excessive consumption of natural resources has led to the problem of fossil energy disappearance, environmental pollution and climate change.
The concept of sustainable development initiates the search for ways to use natural resources rationally, offering a new attitude towards the environment. Development must be designed and implemented in such a way that it contributes to reducing pollution and saving natural resources, that is, by using resources within the limits of their renewability. Considering that energy supply is one of the most important issues for the survival of modern civilization, and to be sustainable in the future, it is necessary to increase the production of energy from renewable sources.

RENEWABLE ENERGY SOURCES

All energy resources can be divided into two main groups: non-renewable and renewable. Non-renewable energy resources are also the most significant environmental pollutants, both directly and indirectly, and represent a group of energy resources that are consumable, non-renewable and limited. Non-renewable energy sources include: wood, coal, oil, gas and uranium in the fission process. Renewable energy sources are renewable, inexhaustible and without consequences or with little impact on ecological systems [1].
Renewables are considered one of the key energy sources of future Earth development. Today, when the greenhouse effect is increasing and industrial production is increasing, renewable energy cannot be viewed without an ecological aspect. Uncontrolled concentration of carbon dioxide (CO_2) in the atmosphere threatens to endanger the ozone layer and increase global temperature, which can cause untold consequences on the planet. With the development of renewable energy applications, almost all environmental degrading impacts will be eliminated while providing virtually unlimited amounts of energy necessary for the further prosperity of humanity [1].
What are the naturally available renewable energy potentials at the world level, as shown by the following data [12]:

- Solar energy provides 2,850 times more energy than current global needs
- Wind energy provides 200 times more energy than current global needs
- Biomass energy provides 20 times more energy than current global needs
- Geothermal energy provides 5 times more energy than current global needs
- Water energy (groundwater, wave, tidal) provides 3 times more energy than current global needs.

Although the total renewable energy potentials are 3,078 times greater than humanity's total needs, the share of global renewable energy consumption is still not satisfactory - in 2015 it was 19.3%. Renewable energy capacity in the world in 2016 was about 921 GW. In the first place is China with about 254 GW, in second place is the USA with about 145 GW, while Germany is third with renewable energy capacity about 98 GW [2].
Renewable energy sources are solar, wind, hydro, geothermal, biomass, tidal, waves and sea currents (Figure 1). Renewables can be divided into two main categories: traditional renewables like solid biomass and large hydroelectric power and "new renewable energy" such as: biofuels, biogas, small hydroelectric power, solar photovoltaics, solar thermal, wind, geothermal energy, sea energy (tides, waves and sea currents).

Figure 1. Overview of renewable energy sources [3]

1) **Biomass energy**, the first and oldest source of energy used by humans, is today a widely used renewable energy source concentrated in waste from agriculture (98%), forestry (1.5%) and wood processing (0.5%). Biomass consists of biodegradable parts of agricultural products or residues, forest waste as well as biodegradable parts of industrial and urban waste. Depending on the aggregate state, biomass can be divided into:
- solid (briquetted or pelleted biomass)
- liquid (bioethanol, biomethanol, biodiesel) and
- gaseous (biogas, landfill, etc.).

Until 2001, biomass was mainly used for the production of heat, and very little for the production of electricity, since then, most of the products have been combined and use for heat and electricity or electricity is produced through biogas [4]. In 2016, the global biomass energy capacity reached a value of 504 TWh. In the first place was the USA with about 68 TWh and in the second place China with about 54 TWh. The production of biofuels in the period 2006-2016. is continuously increased to reach the value of 135 billion liters in 2016. Ethanol production comes first with about 72%, followed by biodiesel production with about 23% and hydrated vegetable oil production with about 4%. The largest biodiesel producers are the USA and Brazil, which represents about 70% of biofuel production [2].

2) **Hydropower** accounts for about 16% of the world's energy production. In the last 30 years, hydroelectric power generation has tripled. It is estimated that about 25% of the world's hydropower potential has been utilized. Technically usable water power is the largest in America (about 36% of the total), followed by Asia (about 30%), Africa (about 16.3%), while in Europe it is about 7%.
Hydropower is divided into two categories:
- river water energy (flow, storage and reversible hydroelectric power plants)
- Sea water energy (wave and sea currents, tides).
Hydropower has four main advantages:

- it is renewable
- is the most environmentally friendly, because it produces insignificant amounts of greenhouse gas
- is the cheapest way to produce and store large quantities of electricity and
- It is easily adaptable to the needs of consumers, so it does not leave too many opportunities for waste [5].

3) **Solar energy** is a renewable and inexhaustible energy resource that can play a significant role in energy. Sunlight can generate heat, electricity or chemical energy. The highest degree of utilization is in converting sunlight into thermal energy, and there are also the greatest needs.
Solar energy is a resource available to any country without import dependency, while being clean energy. If each household had least one unit of solar collector to heat the domestic hot water, a huge amount of conventional energy would be saved, which would represent a significant burden on the power system. Heating domestic and industrial and other buildings, domestic hot water systems, especially in hospitals, nursing homes, student homes, hotels and restaurants, bring enormous savings while not polluting the environment. Solar global capacity in the world year by year, with the development of new technologies that are being applied in the utilization of solar energy is increasing, so in 2016 it amounted to about 303 GW [2].
4) **Wind energy** is the kinetic energy of moving air. Wind turbines are used to generate electricity, which converts wind kinetic energy into mechanical energy, by turning the rotor shaft directly into electrical energy or converting it into energy for other mechanical work (rotation of the irrigation pump rotor or the rolling rollers, scrapers , for launching craft over sails, etc.) [6].
The available wind power is increased eight times when the wind speed is doubled. This is why wind turbines for the grid are especially effective at higher wind speeds. Global wind kinetic energy averaged about 1.50 MJ/m^2 over the period 1979 to 2010, 1.31 MJ/m^2 in the Northern Hemisphere and 1.70 MJ/m^2 in the Southern Hemisphere [7].
The total amount of economically usable power generated from wind is much higher than it represents human energy from all sources. The utilization of wind energy by the turbines now in use ranges from 25% to 45% [3]. Based on the scenario of energy production in the future from renewable energy sources, as a renewable energy source, wind is in second place, after solar energy. Wind farms experienced the fastest growth of all renewable energy sources at the beginning of the 21st century. Their capacity increased more than ninefold from 2006 to 2016, so that global wind energy production in 2016 was about 487 GW [2].
5) **Geothermal energy** is the heat of the Earth. There are thermal and water vapor, hot and hot rocks and magma deposits in the Earth's crust. Compared to the world's coal reserves, geothermal energy is 70 times more. The ways in which geothermal fluids are used depend most on their temperature. Low temperature water (50-75^{0}C) is used to heat apartments, work spaces and greenhouses, medium temperature water (up to 140^{0}C) is used in industrial processes, and high temperature water and dry steam (140-350^{0}C) are used to generate electricity [3].
In EU countries, geothermal energy is used to heat apartments, workplaces and greenhouses, sanitary hot water, electricity production, fish farming and in industry - in technological processes such as drying, evaporation, distillation, washing and dyeing, process heating and heating industrial plants [5].
At the end of 2016, the first in the world to produce geothermal energy was the United States with a global capacity of about 3.6 GW, second is the Philippines with a capacity of about 1.9 GW, and third is Indonesia with a capacity of about 1.6 GW [2] .

ECONOMY OF RENEWABLE ENERGY

The technological and economic progress of a country is measured by the degree of use of natural resources. Most of the development is based on non-renewable resources. Industrial production is recording a steady growth rate and its development base is recording a steady rate of decline in mineral reserves. This leads to a dangerous but unavoidable situation - the complete disappearance of stocks of that type of resource [9].

The fact that the resource base of non-renewable mineral resources is being reduced, as well as the negative impact of their exploitation on the environment, has led to increased interest in renewable energy sources.

In the early 2000s, EU countries adopted Renewable Energy Acts, which encouraged the use of renewable energy. The Council of Ministers of the European Union and the European Parliament adopted in 2001 a directive on the promotion of electricity from RES in the internal electricity market (Directive 2001/77/ EC). The Directive applies to the following renewable energy sources: wind, sun, geothermal energy, waves, tides, hydropower, biomass, natural gas and biogas [4].

The untapped potential of biomass, solar, hydropower, wind and geothermal energy is still high. However, in recent years in many European countries the development of this sector has increased. The European Union has adopted its strategy to combat climate change through the Europe 2020 Sustainable Development Plan. which sets ambitious energy goals (so-called 20-20-20). The main objectives of the EU Directive by 2020 are [10]:

1) 20% less CO2 emissions
2) 20% renewable energy
3) 20% higher energy efficiency.

The transition from conventional energy sources to renewables will not happen overnight. Therefore, society must constantly work to create a clean, safe and inexhaustible way of obtaining energy.

The strategic orientation towards the use of renewable energy sources has at least three reasons:

- Using RES reduces national dependencies on energy imports.
- The use of RES reduces general environmental pollution, both locally and nationally and across borders, because RES conversion systems to other forms of energy do not emit pollutants into the environment.
- RES conversion systems do not emit so-called GHGs that cause global warming, thus contributing to global action to mitigate climate change [11].

Investing in the development of renewable energy technology and the plants themselves that produce energy from these sources cause an increase in the number of direct and indirect jobs, leading to job creation (Figure 2). The estimated number of employees in renewable energy in 2016 (technology and RES plants) is around 8.3 million workers [13]. The largest number of employees in 2016 (directly and indirectly) had solar energy (about 3.9 million workers), followed by energy derived from biomass (about 2.5 million workers), and third, wind energy (about 1.2 million workers) [2].

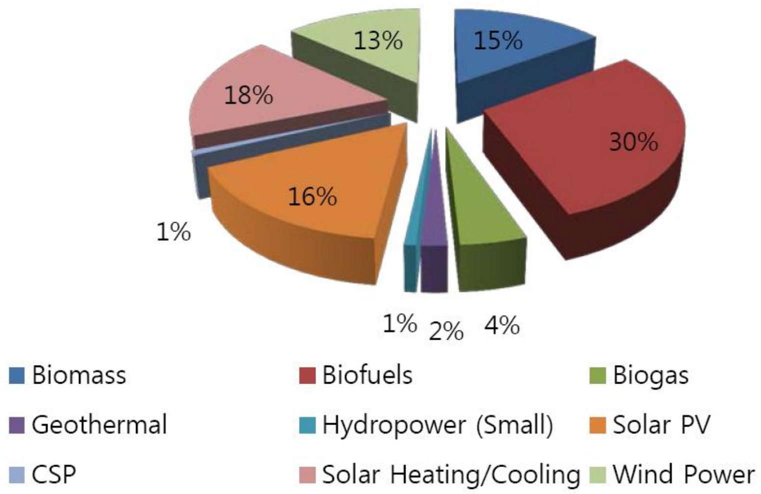

Figure 2. Estimated jobs in renewable energy worldwide, by industry based on the GSR 2012 report [14]

POTENTIAL OF USING RENEWABLE ENERGY IN SERBIA

Serbia has significant renewable energy potential of more than 3,000,000 tonnes of oil equivalent per year. About 80% of this potential is biomass. At the same time, total consumption of fossil fuels is at the level of 12,000,000 tonnes of oil equivalent. Using only 10% of biomass potential to provide thermal energy services, which consumes about 2.5 million tonnes of equivalent oil annually in Serbia, the savings from reduced imports would be about 60 million euros a year [4].
The Republic of Serbia is energy dependent on imports and it is therefore very important to increase the use of renewable energy sources. Strategic commitments in the Republic of Serbia envisage an increase in the share of renewable energy sources, and it can be expected that this issue will soon be extremely topical from an economic and strategic point of view. Applying comfortable and environmentally friendly solutions would make better use of available energy sources, contribute to improving population standards and create jobs [4].

CONCLUSION

Protecting and improving the environment is a significant global problem in modern society. The growth of industrial activity has increased the pressure on the environment, with the energy sector as one of the largest polluters. In order to preserve the environment, one of the most important issues for the sustainable development and survival of modern civilization is the efficient use of energy by maximizing the use of renewable and saving non-renewable natural resources. There are traditional renewables, such as biomass and hydropower and new renewables, which include solar, wind and geothermal.
Renewable energy is considered to be the energy of the future, that is clean energy, which will replace fossil fuels and their harmful impact on the environment. Although the total energy potential of renewable energy sources is 3,078 times higher than current global needs, only 19.3% of the world's total energy is generated. The strategic orientation in the Republic of Serbia envisages an increase in the share of renewable energy sources, since the Republic of Serbia is energy dependent on imports and therefore it is very important to increase the use of renewable energy sources.

REFERENCES

[1] Jovanovic, G., Bozilovic, S.: Alternative energy sources and sustainable development, Entrepreneurship, engineering and management, Innovation: a generator of new knowledge, VII Scientific Conference, pp. 131-136, Zrenjanin, 2018

[2] Karabegovic, I .: Trends in the use of renewable energy in the world - Job creation opportunities, Entrepreneurship, engineering and management, Innovation: a generator of new knowledge, VII Scientific Conference, pp. 37-54, Zrenjanin, 2018

[3] Internet source: httpswww.canstockphoto.comenergy-sources-vector-infographics-34112549

[4] Internet source: http://www.agroplod.rs/renewable-sources-energy/biomas-renewable-sources-energy

[5] Resic, R.: Economics of Natural Resources and the Environment, University of Belgrade, Faculty of Agriculture, Belgrade, 2002

[6] Walker, J. F., Jenkins, N.: Wind Energy Technology, John Wiley & Sons, Chichester, UK, 1997

[7] Internet source: http://www.vtsnis.edu.rs/Predmeti/alternativni_izvori_energije/aie_vezbe_2013_2_4

[8] Entesar, S.: The Importance of Environmental Standards and Environmental Management for Sustainable Development in Libya, Master's thesis, Singidunum University, Faculty of Applied Ecology, Futura, Belgrade, 2018

[9] Magdalinovic, N., Magdalinovic-Kalinovic, M .: Natural Resources Management, Tertius, Bor, 2010

[10] Internet source: http://e-learning.gornjogradska.eu/energyecologyEnglish-children/1-renewable-sources-energy/

[11] Energy Strategy of the Republic of Serbia until 2025, with projections until 2030, "RS Official Gazette", No. 101, Belgrade, 2015

[12] Gburcik, V.: Solar Energy and Wind Energy Resources in Serbia, University and Sustainable Development, (edited by Pavlovic V.), University of Belgrade, Faculty of Political Science, Center for Environmental Policy and Sustainable Development, pp. 207-226, Belgrade, 2011

[13] Martinot, E.: Renewable 2017 Global Status Report, REN21 Secretariat, Paris, 2017

[14] Abolhosseini, S., Heshmati, A., Altmann, J.: A Review of Renewable Energy Supply and Energy Efficiency Technologies. 8145, IZA P.O. Box 7240 53072 Bonn, Germany, April 2014

EXPERIMENTAL DATA IN FIRING PROCESS FOR DIFFERENT TYPES OF BIOMASS

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Abstract: The biomass is one of the most used renewable sources of energy nowadays, because it comes in different forms for energy production, including the biodegradable fraction of products, remnants and residues from logging and wood processing factories.. In this context, the present paper presents a small-scale application regarding the study of the potential of several types of biomass.
Key words: woody biomass, renewable energy, calorific power.

INTRODUCTION

Bioenergy, i.e. the renewable energy produced from organic matter like woody biomass, agricultural crops and organic waste, represents the largest share in this category worldwide (77% or 60 EJ [2]) and will continue to play a critical role for mitigation in the future [3]. The removal of CO2 via bioenergy combined with carbon capture and storage techniques seems indispensable to limit global warming to below 1.5 °C [1, 4]. A review about future contribution of biomass to global energy supply attributes the largest share to energy crops (22–1272 EJ), exceeding that of forestry (60–230 EJ), organic waste (12–120 EJ), agricultural (10–66 EJ) and forestry residues (3–35 EJ) [5].
Biomass can be used in combustion plants of all sizes: stoves and small boilers in single-family homes, central heating in small dwellings, and medium and large thermal power plants [6]. In addition, biomass is the third largest primary energy resource in the world [7]. In the European Union, in 2014, the primary energy consumption of solid biomass was 89.1 Mtoe, with a heat consumption of 69.9 Mtoe and a gross electricity production of 84.8 TWh. Spain accounted for 5.95% of this primary energy consumption. The consumption of heat amounted to 3.7 Mtoe, and 3.8 TWh of electricity was produced [8].
In the residential sector, with the use of biomass for heating and domestic hot water (DHW) solutions, a substantial reduction in CO_2 emissions is expected.
The impact of using biomass boilers on housing has been evaluated in several studies: Kattan and Ruble [9] conducted a study for multi-family dwellings in Lebanon; Stolarski et al. [10], for single-family houses in Poland; Michopoulos et al. [11], for multi-family dwellings in Greece; and Carpio et al. [12], for multi-family dwellings and single-family houses in the Iberian Peninsula. Moreover, the use of biomass in hybrid systems for heating and DHW in residential buildings is of great interest. In this field, there are many possibilities: solar hot water systems and a biomass boiler [13]; combined cooling, heating, and power (CCHP) system utilizing biomass and solar energy [14]; the integration of deep geothermal energy and woody biomass resources in urban energy systems [15]; and the use of biomass in organic Rankine cycles (ORC) for solar-based multigeneration systems with hot and cold thermal storages and hydrogen production [16]. On the other hand, evaluating the energy, environmental, and economic impact of biomass district heating can contribute to strengthening its settlement and development, as Madlener [17], Madlener and Koller [18], and Paredes-Sanchez et al. [19] studied. Additionally, the possibilities of combining energy conservation measures with biomass district heating systems [20] and using low temperature biomass district heating systems [21] should be considered. Finally, enhancing these solutions can help achieve important benefits in rural regions and villages.
The present paper will highlight the possibilities of using a pilot plant in which it was tried to burn various types of wood waste.

MATERIAL AND METHODS

Figure 1 and 2 respectively show the pilot installation used.

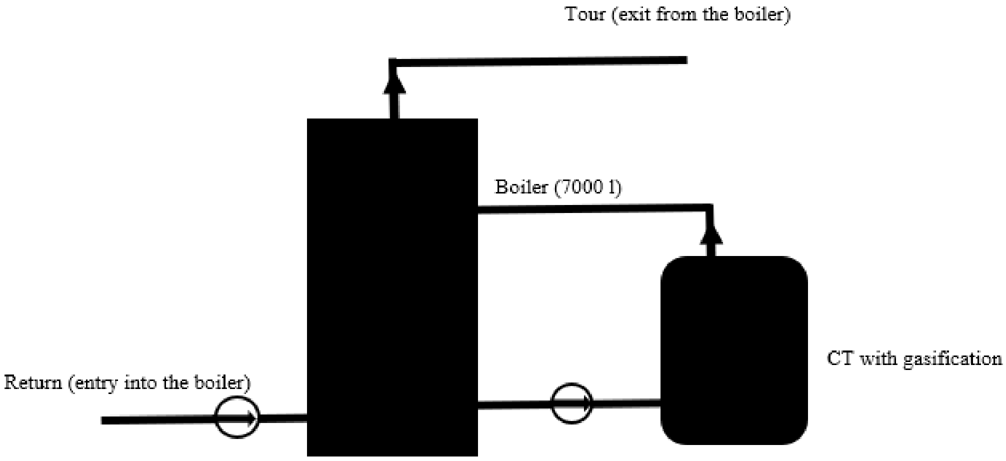

Figure 1. Heating system

The pilot heating system is composed of an experimental heating boiler, a boiler for accumulating hot water and a pump for circulating hot water. The boiler is with natural circulation, manual fuel supply in a bank that gives it a range from 1:30 to 2:30 hours, depending on the material.

Figure 2. Frontal view of the CT with gasification

The measurements were made in November 2018, at an air temperature of 18 C, and the probe was placed in the chimney at 4 ml from the boiler outlet.

RESULTS AND DISCUSSION

The main results are listed in Table 1. Several combustion materials were used, corn and various wood types' chips and small stumps.

Table 1. Flue gas measurements at the CT boiler

No		T [ºC]	O2 [%]	CO [ppm]	NOx [ppm]	Loss [%]	Efficiency [%]
1	Corn (with suppl. air)	133	18,3	972	91	26,2	73,8
2	Corn	128	17,8	1884	47	21,3	78,7
3	Wood wet grinding	110	19,8	1573	37	46,2	53,8
4	Wood dry grinding	181	7,5	1905	267	8,5	91,5
5	Dry Oak	175	13,5	268	114	13,8	86,2
6	Dry Fir	166	6,1	1159	135	7,2	92,8
7	Hemp	152	15,5	1522	120	15,8	84,2

It can be observed from the table 1 and synthetized results in figure 2 that even if wood grindings provides high combustion efficiency – similar to dry oak, fir or hemp – it also generates higher emissions, especially for NOx and CO.

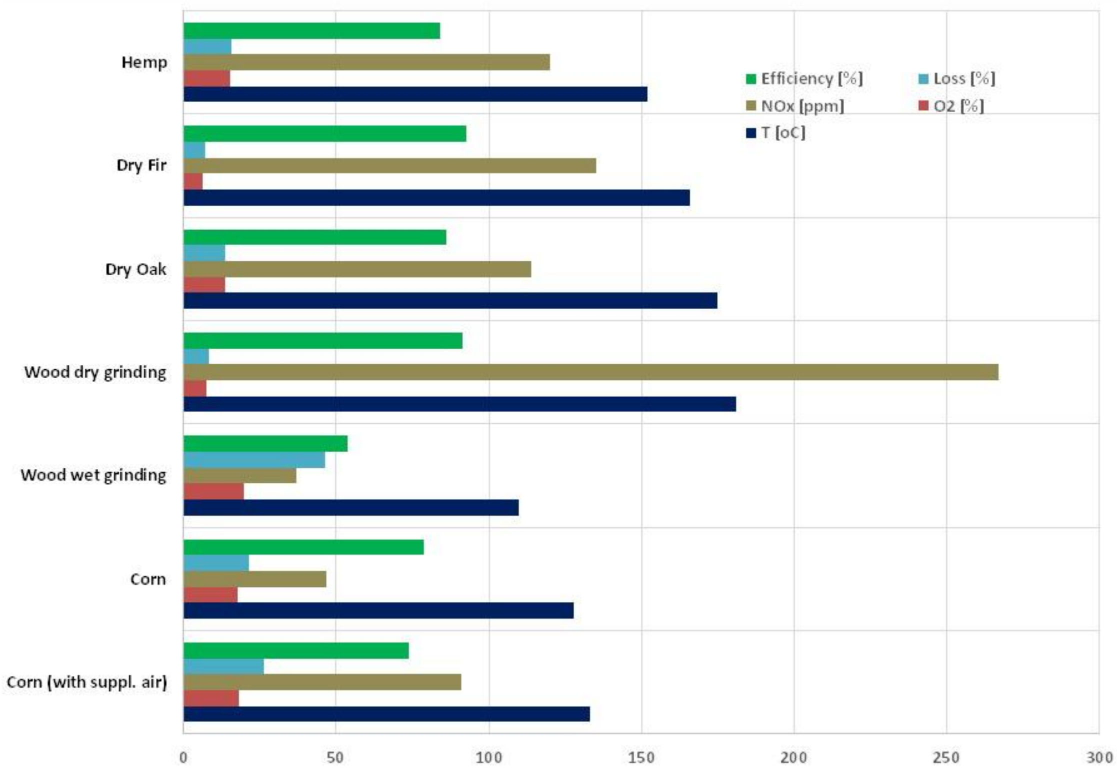

Figure 2. Emission values and combustion parameters for tested materials.

Figure 3 shows the results for CO emissions for tested combustion materials, and its clear that grinding wood is significantly emitting higher CO concentration then small wooden stumps.

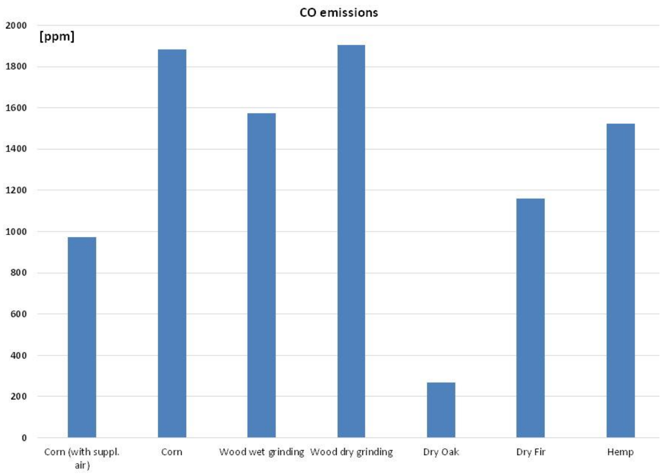

Figure 3. CO emissions

The advantages of this plant:

- simple constructive solution,
- it has no deposits on the outbreak, even when using willow energy with the shell, due to the position of the two exchangers the water / combustion gases disposed after the outbreak,
- does not require forced ventilation, the circulation is realized naturally.

The disadvantages of this small plant:

- low autonomy,
- at the large size of the outbreak, the natural circulation is no longer realized and requires forced circulation,
- high flue gas temperatures.

Due to the high temperature in the basket, the installation will be improved, and in the basket a heat exchanger (superheater) will be fitted to avoid the dew point.

CONCLUSION

Wood biomass represents a renewable fuel material due to two main causes: wood is a renewable material, as a product of photosynthesis and annual growth, and wood residues are inherent products of wood processing flows. However, there are several barriers involved in developing small biomass heating systems, economic, political and environmental barriers. The environmental barrier could be the most relevant even if it's not related to technological issues, but several difficulties arise:

- Difficulties come with the geographical dispersion of biomass resource, season dependence of biomass and difficulties in planning and coordinating biomass harvest.
- The storage of biomass and/or its transport rises issues due to the need of large storage spaces.
- As more and more citizen are moving in urban areas, their new habitat is not suitable for biomass combustion and biomass storage. For urban areas biomass as a renewable resource can only by efficient in applications of large combustion plants with centralized heating system.

REFERENCES¶

[1] IPCC. Pachauri RK, Meyer LA, editors. Climate change 2014: synthesis report. Contribution of working groups I, II and III to the fifth assessment report of the intergovernmental panel on climate change. Geneva, Switzerland: Cambridge University Press; 2014. p. 151.

[2] IEA. Key world energy statistics. Paris: International Energy Agency; 2017. p. 95.

[3] Canadell JG, Schulze ED. Global potential of biospheric carbon management for climate mitigation. Nat Commun 2014;5.

[4] Rogelj J, Luderer G, Pietzcker RC, Kriegler E, Schaeffer M, Krey V, et al. Energy system transformations for limiting end-of-century warming to below 1.5C. Nat Clim Change 2015;5:519.

[5] Slade R, Bauen A, Gross R. Global bioenergy resources. Nat Clim Change 2014;4:99–105.

[6] Scarlat, N., Dallemand, J.-F., Skjelhaugen, O.J., Asplund, D., Nesheim, L., 2011. An overview of the biomass resource potential of Norway for bioenergy use. Renew. Sustain. Energy Rev. 15, 3388e3398. https://doi.org/10.1016/ j.rser.2011.04.028.

[7] Bilgen, S., Keles¸ , S., Sarikaya, I., Kaygusuz, K., 2015. A perspective for potential and technology of bioenergy in Turkey: present case and future view. Renew. Sustain. Energy Rev. 48, 228e239. https://doi.org/10.1016/j.rser.2015.03.096.

[8] EUROBSERV'ER, 2015. Solid Biomass Barometer December 2015. Available at: http:// www.eurobserv-er.org/pdf/solid-biomass-barometer-2015-en/ (Accessed October 10 2016).

[9] Kattan, P., Ruble, I., 2012. An economic assessment of four different boilers for residential heating in Lebanon. Energy Build. 50, 282e289. https://doi.org/ 10.1016/j.enbuild.2012.02.057.

[10] Stolarski, M.J., Krzy_zaniak, M., Warminski, K., Snieg, M., 2013. Energy, economic and environmental assessment of heating a family house with biomass. Energy Build. 66, 395e404. https://doi.org/10.1016/j.enbuild.2013.07.050.

[11] Michopoulos, A., Skoulou, V., Voulgari, V., Tsikaloudaki, A., Kyriakis, N.A., 2014. The exploitation of biomass for building space heating in Greece: energy, environmental and economic considerations. Energy Convers. Manag. 78, 276e285. https://doi.org/10.1016/j.enconman.2013.10.055.

[12] Carpio, M., Zamorano, M., Costa, M., 2013. Impact of using biomass boilers on the energy rating and CO2 emissions of Iberian Peninsula residential buildings. Energy Build. 66, 732e744. https://doi.org/10.1016/j.enbuild.2013.07.079.

[13] Berkovic-Subic, M., Rauch, M., Dovic, D., Andrassy, M., 2014. Primary energy consumption of the dwelling with solar hot water system and biomass boiler. Energy Convers. Manag. 87, 1151e1161. https://doi.org/10.1016/ j.enconman.2014.03.063.

[14] Wang, J., Yang, Y., 2016. Energy, exergy and environmental analysis of a hybrid combined cooling heating and power system utilizing biomass and solar energy. Energy Convers. Manag. 124, 566e577. https://doi.org/10.1016/ j.enconman.2016.07.059.

[15] Moret, S., Peduzzi, E., Gerber, L., Marechal, F., 2016. Integration of deep geothermal energy and woody biomass conversion pathways in urban systems. Energy Convers. Manag. 129, 305e318. https://doi.org/10.1016/j.enconman.2016.09.079.

[16] Almahdi, M., Dincer, I., Rosen, M.A., 2016. A new solar based multigeneration system with hot and cold thermal storages and hydrogen production. Renew. Energy 91, 302e314. https://doi.org/10.1016/j.renene.2016.01.069.

[17] Madlener, R., 2007. Innovation diffusion, public policy, and local initiative: the case of wood-fuelled district heating systems in Austria. Energy Pol. 35, 1992e2008. https://doi.org/10.1016/j.enpol.2006.06.010.

[18] Madlener, R., Koller, M., 2007. Economic and CO2 mitigation impacts of promoting biomass heating systems: an inputeoutput study for Vorarlberg, Austria. Energy Pol. 35, 6021e6035. https://doi.org/10.1016/j.enpol.2007.08.023.

[19] Paredes-Sanchez, J.P., Lopez-Ochoa, L.M., Lopez-Gonzalez, L.M., Xiberta-Bernat, J., 2016. Bioenergy for district bioheating system (DBS) from eucalyptus residues in a european coal-producing region. Energy Convers. Manag. 126, 960e970. https://doi.org/10.1016/j.enconman.2016.08.084.

[20] Lundstr€om, L., Wallin, F., 2016. Heat demand profiles of energy conservation measures in buildings and their impact on a district heating system. Appl. Energy 161, 290e299. https://doi.org/10.1016/j.apenergy.2015.10.024.

[21] Baldvinsson, I., Nakata, T., 2016. A feasibility and performance assessment of a low temperature district heating system e a North Japanese case study. Energy 95, 155e174. https://doi.org/10.1016/j.energy.2015.11.057.

[22] Stephen, J.D., Mabee,W.E., Pribowo, A., Pledger, S., Hart, R., Tallio, S., Bull, G.Q., 2016. Biomass for residential and commercial heating in a remote Canadian aboriginal community. Renew. Energy 86, 563e575. https://doi.org/10.1016/ j.renene.2015.08.048.

USING THE RENEWABLE ENERGY SOURCES IN SERBIA AND IN THE WORLD

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Abstract: We are at the end of one epoch when fossil fuels, conventional or non-renewable energy sources can not be the basis for our future development planning. Consequently, since all of these resources are exhausted, it is necessary to look for and bring in some new sources of energy in usage, and it is the moment when a person turns to nature or to renewable energy sources. Renewable energy sources are inexhaustible energy sources that are obtained from nature and are renewed at a certain interval of time. In this paper, we will present the comparison of some different types of renewable energy sources that are used in Serbia, opposed to those that are used in the world, also we will show some regions on the territory of Serbia which has a good potential for some different types of the RES.
Key words: Renewable energy sources, comparing, natural resources, Serbia, world.

INTRODUCION

Renewable energy sources have significant potential for improving the development of humanity. Energy from renewable sources - water, wind, sun and biomass, among others - can facilitated access to clean and safe energy for millions of people. It can provide an incentive for social and economic development, helping to cope with environmental challenges, and has a key role in successfully dealing with climate change. First of all, we need to define what renewable energy sources are. Renewable energy sources are inexhaustible energy sources of nature that are renewed at a certain time interval, in whole or in part. These energy sources are used for the production of electrical, thermal and mechanical energy, and their significant sustainability is environmental harmony, with reduced or reducing CO_2 emissions in the process of energy production. The usage of this elements are now the most important thing for us because we exhausted some of existing sources of energy. [1,3]
Renewable energy sources can be divided into two categories:[2]

- Traditional renewable energy sources like: biomass and energy of large hydropower plants
- „ New renewable energy sources“ such as energy of Sun, wind energy,geothermal energy, ect.

The development of renewable energy sources, especially from wind, water, sun and biomass, is important for several reasons:[2]

- These energy sources play a very important role in reducing carbon dioxide (CO2) emissions into the atmosphere. This is also an important part of the European Union's policy.
- Increasing the contributino of renewable energy sources we increase the energy sustainability of a country's system. At the same time it helps to improve the security of energy delivery and thus reduces the dependence on imports of energy raw materials as well as electricity,
- Renewable energy sources are expected to become economically competitive with conventional energy sources in due course.

Today, new energy sources produce only a small part of the world's total energy. This share in the future should increase considerably as non-renewable energy sources are getting smaller and their reserves are on the brink, and their detrimental impact is more and more pronounced in the last few years. The Sun, without whom there is no life on our planet, gives Earth several thousand times more energy than mankind is able to spend at the current stage of development. Everything is in favor of the fact that renewable sources can and must start to be better exploited and that if we do wisely, we do not have to worry about energy after fossil fuels.

RENEWABLE ENERGY SOURCES IN SERBIA

Renewable energy sources are the main backbone of Serbia's energy independence in the future. The total potential of energy from renewable sources can satisfy a quarter of the annual needs of Serbia. The total technically available potential of renewable energy sources in the Republic of Serbia is estimated at 5.65 million ten for the year. Of this potential, 1,054 million ten of biomasss (mainly firewood) and 909 thousand ten of hydroelectric power plants. As we said before, biomass present a huge energetical potential for Serbia. [4,5]
The potential of biomass is estimated at 3.448 million ten and in the total potential of RES accounts for 61%. Of this potential, the greatest part is the potential of wood biomass - 1.53 million ten and the potential of agricultural biomass - 1.67 million ten (residues in farming, livestock breeding, fruit growing, viticulture and primary fruit processing), while the potential of biodegradable municipal waste is estimated at 205 thousands of ten. Biodegradable waste (excluding municipal waste) consists of waste edible oils and animal waste (waste slaughterhouse waste) in the total amount of 0.043 million ten / year. Wood biomass is mainly in the area of central Serbia, and agricultural biomass in the area of Vojvodina. However, while the degree of utilization of potential is wood (forest) biomass is relatively high (66.7%), the potential of agricultural biomass is slightly used (~ 2%), while the potential of biodegradable municipal waste is not used at all. [4,5]
The total theoretically available hydropower potential of the waters that flowned on the territory of the Republic of Serbia is around 25,000 GWh / year. The largest part of the hydro-potential (over 70%) is concentrated only on several watercourses with a potential above 1,000 GWh / year: Danube, Drina, Velika Morava, Lim and Ibar. On the other hand, on several rivers in the Republic of Serbia, hydro power potential will only be able to be partially used, due to the priority of water management of water, because some rivers are planned as sources of regional water supply systems: Toplica, Crni Timok, Rasina, Studenica, Veliki Rzav, Mlava , Lepenac, etc. The technically usable potential in the Republic of Serbia is around 19.5 TWh / year, of which about 17.7 TWh / year at facilities greater than 10 MW. So far 16 hydropower plants have been built and produced on average about 10.5 TWh per year. The total technical potential of hydroelectric power plants up to 10 MW is estimated at around 1,800 GWh per year.
Wind energy in the Republic of Serbia can be used in the area of the Kosavsko area, southern Banat, the area of eastern Serbia, the eastern side of Kopaonik, the area of Zlatibor and Pešter and on the location of mountain-crossings that have elevation above 800 m. For the clearer understanding of the potential, it is necessary to continue to devote wind measurements (started in southern Banat and eastern Serbia) in order to produce wind atlas, as one of the conditions for investing in wind power generation capacities. The technically usable wind potential is determined on the basis of the existing technical possibilities of the electric power system to take this energy. Additional assumptions in determining the potential are that the maximum variation of wind power generation will not coincide with the maximum variations in the production of electricity from solar power plants and that the maximum variation will not exceed 90% of the total installed capacity. This means that in the installed capacities it is possible to have 500 MW with the current size of the tertiary power reserve, which can be provided in thermal power plants and accumulation hydroelectric power plants. Considering the maximum possible production of wind farms with this installed power, they can count on their maximum technically usable potential of 1,200 GWh / year (0,103 Mtoe / year).[4,5]
Energy of the Sun represents the energetic potential of the Republic of Serbia, which can be used for the production of heat or electrical energy. The huge part of the territory of the Republic of Serbia, the number of hours of solar radiation is significantly higher than in many European countries (between 1,500 and 2,200 hours per year). The average intensity of solar radiation in the territory of the Republic of Serbia ranges from 1.1 kWh / m^2 / day in the north to 1.7 kWh / m2 / day in the south - during January, and from 5.9 to 6.6 kWh / m^2 / day - during July. Annually, the average value of the energy of radiation is 1,200 kWh / m^2 / year in northwestern Serbia, up to 1,550 kWh / m2 / year in southeastern Serbia, while in the central part it is about 1,400 kWh / m2 / year. The technically usable energy potential for the conversion of solar energy into heat energy (for the preparation of hot water and other purposes) is estimated at 0,194 million ten yearly, assuming the use of solar thermal collectors in 50% of available facilities in the country.[4,5]

The Republic of Serbia is located in the zone of favorable geothermal potentials and resources. Geothermal energy implies petrothermal and hydrogeothermal energy resources that the Republic of Serbia has abundantly used. The use of geothermal energy for heating and other energy purposes in the Republic of Serbia is at an early stage and very modest in terms of potential and resources. The geothermal potential of the Republic of Serbia clearly shows the existence of a large number of spas and natural springs with water temperatures greater than 30 ° S, and a different degree of natural diversity. Based on the existing measurements, the heat flux is above the average for Europe (60 mW / m2), or ranges from 80 to 120 mW / m2. Natural and artificial sources of thermal water have been identified in the territory of more than 60 municipalities. The water temperature is usually in the range of 40 ° S, and only in the territory of six cities / municipalities (Vranje, Sabac, Kuršumlija, Raska, Medveđa, Apatin) the water temperature is over 60 ° S. Average water flows from existing sources and wells are on average up to 20 l / s. At several locations, the flow of water exceeds 50 l / s (Bogatic, Kuršumlija, Pribojska Banja, Niška Banja), and only at one location the flow of water exceeds 100 l / s (Banja Koviljača). The total thermal power that could be obtained by utilizing all existing thermal water sources is about 216 MWt, with the production of thermal energy of 180 thousand ten. Significant but unimaginable geothermal potential lies in the use of negative and sedimented oil and gas wells in Vojvodina, where the exploitation is completed.[4,5]
These are all the most recent facts related to the RES in Serbia, but to see that Serbia had progression on this way, on figure 1. we would show the facts related to the RES from 2012.

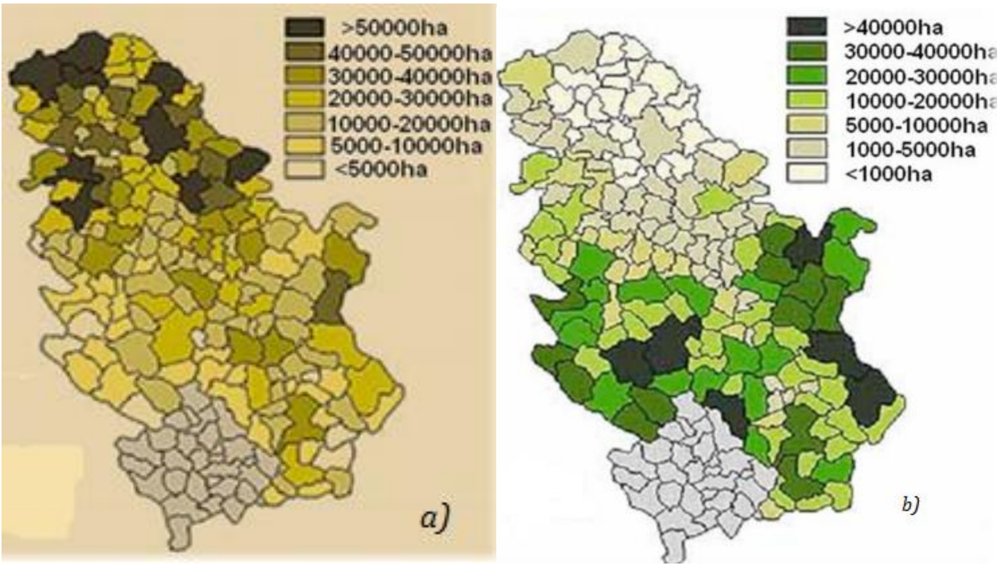

Figure 1. a) and b). Potential for some parts of Serbia for using the RES and the numbered datas from 2012.- a)sources of biomass - arable lands, b)sources of biomass – surface with the forests, c) hidroenergy - total power of small hydropower plans, d) areas with a large number of sunny hour - annual average of the daily energy of global radiation on the horizontal surface, e) wind energy – average annual wind power at 100m, f) geothermal energy - total power from geothermal sources[1]

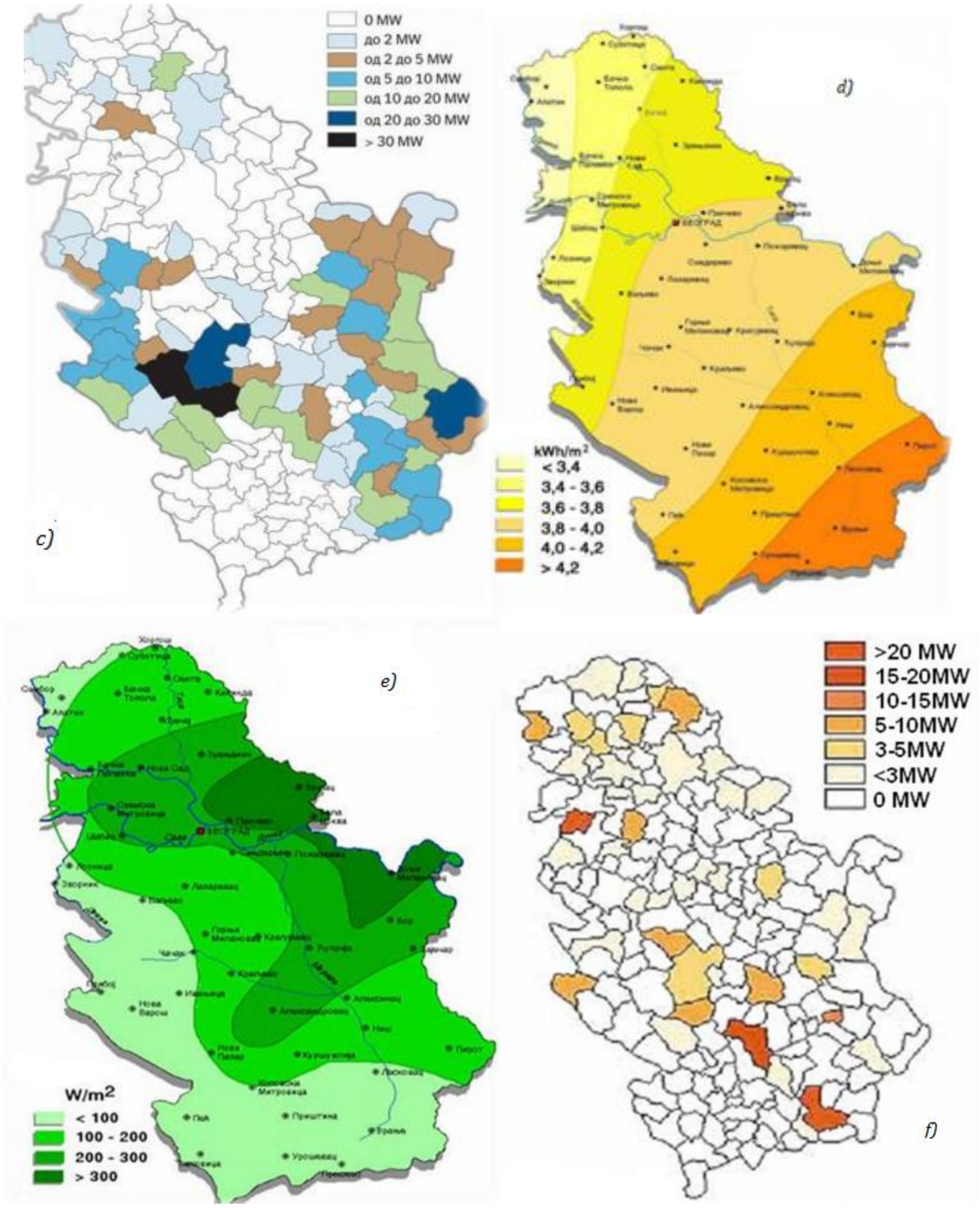

Figure 1. c) d) e) and f) Potential for some parts of Serbia for using the RES and the numbered datas from 2012.- a)sources of biomass - arable lands, b)sources of biomass – surface with the forests, c) hidroenergy - total power of small hydropower plans, d) areas with a large number of sunny hour - annual average of the daily energy of global radiation on the horizontal surface, e) wind energy – average annual wind power at 100m, f) geothermal energy - total power from geothermal sources[1]

RENEWABLE ENERGY SOURCES IN THE WORLD

Renewable technologies include hydropower, solar, wind, geothermal and modern biofuel production (including modern forms of waste-to-biomass conversion). The change & mix of modern renewable consumption over the last 50 years is shown in the figure 2. below. This is measured in terawatt-hours per year and can be viewed across a range of countries and regions. Globally, the world produced approximately 5.9 TWh of modern renewable energy in 2016. This represents a 5 to 6-fold increase since the 1960s. Here we see that hydropower remains the dominant form of modern renewables consumption, accounting for almost 70 percent. Despite absolute growth in production, hydropower's share is, however, declining as other renewable technologies grow.[6,7]

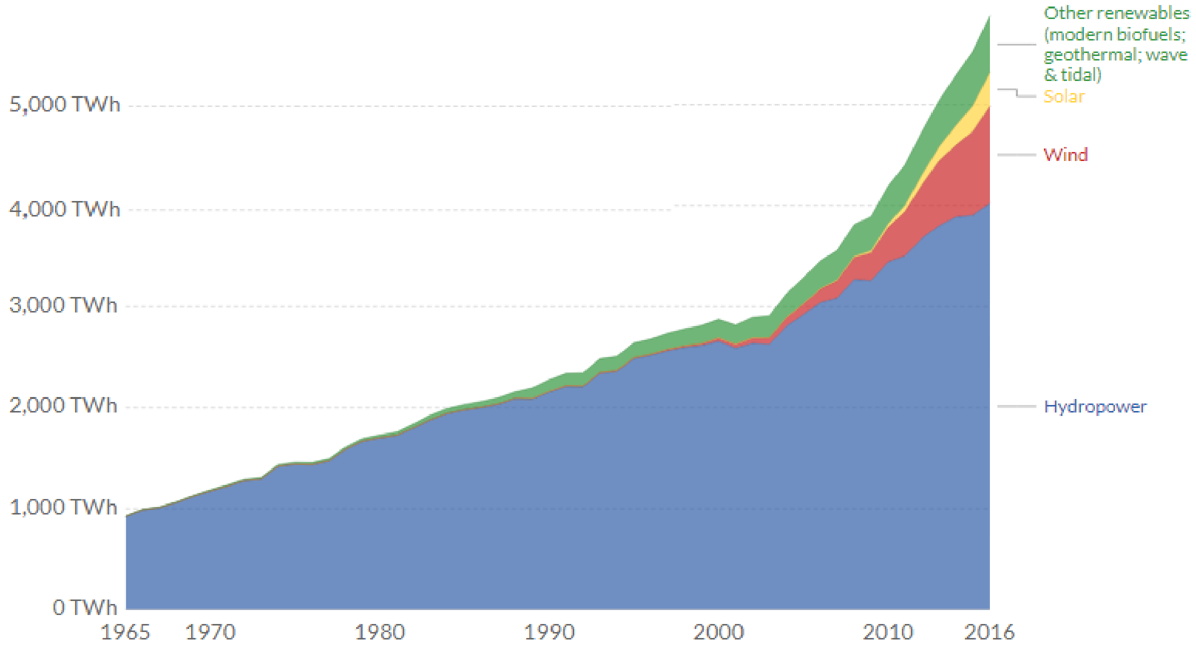

Figure 2. Modern renewable energy consumption over the last 50 years in the world [6]

The concept of renewable energy applications will only continue to grow as the years go by, which can be seen in Figure 3. On figure 3. we can see the predictions for the periods of 2017 to 2023.The share of renewables in meeting global energy demand is expected to grow by one-fifth in the next five years to reach 12.4% in 2023. Renewables will have the fastest growth in the electricity sector, providing almost 30% of power demand in 2023, up from 24% in 2017. During this period, renewables are forecast to meet more than 70% of global electricity generation growth, led by solar PV and followed by wind, hydropower, and bioenergy. Hydropower remains the largest renewable source, meeting 16% of global electricity demand by 2023, followed by wind (6%), solar PV (4%), and bioenergy (3%).[]

While growing more slowly than the power sector, the heat sector – which includes heating for buildings or industry – will account for the biggest overall share of renewables in meeting energy demand in 2023. Renewable heat consumption is expected to increase by 20% over the forecast period to reach a share of 12% of the heating sector demand by 2023. However, a modest increase in the share of renewable heat is foreseen, as robust growth in total heat demand is expected to result from continuous economic and population growth.[8]

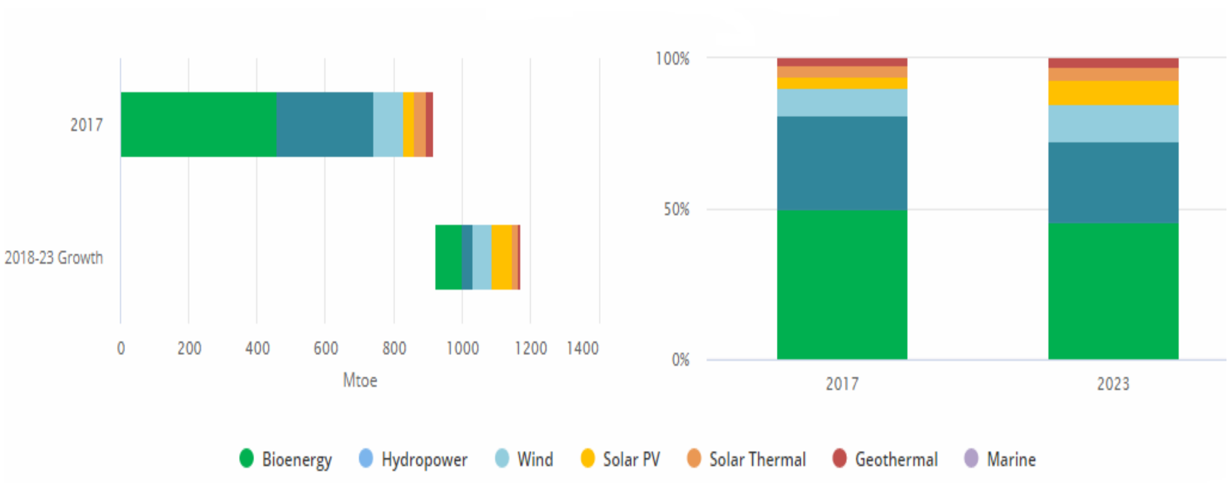

Figure 3. Renewable energy consumption for the period 2017 – 2023 in the world [8]

Renewable energy sources represent the future of every country that wants to sustain development and represents the general field that needs to be invested in the great powers. It is important to note what are the leading world countries that are at the top of the use of renewable energy sources. These countries are shown in Figure 4.

	1	2	3	4	5
Investment in renewable power and fuels (not including hydro over 50 MW)	**China**	United States	Japan	India	Germany
Investment in renewable power and fuels per unit GDP[1]	**Marshall Islands**	Rwanda	Solomon Islands	Guinea-Bissau	Serbia
Geothermal power capacity	**Indonesia**	Turkey	Chile	Iceland	Honduras
Hydropower capacity	**China**	Brazil	India	Angola	Turkey
Solar PV capacity	**China**	United States	India	Japan	Turkey
Concentrating solar thermal power (CSP) capacity[2]	**South Africa**	-	-	-	-
Wind power capacity	**China**	United States	Germany	United Kingdom	India
Solar water heating capacity	**China**	Turkey	India	Brazil	United States
Biodiesel production	**United States**	Brazil	Germany	Argentina	Indonesia
Ethanol production	**United States**	Brazil	China	Canada	Thailand

Figure 4. Top five countries for annual investments, net capacity and for production based on using the RES in 2017. [10]

CONCLUSION

As we said renewable energy sources have significant potential for improving the development of humanity. Energy from renewable sources - water, wind, sun and biomass, among others - can facilitated access to clean and safe energy for millions of people. It can provide an incentive for social and economic development, helping to cope with environmental challenges, and has a key role in successfully dealing with climate change.

The use of RES in the world has seen a significant increase in all sectors and global investments in RES set new record. And this trend is striving to grow even more. Serbia has significant energy potential in this area, but resources are underused in relation to the rest of the world.

REFERENCES

[1] Despotović, Ž., Renewable energy sources – situations and perspectives in Serbia and in the world,presentations, Belgrade, 2012.
[2] https://www.industrija.rs/vesti/clanak/oie-energija-buducnosti
[3] Buchla, D., Kissell, T., Floyd, T., Renewable energy systems, Pearson, 2014.
[4] http://www.rsjp.gov.rs/strategija_razvoja_energetike_do_2025.pdf
[5] Brnabić, A., Turković, M., Roadmap for the development of renewable energy sources in Serbia and the environment: consideration of energy policy in the field of renewable energy sources, Center for International Cooperation and Sustainable Development (CIRSD)., Alta Nova,Belgrade, 2015.
[6] https://ourworldindata.org/renewable-energy#references
[7] Renewable Energy, International Energy Agency, 2002.
[8] https://www.iea.org/renewables2018/
[9] Đereg, N., Kalmar Krnjanski Jović, Z., Apostol, I., Renewable energy sources in Serbia, recommendations, potentials and criteria, center for ecology and sustainable development, Subotica, 2008.
[10] http://www.ren21.net/wpcontent/uploads/2018/06/178652_GSR2018_FullReport_web.pdf

SESSION 3. DESIGNING AND MAINTENANCE

MULLER'S METHOD FOR STUDYING THE OUT OF PLANE VIBRATIONS OF CURVED PIPES CONVEYING FLUID

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Abstract: Two pipes, conveying fluid, with different static schemes and with axes outlined on a semi-circle are considered. The investigated pipes are clamped – clamped and clamped – hinged at their ends. Using Muller's bisection method the first natural frequencies of the free out of plane vibrations are determined for different flow velocities. The flowing fluid is considered as a non-compressible and heavy. The critical fluid velocity for each of the investigated pipes is determined.
Key words: curved pipe, fluid, circular frequency, flow velocity

INTRODUCTION

Curved fluid flow pipes are applied in various areas of the industry - in power stations, in gas pipelines, in nuclear reactors. Therefore, in modern engineering practice, such tubes are subject to vibration and stability studies.
The paper of Svetlitsky, V. [8] is one of the first works about the stability of curved pipes conveying fluid.
Dupuis C. and Rousselet J. [2] have investigated curved fluid conveying pipes. The pipe was treated as a Timoshenko's beam and the fluid was considered incompressible. Zhao Q. and Sun Z. [10] have used the new transfer matrix method to analyze the in-plane vibrations of pipes conveying fluid. Three examples are considered – cantilevered, elastically supported and periodic cantilevered curved pipes conveying fluid. The critical velocity of the fluid and the natural frequency of the system are calculated. Zhao Q. and Sun Z. [9] have applied the Green's function method to investigate the in-plane forced vibrations of curved pipes conveying fluid. Three boundary conditions of beams are considered – clamped-clamped, clamped-pinned and pinned-pinned. The displacements along the tangential and the radial direction are calculated. This method can also be used for investigating the out-of-plane vibrations.
Misra A., Paidoussis M. and Van K. [6] have investigated dynamic stability of curved pipes conveying fluid. The inextensible theory is developed and is applied for two pipes – cantilevered and supported at both ends. The method of finite elements is used for the solution. Liang F., Yang X.-D., Bao R.-D. and Zhang W. [4] have considered the complex mode method to explore the in-plane vibration frequency of a clamped-clamped graded curved pipe conveying fluid. Shankarachar, S., Madabhushi, R., Chellapilla, K. and Babu, P. [7] have investigated straight pipes conveying fluid with different boundary conditions – guided-clamped, guided-simply supported, guided-free and guided-guided. The Muller's Bisection numerical method is used. The natural frequencies of the pipe are obtained for different values of the fluid flow velocity.
In [1] Chen S. has studied the out-of-plane vibrations of curved pipe with flowing fluid. Conservative and non-conservative systems are considered. The natural frequencies are obtained for varying values of the flow velocity.
Lolov D. and Lilkova-Markova S. [5] have investigated fluid conveying pipes which axes are outlined on an arc of a circle. Natural circular frequencies of a pipe in the case of vibrations out-of-plane are obtained for different velocities of the fluid. One of the considered pipes is cantilevered and the other is pinned.
The aim of this paper is to apply Muller's method in the investigation of the out of plane stability of curved pipes conveying fluid.

OUT-OF PLANE VIBRATION OF CURVED PIPE CONVEYING FLUID

The present paper investigates the out of plane stability of curved pipes, conveying fluid. The following static schemes are considered – clamped - clamped and clamped - hinged. The static schemes of the pipes under consideration are shown in Fig. 1. The results obtained show the dependence of the first circular frequency of the system on the fluid velocity. Conclusions are drawn about the stability of the systems.

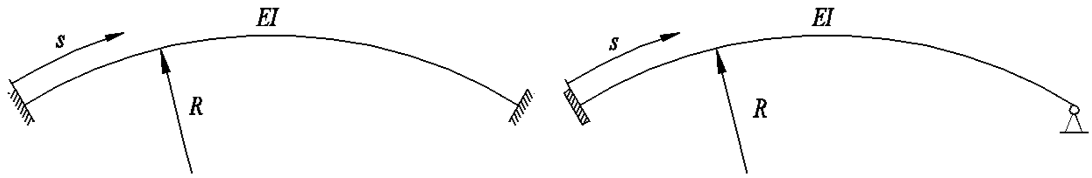

Figure 1. Static schemes of the investigated pipes conveying fluid

A pipe with an axis bent on an arc of circumference with radius R is considered. The differential equation of the free out of plane vibrations of the pipe, shown in [3], is

$$EI\frac{\partial^4 w}{\partial s^4}+\left(MU^2-\frac{GI_c}{R^2}\right)\frac{\partial^2 w}{\partial s^2}+2MU\frac{\partial^2 w}{\partial s\,\partial t}+(M+m)\frac{\partial^2 w}{\partial t^2}=0\,. \tag{1}$$

Here EI is the bending stiffness, G - the shear modulus, I_c - the polar moment of inertia, m - the mass of the pipe per unit length, M - the mass of the fluid per unit length of the pipe, U - the flow velocity, s - the curvilinear coordinate, t – the time.
After division to the bending stiffness the following equation is obtained

$$\frac{\partial^4 w}{\partial s^4}+\frac{MU^2-\dfrac{GI_c}{R^2}}{EI}\frac{\partial^2 w}{\partial s^2}+\frac{2MU}{EI}\frac{\partial^2 w}{\partial s\,\partial t}+\frac{M+m}{EI}\frac{\partial^2 w}{\partial t^2}=0\,, \tag{2}$$

New dimensionless parameters are introduced:

$$\xi=\frac{s}{L};\ \tau=\sqrt{\frac{EI}{M+m}}\frac{t}{L^2};\ v=UL\sqrt{\frac{M}{EI}};\ \beta=\frac{M}{M+m};\ A=\frac{GI_c}{EI}\frac{L^2}{R^2}\,. \tag{3}$$

After transformations, the differential equation (2) takes the forms:

$$\frac{\partial^4 w}{\partial \xi^4}+\frac{MU^2-\dfrac{GI_c}{R^2}}{EI}L^2\frac{\partial^2 w}{\partial \xi^2}+\frac{2MUL}{\sqrt{EI(M+m)}}\frac{\partial^2 w}{\partial \xi\,\partial \tau}+\frac{\partial^2 w}{\partial \tau^2}=0\,; \tag{4}$$

$$\frac{\partial^4 w}{\partial \xi^4}+\left(v^2-A\right)\frac{\partial^2 w}{\partial \xi^2}+2v\sqrt{\beta}\frac{\partial^2 w}{\partial \xi\,\partial \tau}+\frac{\partial^2 w}{\partial \tau^2}=0\,. \tag{5}$$

The function of the displacements w is presented as a product of two functions

$w(\xi;\tau)=W(\xi)e^{i\Omega\tau}$. i is the imaginary unit, Ω is the non-dimensional natural frequencies. (6)

Then the equation (5) will be

$$W^{IV}+\left(v^2-A\right)W^{II}+2v\sqrt{\beta}i\Omega W^{I}-\Omega^2 W=0\,. \tag{7}$$

The function $W(\xi)$ is presented as

$$W(\xi) = ce^{i\lambda\xi} \,. \tag{8}$$

The characteristic equation of (7) will be

$$\lambda^4 + \left(v^2 - A\right)\lambda^2 - 2v\sqrt{\beta}\Omega\lambda - \Omega^2 = 0 \,. \tag{9}$$

This equation has four roots and then the function $W(\xi)$ has the form:

$$W(\xi) = B_1 e^{i\lambda_1\xi} + B_2 e^{i\lambda_2\xi} + B_3 e^{i\lambda_3\xi} + B_4 e^{i\lambda_4\xi} \,. \tag{10}$$

The derivatives are

$$\begin{aligned} W^I(\xi) &= B_1 i\lambda_1 e^{i\lambda_1\xi} + B_2 i\lambda_2 e^{i\lambda_2\xi} + B_3 i\lambda_3 e^{i\lambda_3\xi} + B_4 i\lambda_4 e^{i\lambda_4\xi} \,; \\ W^{II}(\xi) &= -B_1 \lambda_1^2 e^{i\lambda_1\xi} - B_2 \lambda_2^2 e^{i\lambda_2\xi} - B_3 \lambda_3^2 e^{i\lambda_3\xi} - B_4 \lambda_4^2 e^{i\lambda_4\xi} \,; \\ W^{III}(\xi) &= -B_1 i\lambda_1^3 e^{i\lambda_1\xi} - B_2 i\lambda_2^3 e^{i\lambda_2\xi} - B_3 i\lambda_3^3 e^{i\lambda_3\xi} - B_4 i\lambda_4^3 e^{i\lambda_4\xi} \,. \end{aligned} \tag{11}$$

The boundary conditions for the clamped at its ends pipe are

$$\left| \begin{array}{l} W(0) = 0 \\ W^I(0) = 0 \\ W(1) = 0 \\ W^I(1) = 0 \end{array} \right. . \tag{12}$$

Equation (12) is represented trought a linear homogenious system with unknown constants *B*:

$$\begin{vmatrix} 1 & 1 & 1 & 1 \\ i\lambda_1 & i\lambda_2 & i\lambda_3 & i\lambda_4 \\ e^{i\lambda_1} & e^{i\lambda_2} & e^{i\lambda_3} & e^{i\lambda_4} \\ i\lambda_1 e^{i\lambda_1} & i\lambda_2 e^{i\lambda_2} & i\lambda_3 e^{i\lambda_3} & i\lambda_4 e^{i\lambda_4} \end{vmatrix} \begin{Bmatrix} B_1 \\ B_2 \\ B_3 \\ B_4 \end{Bmatrix} = \begin{Bmatrix} 0 \\ 0 \\ 0 \\ 0 \end{Bmatrix} . \tag{13}$$

For non-zero roots of this system must be valid

$$\det \begin{vmatrix} 1 & 1 & 1 & 1 \\ i\lambda_1 & i\lambda_2 & i\lambda_3 & i\lambda_4 \\ e^{i\lambda_1} & e^{i\lambda_2} & e^{i\lambda_3} & e^{i\lambda_4} \\ i\lambda_1 e^{i\lambda_1} & i\lambda_2 e^{i\lambda_2} & i\lambda_3 e^{i\lambda_3} & i\lambda_4 e^{i\lambda_4} \end{vmatrix} = 0 \,. \tag{14}$$

The analogous procedure can be considered for pipe clamped at one of the ends and on a hinge support at its other end.

$$\left| \begin{array}{l} W(0) = 0 \\ W^I(0) = 0 \\ W(1) = 0 \\ W^{II}(1) = 0 \end{array} \right. . \tag{15}$$

$$\begin{vmatrix} 1 & 1 & 1 & 1 \\ i\lambda_1 & i\lambda_2 & i\lambda_3 & i\lambda_4 \\ e^{i\lambda_1} & e^{i\lambda_2} & e^{i\lambda_3} & e^{i\lambda_4} \\ -\lambda_1^2 e^{i\lambda_1} & -\lambda_2^2 e^{i\lambda_2} & -\lambda_3^2 e^{i\lambda_3} & -\lambda_4^2 e^{i\lambda_4} \end{vmatrix} \begin{Bmatrix} B_1 \\ B_2 \\ B_3 \\ B_4 \end{Bmatrix} = \begin{Bmatrix} 0 \\ 0 \\ 0 \\ 0 \end{Bmatrix}. \tag{16}$$

$$\det \begin{vmatrix} 1 & 1 & 1 & 1 \\ i\lambda_1 & i\lambda_2 & i\lambda_3 & i\lambda_4 \\ e^{i\lambda_1} & e^{i\lambda_2} & e^{i\lambda_3} & e^{i\lambda_4} \\ -\lambda_1^2 e^{i\lambda_1} & -\lambda_2^2 e^{i\lambda_2} & -\lambda_3^2 e^{i\lambda_3} & -\lambda_4^2 e^{i\lambda_4} \end{vmatrix} = 0. \tag{17}$$

In expressions (14) and (17) for different values of the non-dimensional velocity v are obtained the non-dimensional natural frequencies Ω.
Muller's Bisection numerical method is used to determine these frequencies. The expressions (14) and (17) are presented as an equation in the form $g(x)=0$. The problem is approached by iteration. A parabola is defined through three points to approach the function $g(x)$ in the zone of its interaction with the axis x. The point of the interaction of the parabola and the axis x is taken into account in the next approximation. Each iteration takes as an input the last three generated approximations.
The parabola is constructed with the following formula

$$y = g(x_i) + (x - x_i) g[x_i, x_{i-1}] + (x - x_i)(x - x_{i-1}) g[x_i, x_{i-1}, x_{i-2}] \tag{18}$$

where:

$$g[x_i, x_{i-1}] = \frac{g(x_{i-1})}{x_{i-1} - x_i} + \frac{g(x_i)}{x_i - x_{i-1}}; \tag{19}$$

$$g[x_i, x_{i-1}, x_{i-2}] = \frac{g(x_{i-2})}{(x_{i-2} - x_{i-1})(x_{i-1} - x_i)} + \frac{g(x_{i-1})}{(x_{i-1} - x_{i-2})(x_{i-1} - x_i)} + \frac{g(x_i)}{(x_i - x_{i-1})(x_i - x_{i-2})} \tag{20}$$

The zero of $g(x)=0$ is

$$x_i + \frac{2a_o}{-a_1 - \sqrt{a_1^2 - 4a_o a_2}}, \tag{21}$$

where:

$$\begin{aligned} a_o &= g(x) \\ a_1 &= g[x_i, x_{i-1}, x_{i-2}] \\ a_2 &= g[x_i, x_{i-1}, x_{i-2}] \end{aligned} \tag{22}$$

RESULTS AND DISCUSSION

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Numerical studies have been carried out for the fluid flowing pipes in Fig. 1. The axes of the pipes are outlined on semi-circles.
The geometric and the material characteristics of the pipes are: the radius *R=1 m*, the inner and the outer radii of the cross-section of the pipes are r_{inner} *= 0,012 m* and r_{outer} *= 0,014m*, Young's modulus

E=210 GPa, the density of the material of the pipe $\rho = 7800\ kg/m^3$. The density of the flowing fluid is $\rho = 1000\ kg/m^3$.
The first circular frequency is obtained for different values of the flow velocity *U*. The results are shown in Fig.2. It is obvious that with increasing the velocity of the fluid the first circular frequency decreases.
Critical fluid velocity values are obtained when the circular frequency is equal to zero.
$U_{cr} = 34{,}02\ m/s$ – for clamped-clamped pipe;
$U_{cr} = 19{,}57\ m/s$ – for clamped-hinged pipe.

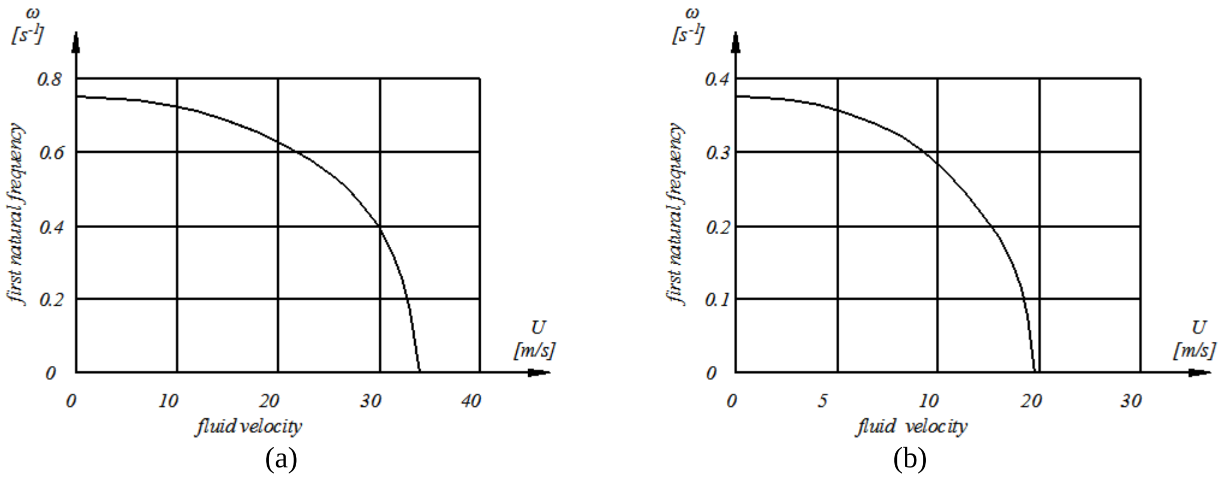

Figure 2. Dependence of the first circular frequency of the system on the fluid velocity:
(a) clamped-clamped arc, (b) clamped-hinged arc

CONCLUSION

The employed Muller's method in the paper allows relatively easy determination of the first natural frequencies of the out of plane vibrations of pipes with axes bent on an arc of circle and with flowing fluid. The method could be competitive with other established approaches for investigating the dynamic stability of the pipes conveying fluid like the Matrix method.
The results show the dependence of the circular frequency of the system on the fluid velocity. Increasing the fluid velocity leads to decrease in the circular frequency. At the point where the circular frequency is equal to zero, the corresponding fluid velocity is known as the critical fluid velocity. When the critical fluid velocity is reached, the system is at the edge of loss of stability.
Results show that the clamped-clamped pipe is more stable, then clamped -hinged.

REFERENCES

[1] Chen, S., Out-of plane vibration and stability of curved tubes conveying fluid, Journal of Applied Mechanics, Transactions ASME, Vol. 40, pp. 362–368, 1973.
[2] Dupuis, C., Rousselet, J., The equation of motion of curved pipes conveying fluid, Journal of Sound and Vibration, Vol. 153, Issue 3, pp. 473-489, 1992.
[3] Hill, J., Davis, C., The Effect of Initial Forces on the Hydroelastic Vibration and Stability of Planar Curved Tubes, Journal of Applied Mechanics, pp.355-359, June 1974.
[4] Liang, F., Yang, X.-D., Bao, R.-D., Zhang, W., Frequency Analysis of Functionally Graded Curved Pipes Conveying Fluid, Advances in Materials Science and Engineering, Vol.2016, Article ID 7574216, 2016.
[5] Lolov, D., Lilkova-Markova, S., Free vibration out-off plane of curved planar pipe conveying fluid in two cases of supporting, Annual of the University of Architecture, Civil Engineering and Geodesy, Mathematics, Mechanics, Vol. XLII, 2002-2003, pp. 123-128, 2006.
[6] Misra, A., Paidoussis M., Van K., On the dynamics of curved pipes transporting fluid. Part I: Inextensible theory, Journal of Fluids and Structures, Vol.2, Issue 3, pp. 221-244, 1988.

[7] Shankarachar, S., Madabhushi, R., Chellapilla, K., Babu, P., Determination of the Natural Frequencies of Fluid Conveying Pipes using Muller’s Method, J. Inst. Eng. India Ser. C, The Institution of Engineers (India), 2018.
[8] Svetlitsky, V., Statics, stability and small vibrations of the flexible tubes conveying ideal incompressible fluid, Raschetv na Prochnost, Vol.14, pp. 332-351, 1969.
[9] Zhao, Q., Sun, Z., In-plane forced vibration of curved pipe conveying fluid by Green function method, Applied Mathematics and Mechanics (English Edition), Vol.38, Issue 10, pp. 1397-1414, 2017.
[10] Zhao, Q., Sun, Z., Flow-induced vibration of curved pipe conveying fluid by a new transfer matrix method, Engineering applications of computational applied mechanics, Vol.12, NO.1, pp. 780-790, 2018.

DESIGN OF THE STRENGTHENED FRAMEWORK FOR A DESIGNED CONCEPT OF THE SPORT CAR BODY

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Abstract: This paper presents design process and checking of the static stiffness of a sport car chassis at the conceptual design stage. Based on the requirement list, the concept of car body is designed, which is then analyzed from the point of aerodynamics, i.e. CFD analysis. With the analysis is determined that the car body is exposed to predominantly laminar flow of fluid with the presence of turbulent flow in the rear part of the car body. According to the data obtained from the aerodynamic analysis, the construction of the chassis is started. The chassis is the central supporting part of the overall car construction, which by its shape needs to follow outer contours of the car body. The chassis is reinforced with front and lateral attenuators. Attenuators are absorbing the energy that is releasing from strike.
Key words: Car chassis, Computational Fluid Dynamics (CFD), Design process, Function, Requirement list

INTRODUCTION

The car body is using for accommodation and protection of driver, passengers and luggage from outside influences. Depending on the design, certain assemblies such as aggregates, tanks, electrical appliances, etc. also can be placed to the car body.
In addition to the general requirements (minimal weight, sufficient lifecycle, simple design), car body needs to satisfied the following specific requirements: space for vehicle assembly accommodation, passive safety of driver and passengers, a suitable aerodynamic profile, good visibility, sound isolation, dust isolation, isolation from the cold, heat and moisture.
Self-supporting car bodies ensure higher stiffness and have lower mass. Such a car body is often calling a chassis. Chassis therefore has the following functions: ensures the safety of passengers, serves as a foundation for attaching other parts of the car and gives the exterior form of the car.
Below the work are presented the chassis design forms used in the auto industry for the production of racing cars. Ladder chassis (Fig. 1a) consists of two longitudinal rails that are assembled with multiple transverse rails [1]. Longitudinal rails take over stress, lateral rails provide resistance to lateral forces and increase chassis torsional stiffness. Because it is a two - dimensional structure, it has small torsional stiffness.

a b c d

Figure 1. Car chassis design forms

Tubular chassis (Fig. 1b) represents a three - dimensional structure with greater torsional stiffness compared to the ladder chassis [2]. Tubes are positioned in different directions to take over stresses from different directions. Tubes are mutually welded. Chassis is expensive for production, takes a lot of space and car access is inaccessible.
One part chassis (Monocoque) consists of one part that defines the entire car form (Fig. 1c). It occurs by welding individual parts into a unified whole. The entire structure makes an exterior shell that is

designed to provide greater space for passengers. Therefore, it has reduced stiffness. It is suitable for mass production and robotization, but it has a large mass [3].
Carbon fiber chassis (Fig. 1d) usually uses kevlar as the kind of carbon fiber for its making [4]. Carbonic components are made of layers of carbon fibers, which are wrapped in aluminum foil after stacking. The foil takes the form of the panel from which the air is extracted. Then, it boils for about 3 hours at 120 ° C under a pressure of 0,6 MPa. After that, the carbon fiber panels are assembled in solid form. This chassis, compared to other chassis, has the smallest weight and the greatest stiffness, but is also the most expensive to make.
In this paper was analyzed the problem of creating a downforce. This force presses the car on the ground and allows better tire adhesion to the ground. The problem was analyzed by installing the rear diffuser in car body. Such a construction solution reduces the area of accumulated turbulent air behind the car. In the rear part of the car body has implemented a spoiler, which in this embodiment does not constitute a separate element. The car body is shaped in such a way that its form is aerodynamic. It looks like a drop of water. This form in the nature is the most aerodynamic body. According to the form of the car body whom we designed, the design of the chassis was started. The chassis form needs to be implemented in a form of a car body. It should be designed as a three - dimensional supporting element. It also should be resistant to torsional stresses, dynamic strikes and made of materials that reduce total chassis mass.

REQUIREMENT LIST OF THE CAR BODY AND CAR CHASSIS

By the requirement list [5] are involved requirements for the design of the car body and chassis. A detailed description of the all requests is presented in [6]. In Table 1 are listed the most important requirements, according to which the forming and design of the car body and car chassis is made.

Table 1. Requirement list of the car body and car chassis

No.	Requirement	No.	Requirement
1.	Car body dimensions: L_{max}=4850 mm, W_{max}=2100 mm, H_{max}=1200 mm	12.	The maximum weight of the vehicle with thrusters is 1550 kg
2.	Wheelbase 2600 mm	13.	The chassis must submit a static load up to 3g
3.	Place two people in the chassis	14.	To form the front part of the chassis to absorb the front dynamic strikes
4.	Most of the car mass place between the axles	15.	To form the side piers of the chassis to absorb side dynamic strikes
5.	To enable the force of aerodynamic thrust by car body geometry	16.	To achieve the force of aerodynamic thrust through an car body to ensure better wheel adhesion on the ground
6.	To enable laminar air flow by car body geometry	17.	To form the rear part of the car body to reduce the impact of the traction force on the car
7.	To reduce turbulence of the wind by car body geometry	18.	To form the roof of the chassis so that it does not bend during uncontrolled rotation of the vehicle
8.	To enable engine cooling by car body geometry	19.	Make chassis from noncorrosive materials
9.	To enable braking system cooling by car body geometry	20.	Make chassis from lightweight materials
10.	Maximum vehicle speed up to 350 km/h	21.	The chassis material should submit dynamic loads
11.	The chassis must wear the car's components	22.	The driver's seat space should not be damaged when the frontal impact of the car is 56 km/h

MODELING A COMPUTER 3D MODEL OF CAR BODY

Because of the complex geometry, modeling of the car body has done in the Autodesk May [7] software package, not in any of the commercial CAD systems. The car body is made of polygons freely deformed in space and there are no necessarily dimensional constraints, as is the case with

commercial CAD systems. This approach allows free form design, which in a much faster way leads to the desired form of car body. A primitive *plane* was used for modeling, which was upgraded with several polygons and then with the free form design techniques formed into a surface model of the car body (Fig. 2a). The final surface model of the car body is shown in figure 2b.
In order to calculate the car body aerodynamics, the model was imported from Autodesk May into one of the commercial CAD systems and a solid model of a car body was made from the surface model of a car body. Generation of solid model was performed in SolidWorks [8].

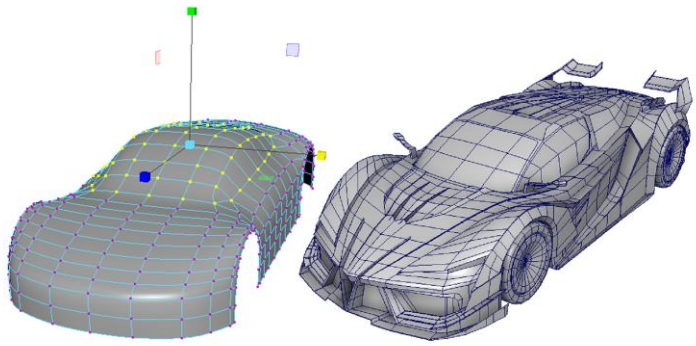


Figure 2. Car body form in Autodesk Maya

Orthogonal projections of the surface model of the car body from Autodesk May were imported into the sketching planes in SolidWorks (Fig. 3a). From orthogonal projections, curves were generated in the sketching planes (Fig. 3b). The curves are interconnected using surface segments and form a closed surface model (Fig. 3c). Procedure is very long and requires great precision in the modeling process. From surface model, by filling the volume, a solid model of car body was generated. The surface model that was generated in the solid model consists of 700 2D sketches, 200 3D sketches and 300 space curves.

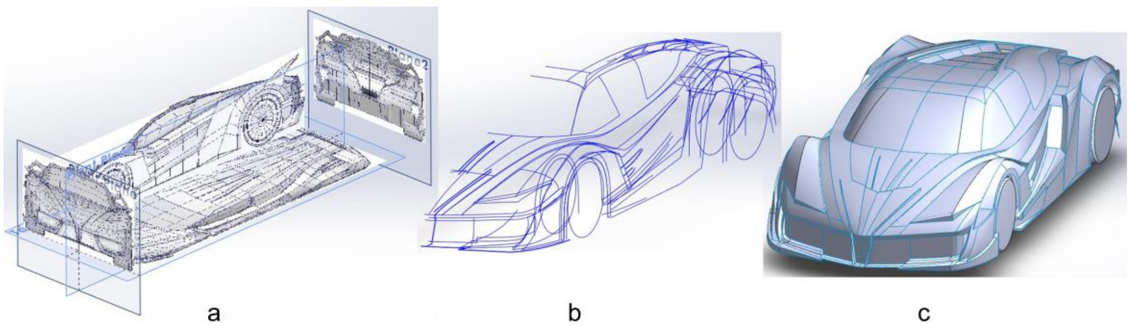


Figure 3. A car body space model in SolidWorks

AERODYNAMIC CALCULATION OF THE CAR BODY

An analysis of the airflow around the car body was made in the ANSYS Fluent [9] software package. Due to the complexity of the geometry and the limited resources of the computer on which the calculation was performed, there was a need to simplify the CAD model. Therefore, the numerical calculation results obtained by CDF analysis are not within the values that would be expected if the above condition was met. Since this is a conceptual solution, these results are satisfactory and acceptable from the point of view of the conceptual design phase. The simplified model contains the basic contours of the car body and presented is in figure 4.
Domain discretization was performed. The goal of the discretization is to divide the physical space in which fluid flow is calculated into a large number of elements called the mesh [10]. The entire car body model was taken into account due to the airflow through the symmetry plane from left side to right side of the car body and inversely. Also, turbulent and laminar flow will not be equal on both sides of the car body. On the car body was added closed space. This space represents air. The Boulean

operator took away the car body from the air body. The final domain is shown in figure 5a. The domain length consists of three car body lengths; two lengths behind the car and one length in front the car. The domain height contains two car body heights. The domain width consists of three car body widths. Tetrahedral finite elements were selected and a structured and unstructured grid was laid (Fig. 5b). The structured mesh is set up in five layers around the car body. The minimum size of the first layer is 5 millimeters and increases by 20% up to the fifth layer. This layer is called the inflationary layer of the mesh (Fig. 5c).

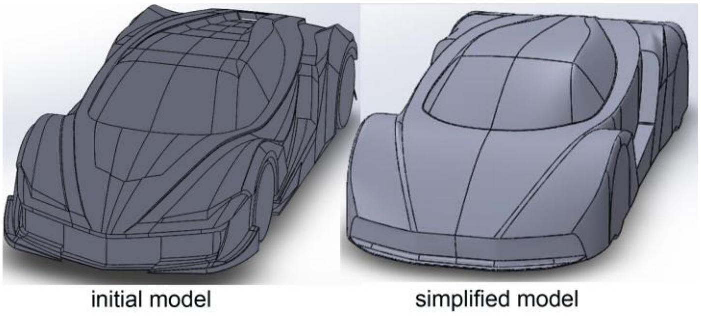


Figure 4. CAD model of car body prepared for aerodynamic analysis

An unstructured network of tetrahedral elements makes the rest of the discretized domain with an initial element size of 5 mm. Towards the edge of the domain the element size is 100 mm. A k - epsilon fluid flow model is placed. Domain`s working media is air with temperature of 25°C. The following boundary conditions are set: the velocity of airflow at the front surface of the domain is 50 m/s, the pressure at the back surface of the domain is equal to atmospheric pressure and is defined as 0 MPa, the surfaces through which air cannot pass and turns down with the path change (lower surface, which is the ground on which the car moves and surfaces that represent the contour of a car within a domain) and definition of the space within which the air motion is analyzed (left / right side surfaces and the top surface of the domain).

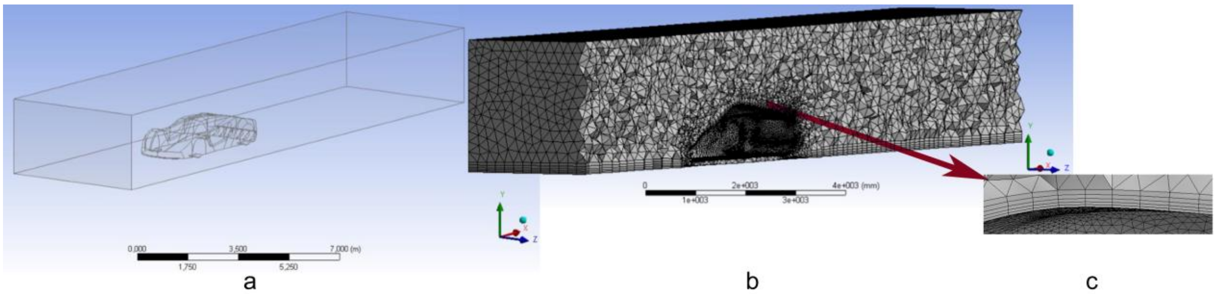


Figure 5. Discretized domain and finite element mesh

With the results of CFD analysis are covered: wind flow velocity in the domain`s area around the car body model (Fig. 6) and pressure distribution on the car body (Fig. 7).

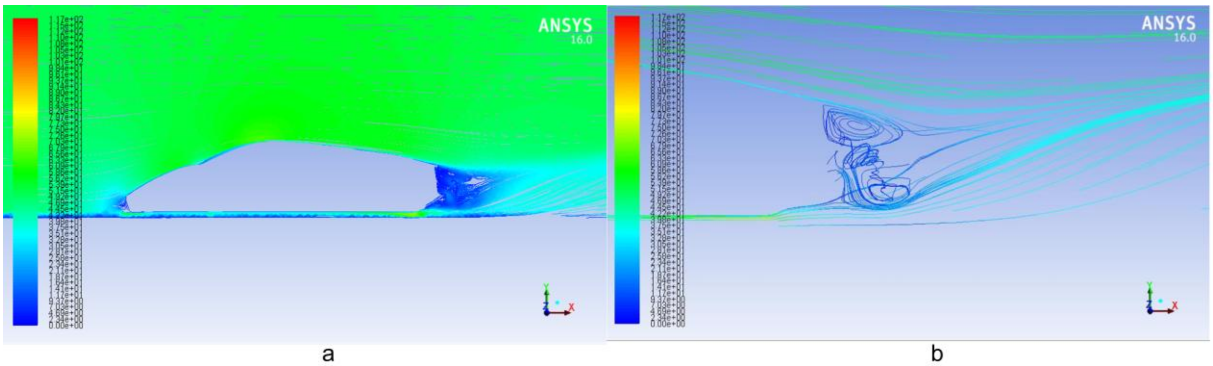
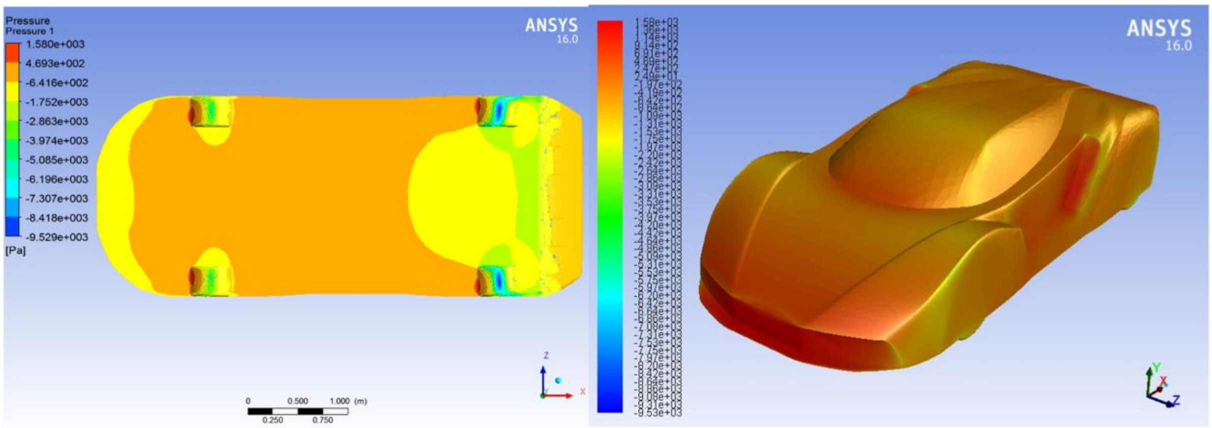


Figure 6. Wind velocity in the area of the discretized domain

The lowest wind velocity is present in front of the car body, because the wind hits the front nose (Fig. 6a). Also, the lowest wind velocity is at the rear car part where the air is spinning (Fig. 6b). Air velocities are higher at places where geometry changes. At the rear diffuser part, the air velocities below the car are increased, where a low-pressure area is created. Therefore, at the exit of the diffuser, the air slows down and pressure increases.
The air velocity before exiting from the diffuser is about 90 m/s (Fig. 6b). This velocity is higher than the air velocity above the car, creates an under pressure area under the car, and draws it to the ground. In the rear part, a region of turbulence is visible, which appears due to the large diffuser angle. Wind flow cannot follow this angle well enough when exiting under the car. The wind separates from the diffuser and creates a larger area of turbulence. It would be desirable to decrease the diffuser angle due to the reduction of the turbulent area behind the car.



a b

Figure 7. Pressure distribution on the car body

Figure 7a shows the pressure distribution below the car. The under pressure area prevails under the car and creates a vacuum that makes the car better fit to the ground with its wheels. This creates a downforce that pushes the car to the ground. Figure 7b shows the pressure distribution over the entire car body. The highest pressures occur at the front of the car body. This is because the body of the car directly encounters air resistance. The same phenomenon occurs in areas where air is sucking into the engine.

DESIGN AND CALCULATION OF CAR CHASSIS STATIC STIFFNESS

The chassis needs to be designed and shaped to follow the outer contours of the car body. It needs to be implemented within the car body. The chassis should absorb as much energy as possible from the impact. This must be achieved by decreasing the material resistance of the front part of the car body to the resistance of the material that forms the structure that protects the driver in the car.

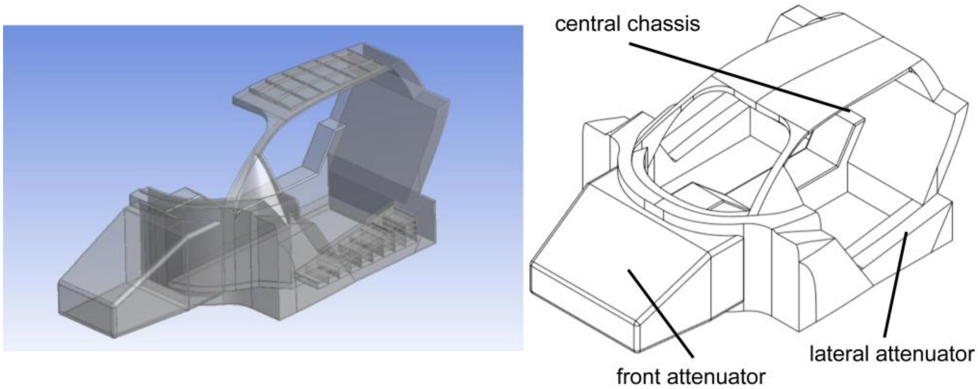


Figure 8. Design solution of car chassis

Therefore, it is necessary to design attenuators. An attenuator is a safety barrier between the driver and the surface exposed to impact. It needs to be deformable and needs to absorb as much as possible of the energy released as a result of the impact. Accordingly, a chassis was designed consisting of a front attenuator, two lateral attenuators and a central chassis (Fig. 8). The chassis is designed as a single body. This kind of chassis has higher torsional stiffness than multi-body chassis. For the chassis material, a composite material from the Ansys Workbench material library is selected. The material properties are presented in Figure 9.

Properties of Outline Row 5: Epoxy_Carbon_UD_395GPa_Prepreg

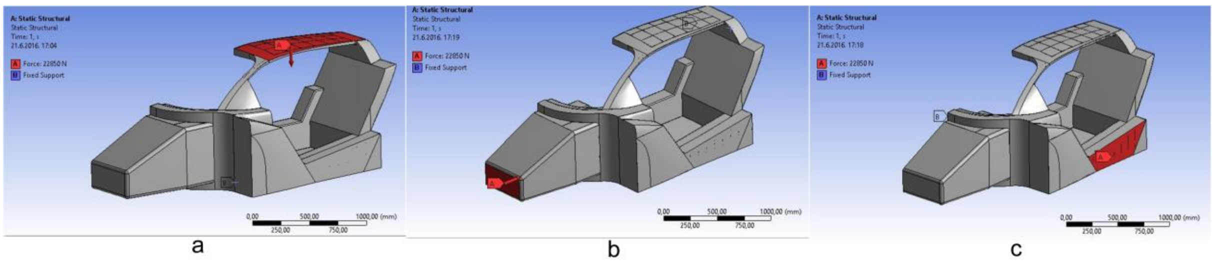
	A	B	C
1	Property	Value	Unit
2	Density	1,54E-09	mm^-3 t
3	Orthotropic Secant Coefficient of Thermal Expansion		
9	Orthotropic Elasticity		
10	Young's Modulus X direction	2,09E+05	MPa
11	Young's Modulus Y direction	9450	MPa
12	Young's Modulus Z direction	9450	MPa
13	Poisson's Ratio XY	0,27	
14	Poisson's Ratio YZ	0,4	
15	Poisson's Ratio XZ	0,27	
16	Shear Modulus XY	5500	MPa
17	Shear Modulus YZ	3900	MPa
18	Shear Modulus XZ	5500	MPa
19	Field Variables		
23	Orthotropic Stress Limits		
24	Tensile X direction	1979	MPa
25	Tensile Y direction	26	MPa
26	Tensile Z direction	26	MPa
27	Compressive X direction	-893	MPa
28	Compressive Y direction	-139	MPa
29	Compressive Z direction	-139	MPa
30	Shear XY	100	MPa
31	Shear YZ	50	MPa
32	Shear XZ	100	MPa

Figure 9. Chassis material properties

The following stresses are applied to the chassis: diagonal accumulation stresses, lateral flexion, vertical flexion at rapid acceleration, torsional stiffness and static stiffness. In this paper, testing was only performed on static stiffness. It is therefore necessary to determine the condition of static stiffness. The chassis must persist 2,5 to 3,5 car weights [11]. The weight of the car also includes the weight of the person. For the average mass of one person, we took the mass of 75 kg. The mass of the vehicle is m_v = 1402,83 kg. Static force by which we load the chasses, according to [11] is:

$$F_z = 3 \cdot g \cdot (m_v + 150) = 3 \cdot 9{,}81 \cdot (1402{,}83 + 150) = 45699{,}78\,\mathrm{N} \approx 45700\,\mathrm{N} \qquad (1)$$

Because the chassis model is symmetrical, we only analyzed half of the model. The amount of static force is F_z = 22850 N. The chassis is on the compressive stress on the roof (Fig. 10a), front attenuator (Fig. 10b) and lateral attenuator (Fig. 10c). The temperature of the composite material is 22°C. The chassis model is cross-linked using 5 mm tetrahedral elements.



a b c

Figure 10. The activity of static force on the chassis

When loading the chassis by force F_z from the top side, a maximum displacement of 10,272 mm was obtained (Fig. 11a). Depending on the type of material, the amount of displacement is acceptable. The amount of maximum stress is 212,18 MPa (Fig. 11b). Such stress appears at sharp edges because the material is on that place thin. Because the amount of stress is less than the allowed material stress, no plastic deformation of the material has occurred. Therefore, it is possible to conclude that the construction satisfies.

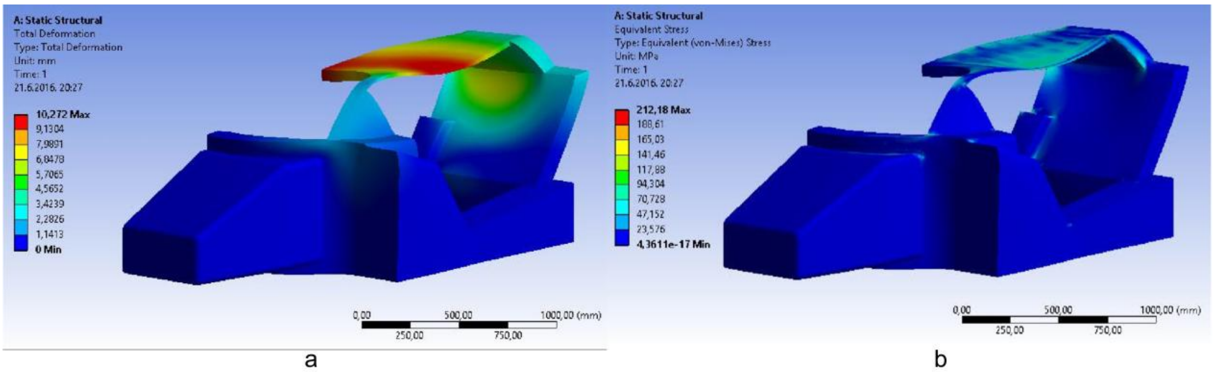


Figure 11. Overall displacement and stress of the upper chassis part

When loading the chassis by force F_z from the front part, a maximum displacement of 4,9915 mm was obtained (Fig. 12a). The amount of displacement is acceptable. The amount of maximum stress is 101,04 MPa (Fig. 12b). Because the amount of stress is less than the allowed material stress, no plastic deformation of the material has occurred. It is possible to conclude that the construction satisfies.

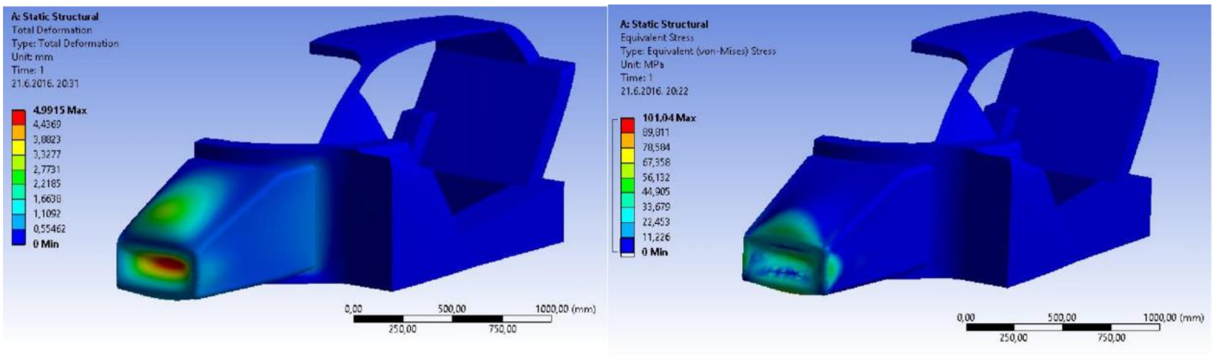


Figure 12. Overall displacement and stress of the front attenuator

When loading the chassis by force F_z from the lateral side, a maximum displacement of 0,68812 mm was obtained (Fig. 13a). The amount of displacement is negligible, and the chassis has a very high static stiffness on the lateral side. The amount of maximum stress is 79,156 MPa (Fig. 13b). Because the amount of stress is less than the allowed material stress, no plastic deformation of the material has occurred. It is possible to conclude that the construction satisfies.

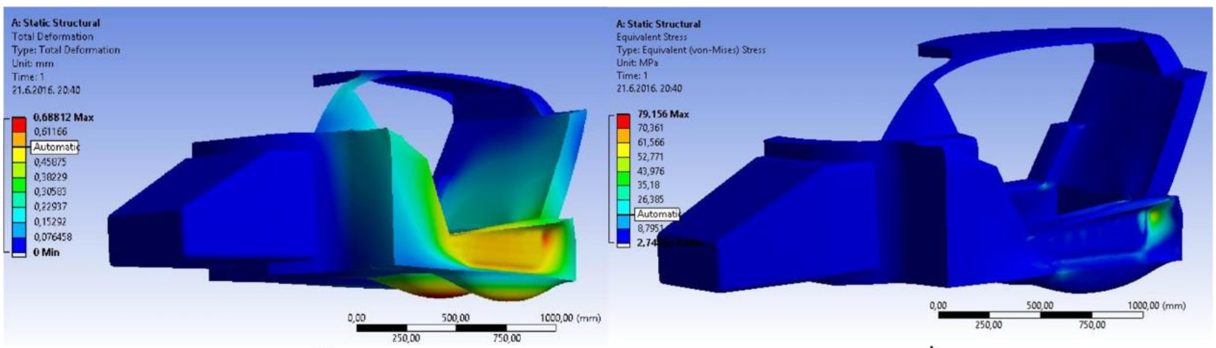


Figure 13. Overall displacement and stress of the lateral attenuator

CONCLUSION

The aim of this paper is to present the design procedure and calculation of the static stiffness of a sports car chassis in the conceptual design phase. After the car body was designed according to the requirements in the requirement list, the aerodynamic calculation of the car body was performed. Analysis of the airflow around the car body, using CFD analysis, was performed in the ANSYS Fluent software package. The analysis shows that the airflows is laminar along the above contour of the car body. Below the car body, the air is accelerated relative to the air velocity above the car body. This is why a vacuum is created under the car body. This creates a downforce that pushes the car to the ground and allows better tires grip.

Turbulence occurs at the rear part of the car body, due to the large diffuser angle. Wind flow cannot follow this angle well enough when exiting under the car, therefore the wind separates from the diffuser. The problem should be solved by optimizing the angle of the diffuser.

The calculation of the static stiffness of the chassis with respect to the static force has performed. The calculation results are satisfactory with regard to the choice of composite material. From the results obtained from the calculation of static stiffness, it can be concluded that the chassis can be further optimized in order to reduce its mass. This is also desirable in order to reduce the overall mass of the sports car and in such a way improve driving performance.

The paper proposes some guidelines that could produce better results, but for such approaches, it is necessary to have more powerful computers and knowledge that sports car manufacturers are not yet ready to cede outside their research institutes. The reasons are more than clear, as they greatly affect to their competitiveness.

REFERENCES

[1] HotRod Magazine, PalmCoast, FL, Christopher Campbell: 64-81 Muscle Car Chasis Guide-Getting Framed: http://www.hotrod.com/howto/chassis-suspension/1208phr-64-81-muscle-car-chassis-guide/
[2] British RaceCar, Connecticut, Bob Millstein: Walt Hansgen Jaguar XK120 Special: http://www.britishracecar.com/BobMillstein-Jaguar-HansgenSpecial.htm
[3] CarThrottle, Matt Robinson: Watch Your Back: https://www.carthrottle.com/post/watch-your-back-bmw-3-series-the-new-jag-we-is-gunning for-you/
[4] Motortrend, ElSegundo, CA, Eric Ayapana: 2012 Paris: Ferrari shows off carbon fiber chassis of enzo sucessor: http://www.motortrend.com/news/2012-paris-ferrari-shows-off-carbon-fiber-chassis-of-enzo-successor-268659/
[5] Eder, V. E., Theory of Technical Systems-Educational Tool for Engineering, Universal Journal of Educational Research, Vol. 4, No. 6, pp. 1395-1405, doi: 10.13189/ujer.2016040617, 2016.
[6] Salamunović, D., Konstruiranje ojačanog okvira I platforme za dizajniranu oplatu sportskog automobile, Strojarski fakultet u Slavonskom Brodu, 2016.
[7] Autodesk Maya, Release 2012, Autodesk Inc., 2012.
[8] SolidWorks 2018, Release 2018, DassaultSystem SE, 2018.
[9] Ansys CFX, Release 16.0, ANSYS Inc., 2016.
[10] Wallin, S., Applied Computational Fluid Dynamics, 2nd Edition, Stockholm Dept. Of Mechanicsand Systems Dept., FOI, 2009.
[11] Trzesniowski, M., Rennwagentechnik, Grundlagen, Konstruktion, Komponenten, Systeme, Auflage 2, Wiesbaden, Springer, 2008.

SOME ASPECTS OF THE ELECTRICAL POWER QUALITY

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Abstract: The paper presents basic definitions, terms and indicators of the quality of electricity. Higher harmonics and their consequences are presented. Degradation of basic voltage parameters (effective value, frequency, phase shift, symmetry, etc.) as well as waveform distortion, ie short-term or long-term deviations from the sinusoidal shape (higher harmonics, short-term interruptions, voltage failures, impulse overvoltages and others) represents a low-frequency part of the conduction disturbances that most affect the voltage quality as part of the electromagnetic compatibility problem. Basic standards and recommendations for controlling higher harmonics in electrical networks are given.
Key words: electrical power quality, higher harmonics, standards

INTRODUCTION

The concept of quality of electricity is complex [1-4], because in addition to user, ecological and commercial quality it implies technical quality as a synonym for the quality of electricity, which includes problems of reliability and security of power supply, overall stability of system operation, numerous disruptions as well as the rental ratio of the electric power system - consumer and vice versa.
The problem of the technical quality of electricity is any phenomenon that is reflected in the disturbance of the basic parameters of the voltage in the established or transient states, disturbing the waveforms of the voltage and the current, their phase shift as well as the deviation of the frequency [1-4].
Ideally, the voltage of the electrical network should be the sine waveform, the nominal frequency, the nominal effective value, while the ideal current is also sinusoidal, without harmonic distortion and in the phase with voltage [1-4]. In reality, however, the quality of the delivered electricity is impaired by various irregularities, such as: overvoltages, undervoltage, short-term voltage abnormalities, voltage peaks, flickers, higher harmonics, etc.
Non-linear consumers (electrical energy devices, electric machines, electric furnaces and others) have a dominant influence on the physical voltage quality, transient phenomena due to commutations in the system with switches, automatic re-switch, switching on / off of large consumers etc.).
The switching nature of the operation of the power electronics device and the consumption of non-ionic currents causes the appearance of higher harmonics, deforms the waveform of the network voltage, a weak power factor, causes electromagnetic interference, and hence degrades the quality of electricity.
Degradation of basic voltage parameters (effective value, frequency, phase shift, symmetry, etc.) as well as waveform distortion, ie short-term or long-term deviations from the sinusoidal shape (higher harmonics, short-term interruptions, voltage failures, impulse overvoltages and others) represents a low-frequency part of the conduction disturbances that most affect the voltage quality as one part of the EMC problem [1-4].
Today there are extensive research of quality parameters, continuous testing and supplementation of technical regulations for limitations of harmonics and flicker levels, more stringent standards for connecting non-linear consumers are introduced. Based on the large number of research papers, and in particular the recommendations of the working groups, the relevant organizations relevant to the EMC, international and national standards are continuously updated, adjusted and improved.

BASIC DEFINITIONS, TERMS AND INDICATORS OF THE QUALITY OF ELECTRICITY

Many answers apply to this simple question. They all depend on your perspective. From the utility perspective, Power Quality has been defined as the parameters of the voltage that affect the customer's supersensitive equipment. From the power user perspective, Power Quality may be defined as any electrical parameter or connection that affects the operation of the equipment. This includes all electrical parameters, connections and grounds, whether the source from the utility, local equipment or other users. From the Power Quality market or industry perspective, it is any product or service that is supplied to users or utilities to measure, treat, remedy, educate engineers or prevent Power Quality issues, problems and related items.
Power distribution systems, ideally, should provide their customers with an uninterrupted flow of energy with a clean sinusoidal voltage at the contracted voltage level (110kV, 30kV, 10kV, 415V) and frequency (50Hz) (Fig.1). However, in practice, power systems, face a variety of challenges either from generation, transmission and distribution or even within a customer facility which impacts the quality of power. These power quality issues can affect the uninterrupted operation of customer loads, but the safety-related issues can reduce the life of the connected loads and electrical equipment. A customer having numerous nonlinear loads can also affect the quality of power supply and the purity of the voltage waveform is lost which can affect other loads within the facility or even outside the customer facility. Apart from nonlinear loads, some system events, both usual (e.g. capacitor switching, motor starting) and unusual (e.g. faults) could also inflict power quality (PQ) problems.

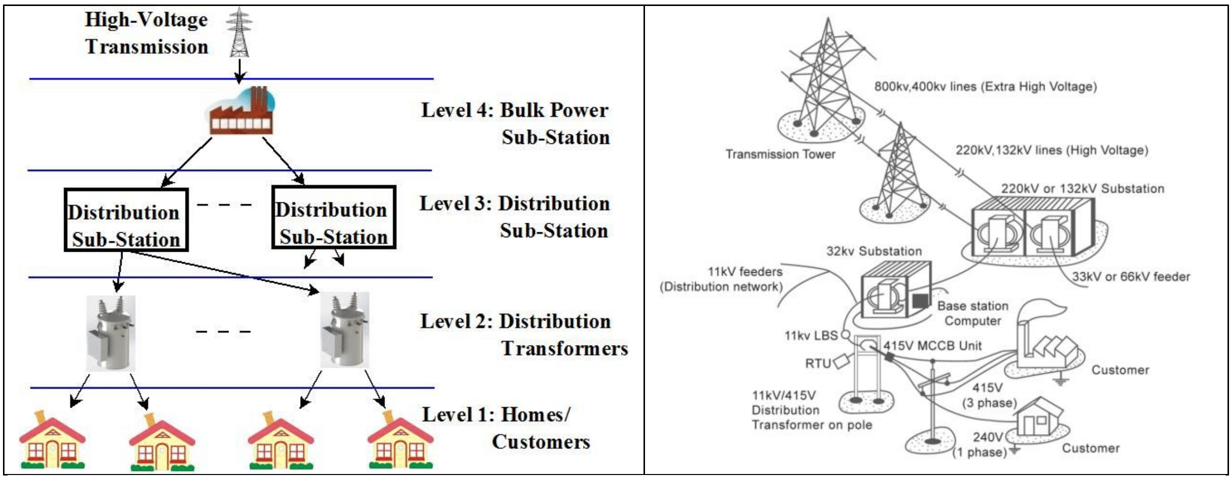

Figure 1. Typical electricity distribution hierarchy.

The quality of electricity is mostly related to the quality of voltage and frequency, i.e. their deviation from the nominal value as well as the comparison of the waveforms of the current and voltage relative to the ideal sinusoid.
The basic parameters and deformation of waveforms, among others, are two groups of factors that determine the quality of the used voltage [2]. The basic parameters of the used voltage include the variation of the effective value of the voltage, frequency and the occurrence of an asymmetry in the supply. The deformation of the waveforms of the voltage includes the following states: stable states of the system (harmonics, voltage notches, flickers and noise), transient regime of the system (overvoltages, undervoltage, voltage failure, voltage overload, short-circuit breaks) and transient states (impulses and oscillations). On Fig.2. gives an overview of the factors of the quality of the used voltage.

Harmonics are sinusoidal voltages and currents at frequencies that are integers of the basic network frequency. Distorted waveforms consist of a fundamental component and components with frequencies up to 5 kHz (Fig.3).

Voltage cutouts are periodic intermittent faults that last less than 1 ms, typically 0.3 ms. The result is commutations with a network of switched converters. Typical values are in the range 10 -90% of the nominal voltage.

Noise (electromagnetic interference): corresponds to high frequency electromagnetic noise, which can, for instance, be produced bythe fast switching of electronic power converters (Fig.4).

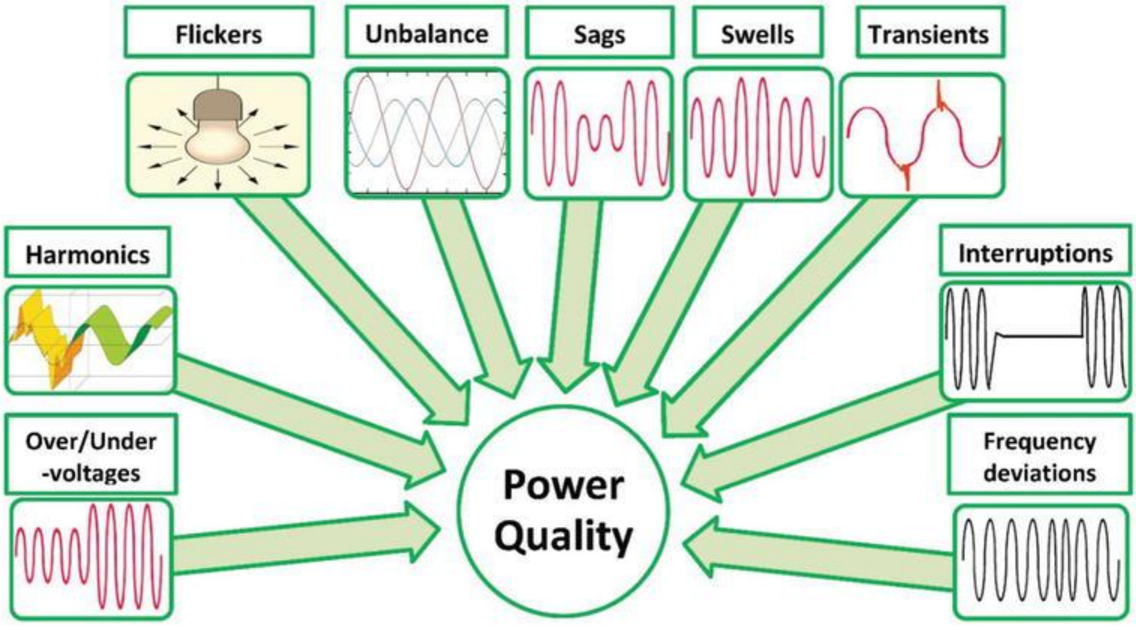

Figure 2. The common power quality problems

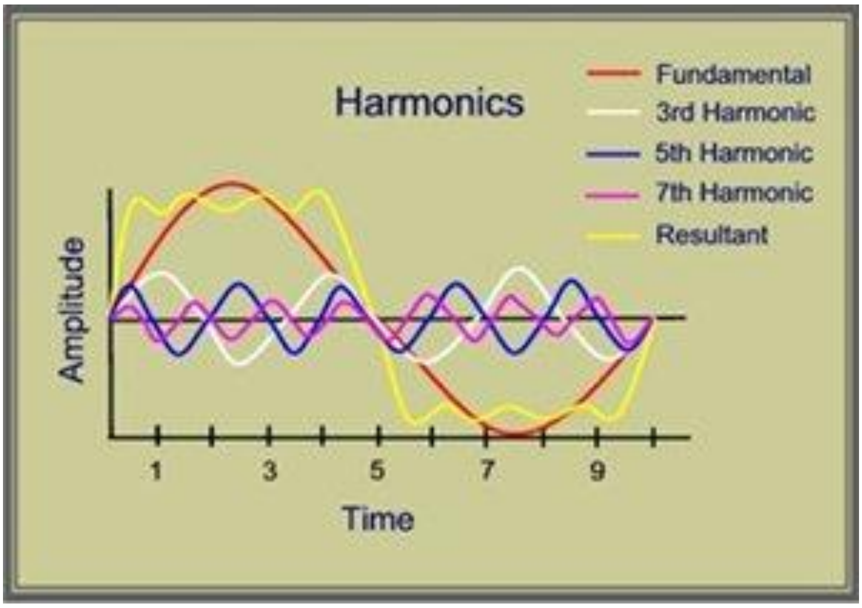

Figure 3. Decomposition example of a complex distorted signal, as addition of 50Hz fundamental and 3rd, 5th and 7th harmonics (150Hz, 250Hz, 350Hz respectively).

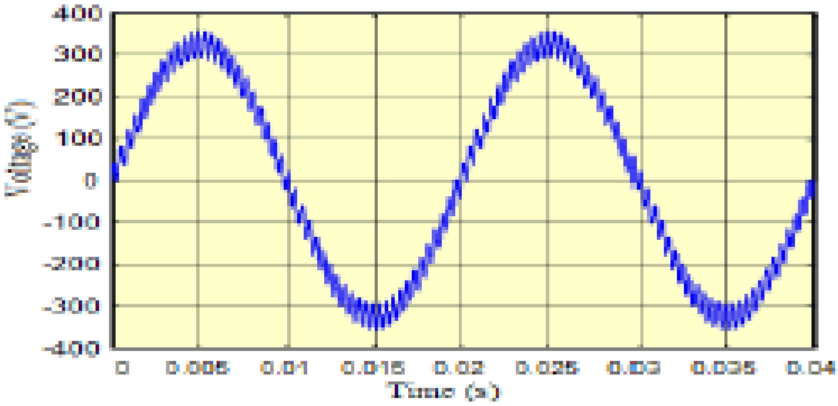

Figure 4. Noise (electromagnetic interference) [6]

Momentary interruption: occurs, for instance, when the electrical system has automatic reset circuit breakers, that opens when a fault occurs, closing automatically after some milliseconds (and is kept closed if the short-circuit is extinguished) (Fig.5.).

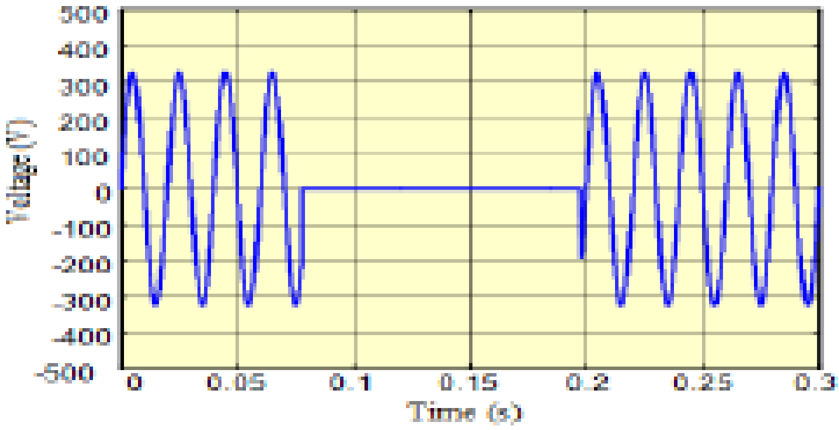

Figure 5. Momentary interruption

Voltage sag: can be caused, for instance, by a momentary short-circuit at another branch of the same electrical system, which is eliminated after some milliseconds by the opening of the branch circuit breaker (Fig.6.).

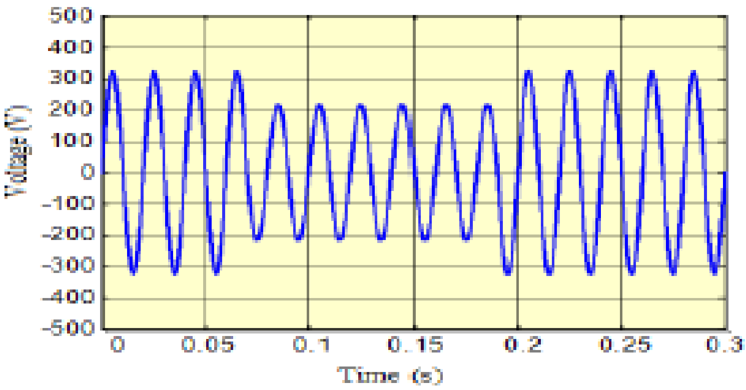

Figure 6. Voltage sag [6]

Voltage swell: can be caused, amongst other cases, by fault situations or by commutation operations of equipments connected to the electrical grid (Fig.7).

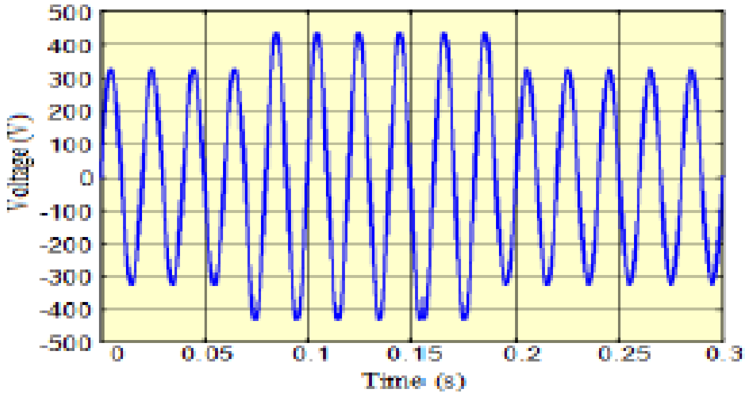

Figure 7. Voltage swell

Flicker: it happens due to intermittent variations of certain loads, causing voltage fluctuations (which results, for instance, in oscillations on electric light intensity) (Fig.8).

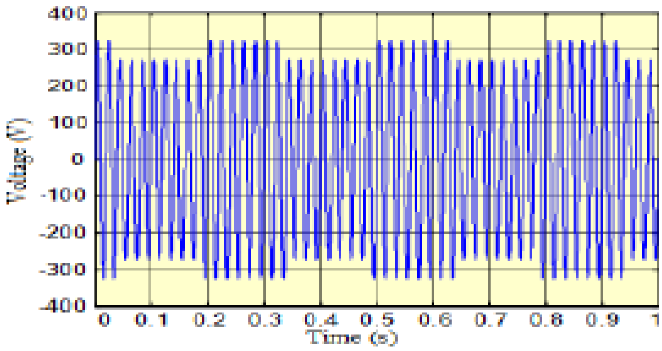

Figure 8. Flicker

Notches: Consist in small periodic cuts on the voltage waveform, which result from voltage drops on the line inductances of the electrical system. These occur due to loads which consume currents with abrupt periodical variations (like rectifiers with capacitive or inductive filter)(Fig.9).

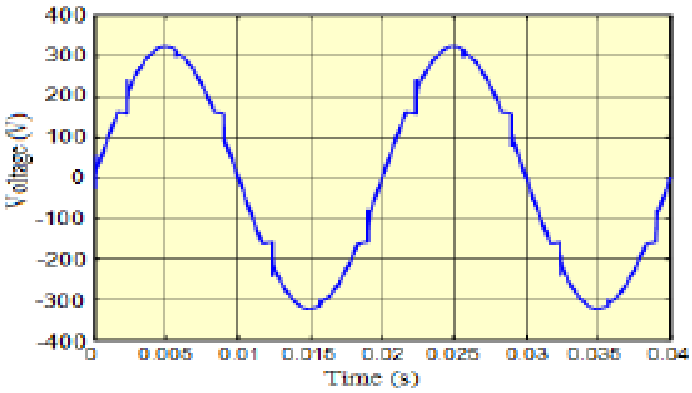

Figure 9. Notches [6]

Transients: occur as a result of transitory phenomena, such as capacitor bank switching or atmospheric discharges (Fig. 10).

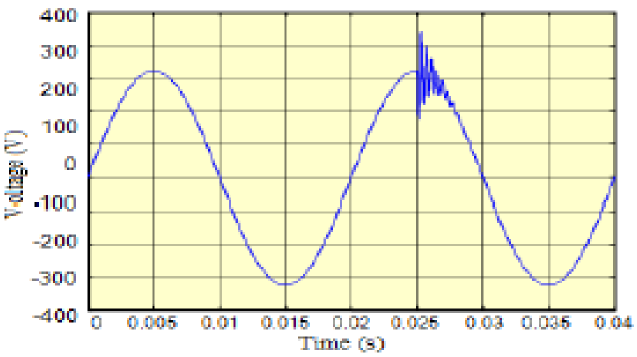

Figure 10. Transients

HARMONICS AND THEIR CONSEQUENCES

One of the definitions of harmonics is that it represents a periodic oscillation present in a complex function, the value of which is an integer multiplication of the basic frequency [2-4]. Similarly, in electrical engineering according to the IEC vocabulary, the term harmonics is a component of a Fourier order of some periodic size whose order is greater than one. Harmonics occur even in the process of electricity generation, transmission and by individual consumers.

The development of powerful semiconductor components, and a series of new topologies of power converters, have led to their widespread use. The non-linear (switching) nature of these devices is the cause of higher harmonics of voltage and current in the network to which they are connected, and when it comes to the high power of these devices or a larger number of devices, less power makes them the main cause of the disruption of the quality of electricity.

Higher harmonics cause a variety of side effects. These are interruptions in the operation of computers, faults in the operation of protective equipment, measurement errors, overvoltages, interference with communication and signaling devices, additional heating of electrical machines, etc. All of these effects can have very serious technical and economic consequences, so today special attention is paid to the problem of eliminating higher harmonics from the network.

The current modern electrical and electronic equipment should be designed to work reliably even under "polluted" conditions, since any limitation of the higher harmonics level must respect real technical, technological and economic conditions, since the complete elimination of higher harmonics is practically impossible [2-5].

For complete processing and analysis of higher harmonics, it is necessary to gain insight into different aspects of their appearance, influence, measurement (measuring size, places and methods of measurement), monitoring methods, standardization (standards, recommendations, instructions, harmonization of regulation) and, ultimately, effective elimination of harmonics [2-4]. All these aspects of higher harmonics are processed as part of a comprehensive topic of electromagnetic compatibility (EMC).

According to the frequency range, four types of harmonics are distinguished:

1. subharmonic - the frequency that is part of the basic, i.e $f_n = f_1 / n$ where:

f_1 - basic frequency (50 or 60 Hz),

n - natural number (2, 3, 5 ...)

The effect of the subharmonic is reflected in the flicker of light (flicker). The biggest "producers" of the subharmonic are the electric furnace furnaces.

2. low-frequency harmonics-frequencies that are multiply basic,
i.e. $f_n = nf_1$

In this case, the value is usually less than 100. Low-frequency harmonics are those most commonly called "higher harmonics". In the analysis, most often go to the 25th harmonica, and recently to 50.

Their most common source is rectifiers, inverters, cyclone converters, saturated transformers, rotary electric machines, electric furnaces, etc.

3. interharmonic - fractional harmonics or asynchronous harmonics, frequencies that are not integer multiples of the basic frequency (f_1), f_n less than 10 kHz. They are mainly connected to the operation of the electric motor drive with speed control by means of a converter coupler adapter - inverter. Negatively affect systems for tone-frequency command and telemetry, which use power lines for signal transmission.

4. high-frequency harmonics - often called radio interference, frequencies exceeding 10 kHz. The result of commutation transitions in energy switching components and negatively affect telecommunication signals as well as the operation of microcircuits in computer systems.

Higher harmonics are one of the main parameters of the quality of electricity, and most often appear as a result of the work of a large number of non-linear consumers. Since equipment and consumers need to show a certain degree of tolerance or immunity to multiple harmonics, from this aspect higher harmonics appear as part of the problem of electromagnetic compatibility, as high-frequency conductive disturbances [2-5].
The vast majority of the problems that occur on electrical systems have its origins on the excessive distortion of the currents or voltages near the final consumer. The main cause for this phenomena, which can be regarded has a sort of electromagnetic environment pollution, is due to the growth of the usage of electronic equipment fed by the electrical grid, such as computers, printers, television sets, electronic ballasts for gas-discharge lamps, electronic controllers for different varieties of industrial loads, etc. Almost every electronic equipments, single-phase or three phase, embodies a rectifier circuit at its entrance, followed by a commuted converter of the type DC-DC or DC-AC. One of the most usual rectifiers for low-power equipments is the single-phase full wave rectifier with capacitive filter, which has a highly distorted current consumption, as it can be seen on figures 11 and 12. The current's high harmonic content distorts the voltage on the loads due to the voltage drops in the electrical systems impedances. Phase fired controllers, widely used to control power consumption of heating systems and to adjust luminous intensity of lamps (dimmers), also consume currents with substantial harmonic content and with high-frequency electromagnetic interference. Even the ordinary fluorescent lamps contribute significantly for the presence of harmonics in the electrical grid, due to the non-linear behavior of the electrical discharges on the gaseous environment, and also to the ballast's magnetic circuit, that can operate on the saturation region.

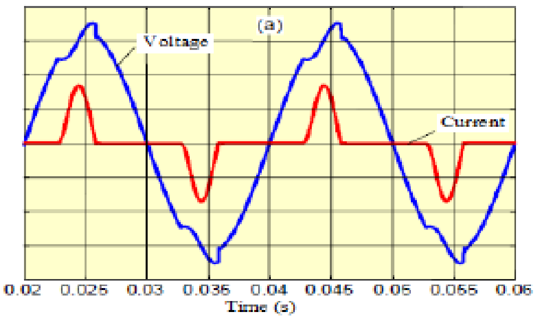

Figure 11. Voltage and current in a single phase rectifier with a capacitive filter [6]

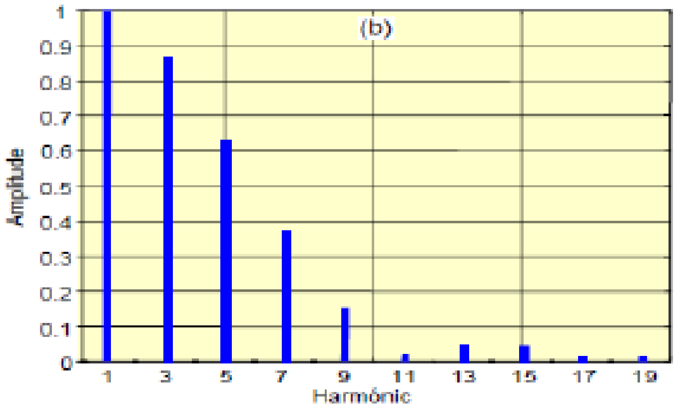

Figure 12. Harmonic of the current in input [6]

OVERVIEW OF IEC STANDARDS ON HARMONICS

The International Electrotechnical Commission (IEC), currently with headquarters in Geneva, Switzerland, has defined a category of electromagnetic compatibility (EMC) standards that deal with power quality issues. The term electromagnetic compatibility includes concerns for both radiated and conducted interference with end-use equipment. The IEC standards are broken down into six parts [7]:

■ **Part 1: General.** These standards deal with general considerations such as introduction, fundamental principles, rationale, definitions, and terminologies. They can also describe the application and interpretation of fundamental definitions and terms. Their designation number is IEC 61000-1-x.

■ **Part 2**: **Environment.** These standards define characteristics of the environment where equipment will be applied, the classification of such environment, and its compatibility levels. Their designation number is **IEC 61000-2-x** [7]:**.**

■ **Part 3: Limits**. These standards define the permissible levels of emissions that can be generated by equipment connected to the environment. They set numerical emission limits and also immunity limits. Their designation number is **IEC 61000-3-x.**

■ **Part 4: Testing and measurement techniques**. These standards provide detailed guidelines for measurement equipment and test procedures to ensure compliance with the other parts of the standards. Their designation number is **IEC 61000-4-x.**

■ **Part 5: Installation and mitigation guidelines**. These standards provide guidelines in application of equipment such as earthing and cabling of electrical and electronic systems for ensuring electromagnetic compatibility among electrical and electronic apparatus or systems. They also describe protection concepts for civil facilities against the high-altitude electromagnetic pulse (HEMP) due to highaltitude nuclear explosions. They are designated with **IEC 61000-5- x.**

■ **Part 6: Miscellaneous**. These standards are generic standards defining immunity and emission levels required for equipment in general categories or for specific types of equipment. Their designation number is **IEC 61000-6-x**.

Unlike the IEEE standards on harmonics where there is only a single publication covering all issues related to harmonics, IEC standards on

harmonics are separated into several publications. There are standards dealing with environments and limits which are further broken down based on the voltage and current levels. These key standards are as follows:

■ **IEC 61000-2-2 (1993):** Electromagnetic Compatibility (EMC). Part 2: Environment. Section 2: Compatibility Levels for Low-Frequency Conducted Disturbances and Signaling in Public Low-Voltage Power Supply Systems [7].

■ **IEC 61000-3-2 (2000):** Electromagnetic Compatibility (EMC). Part 3: Limits. Section 2: Limits for Harmonic Current Emissions (Equipment Input Current Up to and Including 16 A per Phase).

■ **IEC 61000-3-4 (1998):** Electromagnetic Compatibility (EMC). Part 3: Limits. Section 4: Limitation of Emission of Harmonic Currents in Low-Voltage Power Supply Systems for Equipment with Rated Current Greater Than 16 A.

■ **IEC 61000-3-6 (1996):** Electromagnetic Compatibility (EMC). Part 3: Limits. Section 6: Assessment of Emission Limits for Distorting Loads in MV and HV Power Systems. Basic EMC publication.

CONCLUSION

The quality of electricity is mostly related to the quality of voltage and frequency, i.e. their deviation from the nominal value as well as the comparison of the waveforms of the current and voltage relative to the ideal sinusoid. There are a number of electrical devices that have nonlinear operating characteristics i.e. even when the applied voltage is sinusoidal in nature, the current drawn by the device is nonsinusoidal in nature. These nonlinear devices used in power distribution circuits create nonlinear currents and which subsequently causes voltage distortions. These nonlinear currents and voltages have been generally referred to as harmonic currents and voltages. The proliferation of electronic switching devices in modern equipment has resulted in a significant increase in the amount of harmonic pollution in the electrical distribution systems. Harmonic currents and voltages can cause many unfavorable effects on the power system itself and the connected loads.

REFERENCES

[1] V.Šinik, "Improving Performance in Automatic Powerless Power Systems", Master thesis, Faculty of Electrical Engineering, Sarajevo, June, 1991.
[2] V.Šinik, "One approach to the analysis of the system of automatic uninterruptible power supply", Doctoral dissertation, Faculty of Technical Sciences "Mihajlo Pupin" Zrenjanin, July, 2009..
[3] Ž. Janda, One class of three-phase rectifiers with sinusoidal current using injection of higher current harmonics, Doctoral dissertation, Belgrade 2004.
[4] V. Katic, "Power Quality-higher harmonics", *Faculty of Technical Sciences Novi Sad*, Novi Sad 2002nd
[5] D. Graovac,"Universal system for power quality correction", *Ph.D. Thesis, Faculty of Technical Sciences,* Novi Sad, 2000.
[6] Maravathu Nagarjuna, Voltage Quality and Power Quality Factor Improvement using Active Power Line Conditioner, Department of Electrical Engineering National Institute of Technology – Rourkela 2012-2014
[7] Standards from the group IEC 61000

RISK BASED MAINTENANCE STRATEGY SELECTION

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Abstract: This paper presents decision-making model for maintenance strategy selection. Problem of right maintenance strategy selection is one of the most important problem in manufacturing enterprises, process industries or enterprises where failure of equipment has major impact on production flow, people, environment or business costs. Presented decision making model for maintenance strategy selection takes into account risk exposure to mechanical equipment failure, business costs, people health and environmental safety. At the other hand each strategy options has its benefits expressed by cost savings. This decision making model for maintenance strategy selection try to optimize between these opposite influential criteria.
Key words: maintenance strategy, decision-making process, risk matrix.

INTRODUCTION

Most often choosing right strategy is decision based on cost-benefit analysis. Benefits are measured in cost savings, maintenance time savings, maintenance material savings, and all maintenance resources savings and not less important – reliability mechanical equipment keeping on desired level. Some strategy options has aim to increase reliability of mechanical equipment but it leads to overmaintenace. So optimal maintenance strategy presents balance between corrective and preventive activity in accordance with business processes [1]. Historically main maintenance strategy differed on: failure replacement, periodical inspection, age replacement, risk-based inspection, continuous monitoring strategies, etc. developed in four basic types of maintenance philosophies: corrective maintenance, preventive maintenance, risk-based maintenance, condition-based maintenance. Nguyen[2] shows that replacement decision nowadays is more complex because decision maker often must decide which available technology on the market to choose for replacement of the current asset. Rapid technological development involve in maintenance decision making process one new aspect in replacement with technologically better solutions compatible with current assets.
Ierace and Cavalieri [3] noticed that in the literature, there was insufficient attention been paid to formulation of a methodological framework for selecting suitable techniques for maintenance strategy selection. They says that the framework should takes into account the organizational competencies with respect to applying the specific risk assessment technique. In such concept of developing methodological framework for maintenance strategy selection, chances of success increase.
In literature, lot of method and techniques was used for solving problem of maintenance strategy selection: AHP, FAHAP, ANP[4], TOPSIS, FME, FTA, ES, etc. Also, number and type of influential criteria for comparing alternative maintenance strategy option vary. In this paper is presented combined approach to maintenance strategy selection, using 4 types of risk matrix for each maintenance strategy option evaluation, and decision support system based on analytic hierarchy process for ranking maintenance strategy options by priorization influential criteria.

CASE STUDY

In this Case study we observed one manufacturing enterprise which is considering three maintenance strategy options. First strategy (STM1-Strategy Maintenance option 1) characteristics are estimated using qualitative risk exposure matrix and this strategy options present current strategy, shown on Figure 1.

Risk Exposure (E)					
Probability (P)	E=P*I				
Very High (>0.7)	MEDIUM	MEDIUM	HIGH	HIGH	HIGH
High (<0.7)	LOW	MEDIUM	MEDIUM	HIGH	HIGH
Medium (<0.5)	LOW	MEDIUM	MEDIUM	HIGH	HIGH
Low (<0.3)	LOW	LOW	MEDIUM	MEDIUM	HIGH
Very low (<0.1)	LOW	LOW	LOW	LOW	MEDIUM
Increases development time	<1%	<5%	<10%	<15%	>15%
	Impact (I)				

Figure 1. Qualitative assessment risk exposure matrix

Using qualitative risk exposure matrix shown on figure 1, risk exposure for STM1 for equipment failure is estimated based on corporate memory and expert opinion, on figure 2. The analysis is conducted for four equipment assets.

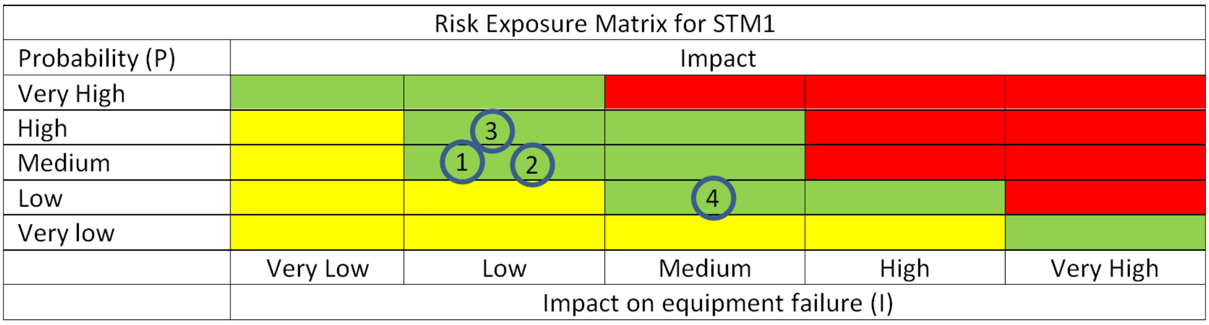

Figure 2. Risk exposure matrix for STM1 equipment failure

For same probability of equipment failure, shown on figure 1, next risk matrix shows its impacts on business costs. Figure 2 shows that failure has different significance form aspects of business costs.

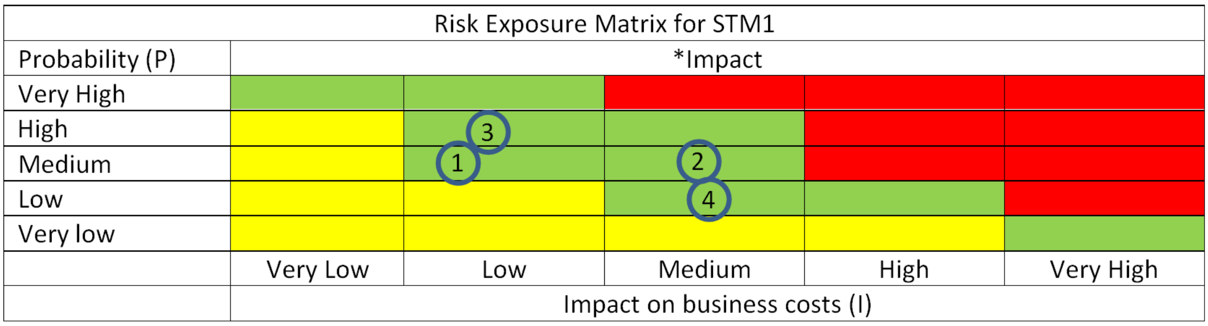

Figure 3. Risk exposure matrix for STM1 business costs

Also, for same probability of equipment failure, shown on figure 1, next risk matrix shows its impacts on people. Figure 4 shows that failure of equipment assets no. 1 has high on people and also on environment, figure 5. Equipment 5 is a reservoir under pressure containing compressed natural gas.

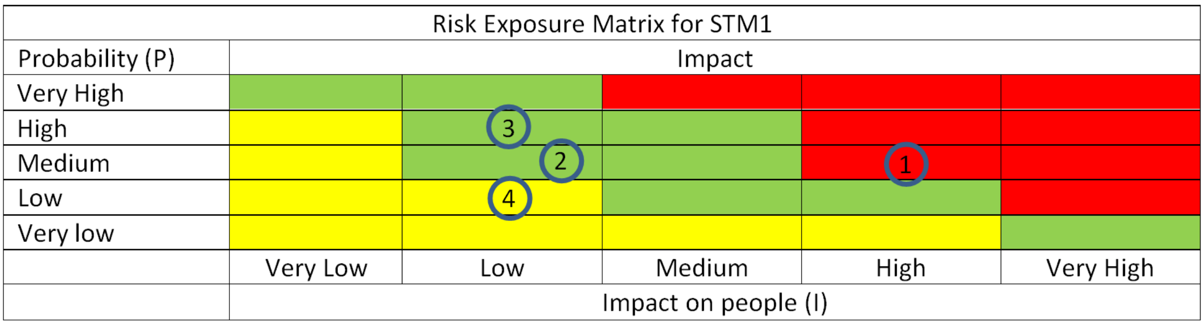

Figure 4. Risk exposure matrix for STM1 people

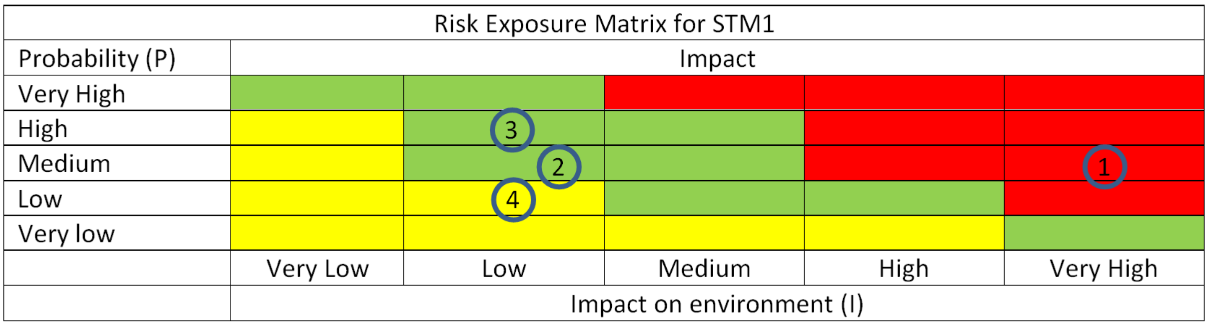

Figure 5. Risk exposure matrix for STM1 environment

All four risk exposure matrix are performed for strategy 2 (STM2) and strategy 3 (STM3) option and for observed equipment, total costs are calculated: preventive maintenance, corrective maintenance, lubrication as specific PM task, contracted preventive and corrective maintenance, inspection costs, replacement costs, ''non-working'' maintenance (safety, meetings), supervision, planning, lubricants, capital improvements, etc. Maintenance costs are shown in table 1.

Table 1. Maintenance costs for STM1, STM2 and STM3

	STM1	STM2	STM3
Total maintenance costs (in thousands of RSD) /per year	152000	142500	124500
Percent (%)	100	93.75	81.90789
Cost savings (%)	0	6.25	18.08

STM1 has the biggest total maintenance costs, so if this is a referent value, STM2 has 6,25 % cost savings, and STM3 has 18,08% cost savings.

DECISION SUPPORT TOOL

In this section decision support tool was used for evaluation each strategy options. Very important issue in design decision making model framework is to compare different measurement units in same decision model: different risk exposure and costs savings for each strategy options. In this sense we use weights for influence criteria. In the next table is shown decision making matrix.

Table 2. Decision making matrix

	R - FAILURE	R - BUSINESS	R- PEOPLE	R- ENVIRONMENT	COST SAVINGS
WEIGHTS	Critical	Very Important	Critical	Critical	Very Important
STM1	MEDIUM	MEDIUM	HIGH	HIGH	0
STM2	MEDIUM	LOW	MEDIUM	MEDIUM	6,25
STM3	MEDIUM	MEDIUM	HIGH	HIGH	18,08

Verbal scale for weights of influence criteria is five-stages (Critical – 100%, Very important – 75%, Important – 50%, Unimportant – 25%, Trivial - 0%), while verbal scale for risk exposure is three-stages (High – 100%. Medium - 50%, Low - 0%). Using results from case study for specific enterprises, by monitoring 4 equipment assets, and determining its positions in risk exposure matrix (fig.1,2,3,4 for strategy maintenance option 1 is shown in this paper), further research was continuing by determining overall qualitative evaluation. So, for STM1, overall evaluation for "R-failure" matrix is "medium"; overall evaluation for "R-business" overall evaluation is "medium"; for "R-people" overall evaluation is "high"; for "R-environment" overall evaluation is "high" and for "cost savings" overall evaluation is zero. This overall conclusion was made by observing areas in risk matrix where equipment assess belong. The similar procedure was conducted for second and third maintenance strategy option, and a final result is given in table 2.
Using analytical hierarchy process as one of the method for decision making for optimal maintenance strategy [5,6,7], results are obtained, table 3.

Table 3. Calculating priorities for different strategy option

Goal	**Weights**	**Priorities**	**Rating Set**	**Attributes**	**STM1 Rating**	**STM1 Priority**	**STM2 Rating**	**STM2 Priority**	**STM3 Rating**	**STM3 Priority**
Goal	100,00	0,222	Rf	Rf	50,00	0,500	50,00	0,500	50,00	0,500
	75,00	0,167	Rb	Rb	50,00	0,500	100,00	1,000	50,00	0,500
	100,00	0,222	Rp	Rp	0,00	0,000	50,00	0,500	0,00	0,000
	100,00	0,222	Rr	Rr	0,00	0,000	50,00	0,500	0,00	0,000
	75,00	0,167	Cost Savings	Cost Savings	0,00	0,000	6,00	0,333	18,00	1,000

Table 4 shows ranking maintenance strategy options. Strategy STM2 present the best alternative in this enterprise.

Table 4. Ranking alternatives

LOWEST LEVEL	**STM3**	**STM2**	**STM1**	**MODEL WEIGHTS**
Re	0,000	0,500	0,000	0,222
Rp	0,000	0,500	0,000	0,222
Rb	0,500	1,000	0,500	0,167
Rf	0,500	0,500	0,500	0,222
Cost Savings	1,000	0,333	0,000	0,167
Results	0,361	0,556	0,194	

Although STM3 has the most significant cost savings, its risk exposure for people and environment is high. STM1 also has high evaluation mark in risk matrix for people and environment and has no cost savings, so STM1 is the worst strategy option. STM2 has moderate risk exposure for people, failure and environment (which are the critical influential criteria's) and has 6,25% cost saving comparing to current maintenance strategy, which make this strategy option the best solution in this study case.

CONCLUSION

In this paper the decision model for maintenance strategy selection is presented. Concept of decision making model involves all risk exposure aspects: risk exposure matrix for equipment failure, risk exposure matrix for business losses (measured by costs), risk exposure for people, risk exposure on environment and in model are involved benefits of each strategy options expressed through cost savings. Decision making model for maintenance strategy selection uses weights of influential criteria and calculate significance each alternative according to priority. Presented decision making-model for strategy selection can be used in different manufacturing enterprises, simple procedure make it easy for application by decision makers on all managerial levels. Presented model gives better review of advantages or disadvantages of several maintenance strategy option then traditional cost benefit models. Risk exposure to all aspects by using this methodology can be observed together with potential cost savings.

REFERENCES

[1] Zhaoyang, T., Jianfeng, L., Zongzhi, W., Zheng, J., Weifeng, H., An evaluation of maintenance strategy using Risk-based inspection, Safety Science, Vol. 49, No. 6, pp. 852-860, 2011.

[2] Nguyen, T.K., Yeung, T.G., Castanier B., Optimal maintenance and replacement decisions under technological change with consideration of spare parts inventories, International Journal of Production Economics, Vol. 143, No. 2, pp. 472–477, 2013.

[3] Ierace S, Cavalieri S. An Analytic Hierarchy Process Based Model for the Selection of Decision Categories in Maintenance Systems. Management & Production Engineering Review (MPER). 2013;4(2):37-49.

[4] Chemweno, P., Pintelon, L., Horenbeek, AH., Muchiri, P., Development of a risk assessment selection methodology for asset maintenance decision making: An analytic network process (ANP) approach, International Journal of Production Economics, Elsevier, Vol. 170, pp. 663-676, 2015.

[5] Arunraj, N.S., Risk-based maintenance policy selection using AHP and goal programming, Safety Science, Vol. 4, No. 2, pp. 238-247, 2010.

[6] da Cunha Barbosa GE, de Souza GFM. A risk-based framework with Design Structure Matrix to select alternatives of product modernisation. Journal of Engineering Design. Vol. 28, No.1, pp. 23-46, 2017.

[7] Rusov, J., Misita, M., Model of Decision Support System used for Assessment of Insurance Risk, Journal of Applied Science, Vol. 14, pp.13-20, 2016.

CONSTRUCTION OF WELDING TOOLS TO REDUCE THE CABIN PILLAR DEFORMATION

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Abstract: The authors of the paper are based on the presentation of a unique welding tool that aims to reduce the deformation occurring on the pillar of the train cabin. Deformations are the product of excessive heat that occurs when constructing a cabin pole. Throughout the work, a comparative analysis of the relevant parameters will be performed on the pillars of the train cab that are welded outside the engineered tool and the engineered tool. The data that is measured as an indicator of the correctness of the cabin pole is the clearance. The construction of the mentioned tool was done in the Catia V5 software tool.
Key words: welding tool, deformation, cabin, pillar, heat, construction, Catia V5.

INTRODUCTION

The rail industry and manufacturing in this domain are largely based on the welding process, and this process is the center of this industry. The quality of welding can depend on many factors, and one of the factors is working conditions, that is, working opportunities when welding certain, special parts. When it comes to the rail industry, the base will be installed around the construction of a suitable welding tool, in order to reduce the deformation on the mast of the train cab, which occurs due to the presence of increased temperatures. The using of the modern software package Catia V5 approaches the construction of a unique model of the tool that will be used for welding the pillar. The main purpose of the tool is to reduce the gap that occurs due to welding and thus to eliminate all problems that occurred before the implementation of the said welding tool and to bring all the measures into tolerance and thus meet the appropriate, the required quality. The obtained results are presented in measuring lists, through which current and allowed measures are compared, and thus the analysis of the successful implementation of a modern tool constructed in the Catia V5 software tool is made. After the welding process, the clearance of the gap is made with a device called a measuring kilo, thus giving a clear picture of the differences that arise with the use of a constructed tool.
Creating three-dimensional (3D) models using a computer offers several advantages. Such models greatly facilitate the subsequent process of computerized parts production. Computer modeling enables further analysis ie. can serve as a basis for calculations using the numerical method. 3D models and virtual circuits can easily be made classic [1].
By designing a modern tool, it also contributes to the optimization of production from the aspect of the indirect cycle production cycle, ie refinement of a not perfectly constructed train cabin pole, which in this case refers to the production of a train cabin pole outside the aforementioned, constructed welding tool.

THEORETICAL BASIS AND PHASES OF CONSTRUCTION OF PRODUCTS IN INDUSTRIAL SYSTEMS

The emergence of a machine is conditioned by the need for that machine. This solves the question of the purpose of the machine. Knowing its purpose, the machine is presented in the form of a conceptual design, by making a series of sketches on which the individual parts of the machine are tied together in various ways, until the most favorable kinematic solution is obtained. In deciding which version is best, an inevitable compromise is made between what can be sacrificed at the expense of something else. The knowledge and experience gained from the practice add to the quality of the proposed solution. After the study phase, the real construction is based on scientific principle and experience.
In addition to its great influence on market characteristics, design also affects the general characteristics of the product (function, purpose, structure, size, type of material, etc.), which

necessitated the special study of the shape of the product in terms of its general characteristics. In addition, with the proper construction of the product, it is necessary to enable easy handling during installation, operation, service, maintenance and overhaul [2].

Figure 1 represents a schematic representation of the stage of the construction process.

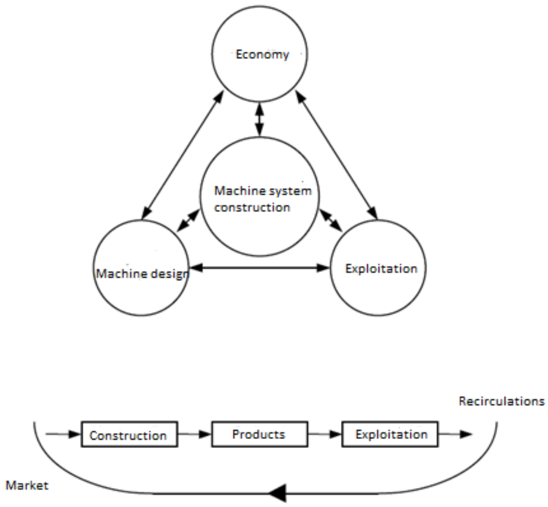

Figure 1. Stages of the construction process [3]

Figure 2, shows a block diagram of the design process from the initial phase to the final phase, that is, the product.

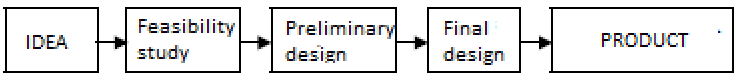

Figure 2. Block diagram of the design process from idea to product [4]

CONSTRUCTION OF WELDING TOOLS IN CATIA V5 SOFTWARE

Since the top-down method is used in the construction process, we will import a 3D model of the cabin pole into CATIA V5 software tools and build the tool based on it. CATIA is offered in the form of different sets of program modules. These sets aim to group different sets of Workbenches to meet the needs of users with different roles in the product development process. Defines the Workbench as a specific environment consisting of a set of tools that allow the user to perform specific construction tasks in a particular area. Figure 3. shows the basic dedicated module sets that can be found in CATIA.

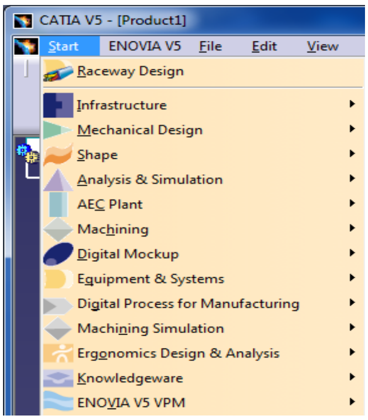

Figure 3. Module Sets in CATIA [5]

In this paper, only the final welding tool model will be appropriate because there are many steps involved. Figure 5 shows the constructed tool in the 3D environment.

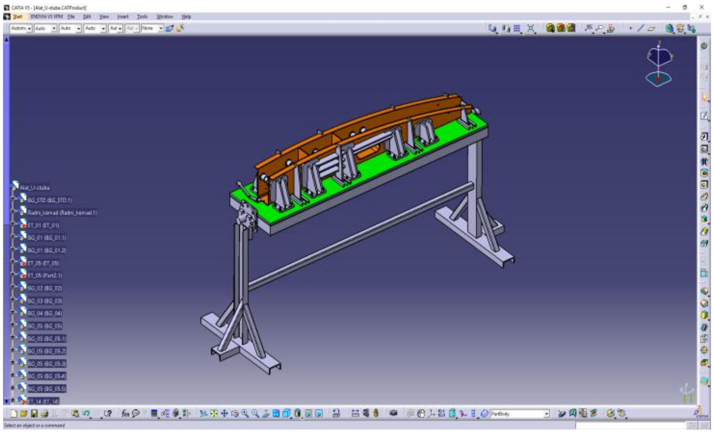

Figure 5. Modeled welding tool

DESIGN OF THE CONSTRUCTED PART AND THE RESULTS OF COMPARATIVE ANALYSIS

After designing the tools in the software package, practical design of the projected part is started. Figure 6, shows the fabricated tool that will be used further in the process of welding the train cabin pole.

Figure 6. Welding tool in a real environment

In Figure 7 the measured gap value on the pillar made on the welding table is shown, while in Figure 8. the displayed clearance value on a pole made in a constructed tool.

Figure 7. Pillar welding out of tool

Figure 8. Pillar welding in contruction tool

Table 1. Measuring list of welding pillar in tool

Serial No.	Language: En	Revision: 0_2019-05-02	Page:2	Article No: 3EGH489021-6766
FINISHED CONDITION				
Position	Value	Tolerance	Right	Left
X 1.1	1448	0/-3	1447,0	1448,0
X 1.2			1445,0	1445,0
X 1.3			1447,0	1448,0
X 2.1	850	±3	847,0	850,0
X 2.2			849,0	850,0
Z 1.1	2412	0/-2	2412,0	2412,0
Z 1.2			-	2410,0
Z 2	2	+1/0	3,0	3,0
G1	Streightness Upper Beam	2	1,0	0
G2	**Streightness Pillar WE1**	**2**	**2,0**	**1,0**
G3	Streightness Pillar WE2	2	1,0	1,0
E1	Levelness Pillars	2	3,0	0

Table 2. Measuring list of welding pillar out of tool

Serial No.	Language: En	Revision: 0_2019-05-02	Page:2	Article No: 3EGH489021-6766
FINISHED CONDITION				
Position	Value	Tolerance	Right	Left
X 1.1	1448	0/-3	1448,0	1447,0
X 1.2			1445,0	1446,0
X 1.3			1445,0	1445,0
X 2.1	850	±3	850,0	858,0
X 2.2			847,0	849,0
Z 1.1	2412	0/-2	2411,0	2412,0
Z 1.2			2410,0	2411,0
Z 2	2	+1/0	2,2	2,0
G1	Streightness Upper Beam	2	0,0	0,0
G2	**Streightness Pillar WE1**	**2**	**4,9**	**2,2**
G3	Streightness Pillar WE2	2	1,8	1,7
E1	Levelness Pillars	2	1,0	1,2

CONCLUSION

According to the measured dimensions contained in the measurement list shown, it can be concluded that the engineered tool has influenced the reduction of the deformation of the pillar cabin.
The application of modern software packages, as in the case of the Catia V5, enables a high level of productivity in the manufacturing and manufacturing sector. Productivity through the mentioned

program is most reflected in the aspect of reducing the time of making a technological-structural solution, while the other aspect is related to simplification of design, because the software tools provide a high level of flexibility. As already mentioned and shown in the metering lists, the newly constructed welding tool gave positive results, because through the parameter of straightness of the pole and the comparative analysis of the plane of the pole of the cabin which was made outside the engineered tool and the pole of the cabin of the train that was made on the constructed welding tool, t was concluded that the application of the new tool reduced the gap from 4,9 mm that occurred to 1 mm. Such research results conclude that the application of the newly engineered tool with the Catia V5 software reduces the overall deformation of the cable car pole, thereby increasing productivity and economy of production. The application of this tool can be used in the further production of elements in the aforementioned branch of industry.

REFERENCE

[1] Vrekić, S., Parametric Modeling In Software CAD/CAM/CAE Packages, Kopaonik: Yuinfo, 2010.
[2] Desnica, E., Nikolić, M., Industrijski dizajn, Tehnički fakultet „Mihajlo Pupin“, Zrenjanin, 2012.
[3] Olević, S., Lemeš, S., Osnovi Konstruisanja, Mašinski fakultet, Zenica, 1998.
[4] Kovačević, A., Osnovi Projektovanja, Mašinski fakultet, Tuzla, 2002.
[5] Tickoo, S., Singh, V., CATIAV5R18 za mašinske inženjere, CADCIM Technologies, Beograd, 2009.

SESSION 4. OIL AND GAS ENGINEERING

SCADA FOR TANK MANAGEMENT SYSTEM IN REFINERIES

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Abstract: SCADA (Supervisory Control And Data Acquisition) have wide application in the management and monitoring of the operation of industrial plants and equipment in telecommunications, oil and gas industry, energy, wastewater systems and other fields. The aim of this paper is to present SCADA for tank management system at refineries. SCADA represents a system for monitoring, monitoring, archiving and control of industrial systems with parameter display, with the availability and reliability of such a system at a high level. These systems include a wide range of equipment, subsystems and technical solutions that enable the collection and processing of process data, and responding in an adequate optimal way. SCADA in industrial systems is the highest quality, but a costly solution. Its advantage is providing a consistent, intuitive development environment that allows software engineers to build applications quickly and easily, mobility, simple and quick installation, user friendly usage and accessibility.
Key words: SCADA, Tank Management System, Custody transfer

INTRODUCTION

In order to increase the reliability and security of a tank management system and ensure economic feasibility, it is necessary to effectively address all technical, safety, organizational and environmental challenges and ensure compliance with the latest standards in this field [4], [5], [6]. Tank management systems should be designed according to the highest international standards of safety so staff, plant, and environment can be protected [6], [14]. It should ensure highest reliability and accuracy of all subprocesses within the system (custody transfer level and flow measurements, liquid and gas analysis, temperature measurements, etc.) and enable plant running in accordance to international laws and regulations. For all tank management systems, it is very important to determine the quality of petroleum products such as the water and sediment [1] and API gravity and sulfur content of crude oil and petroleum fractions [2]. Another important aspect is to enable highly accurate tank measurement with custody transfer approved level, temperature, and pressure instruments [10], [11], [14], [15].Traditional automation and control uses hardware interfaces and custom designed algorithms to control a self-contained process. A HMI (Human Machine Iinterface) may be part of SCADA distributed control systems [13], [16]. SCADA (Supervisory Control And Data Acquisition) systems provide tools for analyzing, reporting, and fine-tuning those processes and monitoring a variety of plant data including: flows, motor current, temperatures, water levels, voltages, and pressure [12]. Alarms at central or remote sites triggered by any abnormal conditions are propagated to the HMI computer for operator's attention. In addition to alarms, important plant information will be logged in the HMI computer database for reports and trends [12]. SCADA systems and their applications in monitoring and controlling equipment and industrial plants are frequently used in following areas of researches: plant engineering, manufacturing, telecommunications, water and waste control, energy, oil and gas refining and transportation [7], [8].
Advantages of the SCADA system are its mobility, simple and quick installation, user friendly usage and accessibility [7]. Legislative unique metrology for tank management, oil transport control and management systems is used all around the world in area of oil, gas and petrol industry [1]. In our country this procedures and processes must be performed in accordance with „Law of planning and construction“ (“Official Gazette of Republic of Serbia, NO. 47/2003 and 34/2006, „Law on security and health at work in Republic of Serbia“ and „Fire protection and prevention Act“.

MATERIAL AND METHODS

When starting SCADA applications opens the home screen, where it is necessary to click anywhere on the screen to the middle opened a small window for logging. There are two types of users - with and without password. Password users have the ability to change alarm limits, simulate values, generate reports, and enter density for each tank, while password-free users only have the ability to monitor current values.In Fig.1. a screen for users without a password is displayed. The red box represents the currently selected user. If you want to change the user, click on his field. After selecting the user, the exit field (field X) is pressed, after which the main screen opens. If a user with a password is required, the box in the upper left corner ("Password users") is pressed. In this case, the following window opens.

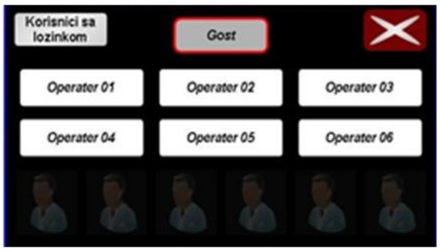


Figure 1. Logging of SCADA system users

When logging is necessary to first select the user and then in the field below enter the password. Then ENTER is pressed and if the password matches the selected user, an “X” button will appear in the upper right corner. Pressing this button opens the SCADA system home screen as shown in Fig. 2.

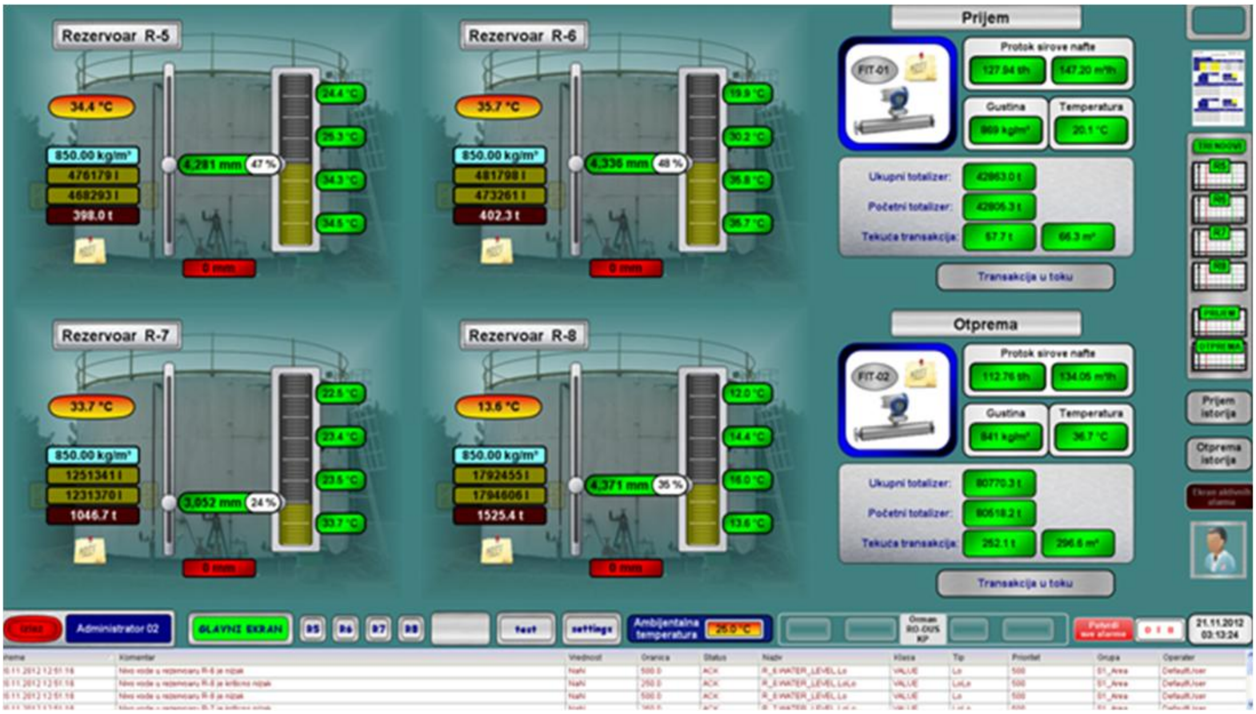


Figure 2. Main screen of SCADA application

At this location is measured to the reservoir 4, - R5, R6, R7 and R8, as well as the measurement of the flow of oil. The text below describes the system by which values are measured, alarms and simulated values are displayed, as well as settings that the user can use, as shown in Fig. 3.

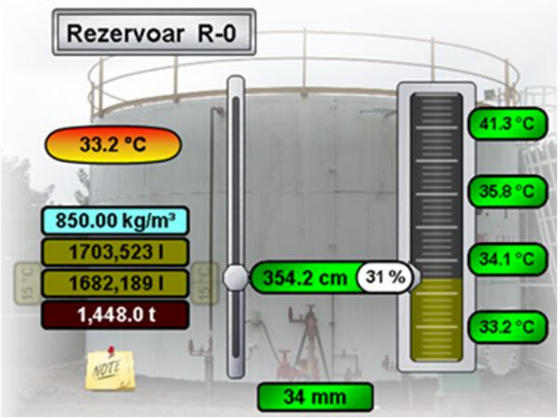


Figure 3. SCADA screen for displaying measured values, displaying alarms and simulated values

The temperature measurements in the reservoir are shown on the right, as shown in Fig. 4a. The lowest measured temperature is Temperature 01, while the highest temperature is displayed at the top 04. The field displaying temperatures can be colored in several ways:

- Green colored field - The value is displayed normally. No alarms are active or simulation is on.
- Yellow colored field - A high or low alarm is activated. In case of a new (unconfirmed) alarm the field will move along a circular path. Only when the alarm is confirmed will the field be fixed in place. The difference between unconfirmed and already confirmed alarms is just that with "new" alarms the field is constantly moving.
- Red colored field - A critically high or critically low alarm is activated. The field behaves the same as when a "regular" alarm is activated, except that instead of yellow, the field is colored red.
- Purple colored field - A simulation of a given value is included. The field no longer shows the actual measured value, but the value entered manually.

a) b) c)

Figure 4. SCADA screen for Measuring the temperature, level and water level of a tank

Level measurements in the reservoir are shown at the very middle, as shown in Fig. 4b. The display on the left shows the level (in mm or cm), and immediately to the right next to it, what is the percentage of the maximum value. The field will move vertically with decreasing or decreasing levels. The bottommost position coincides with the bottom of the vertical opening / window to the right (zero value), while the far upper position coincides with the top of the opening to the right (100% level). The window to the right will also be filled vertically depending on the level in the tank. The color fields (green, yellow, red, and purple) behave the same way as the temperature display. The only difference is the way the new (unconfirmed) alarm is displayed.

As the temperature moves in a circle, the moving star will appear at the level immediately to the left of the level field. The asterisk will be visible while the alarm is unconfirmed.

The water level measurements in the tank are shown in the middle of the tank as shown in Fig. 4c. Field colors (green, yellow, red, and purple) behave the same as for temperature and level displays. If

the alarm is new (unconfirmed), the water measurement display box will move left to right at the bottom of the screen.
The calculated average temperature is shown in the upper left part of the screen in Fig. 3, in the orange field. The system calculates the average temperature in relation to the level in the tank, ie. of the four temperature measurements (temperatures 01-04), only are taken into account those temperatures that are "submerged" at a given moment.
The system does not measure the density in the tank, but manually inputs the user as pinned in Fig. 5. The density (reduced to 15 ° C) is displayed (and entered) in the light blue field on the left side of the screen. The density is entered by clicking on the field, then entering the desired density via the keyboard, and finally pressing Enter.

Figure 5. SCADA screen for manual input density in the tank

The actual calculated volume is located just below the field for density. The actual volume is shown below the current volume (small markings for 15 ° C are next to it). At the bottom is in a brown field shows the calculated mass (for the density entered by the user). These four parameters are shown in Fig. 6.

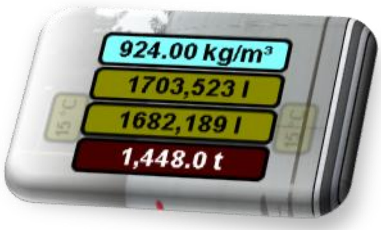


Figure 6. Density display, actual calculated sign, volume, reduced volume, calculated mass

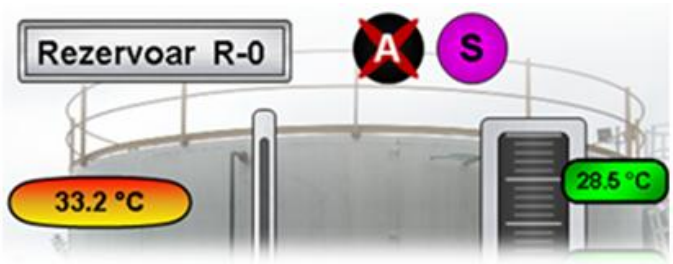


Figure 7. Tank designation, Blocked alarm active simulation sign

The tank designation can be seen on the gray tile in the top in the left corner, above the tank image shown in Fig. 7. The blocked alarm sign in Fig. 7. appears when the alarm (one or more of them) is blocked by the user. Similarly, the active simulation sign in Fig. 7 occurs when a user has included one of the simulations, and no longer monitors the actual measurement.
The annotation box is opened by clicking on the note thumbnail (bottom left corner of the tank) as shown in Fig. 3. In the annotation window it is possible to enter the text of the message that the user wants to enter.
"See" in the system as shown in Fig. 8. After each text entry / edit, the user needs to click the button to confirm the entry. If the user thinks the message is important, it can trigger an alert. The alert is switched on and off by clicking on the warning sign (exclamation mark in the orange circle). A dimmed sign means the alert is not on. Also, if a warning is activated, the same will be visible on the main screen, next to the note thumbnail that calls the note window.

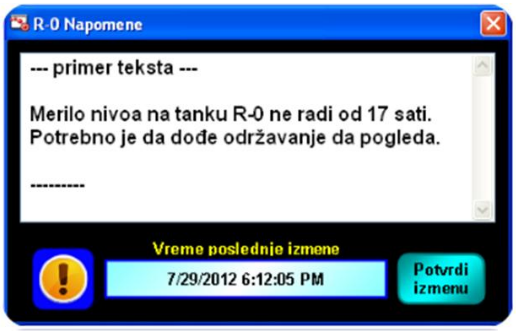


Figure 8. SCADA screen for Notes field

The value setting window opens by clicking on the value field in the main screen of Fig. 2. It is possible to adjust the level, water level, and any temperature (except average temperature). The alarm settings window opens by clicking on the field with this value in the main screen in Fig. 2. It is possible to set alarms for current flow (in tons), current density and current temperature. Adjustment windows look and behave the same as similar windows on tanks, as shown in Fig. 9. The only difference is that the flowmeter does not simulate these values in the system. The reservoir screens open full screen by clicking the buttons in the header below, as shown in Fig. 10.

Figure 9. SCADA screen for Adjusting flow, density and temperature

Figure 10. SCADA screen for displaying all tank screens

The reservoir screen shown in Fig. 11 shows in one place all the settings and all values related to a given tank. There are all six setting windows (level, water level, temperatures 1-4), display of average temperature, volume (current and reduced), masses, annotation field, as well as commands for switching off / on all alarms and all simulations simultaneously.
On the right side of the window of Fig. 11 are the name of the value to be adjusted and the simulation field. Simulation is switched on and off by clicking on the square box. The box shows a green check mark when the simulation is active, and a red cross when inactive. When the simulation is active, it is possible to manually enter the value that the user wants to simulate. On the left side of the window in Fig. 11 there are alarm limits and a field showing the current value. Each alarm can be independently switched on / off, as well as changing my limit value. Low and high alarms are yellow beats, while critically low and critically high alarms are red. The center field with the current value behaves the same as the displays on the main screen (green, yellow, red, purple). A new (unconfirmed) alarm is displayed in a black box flickering around the center field.

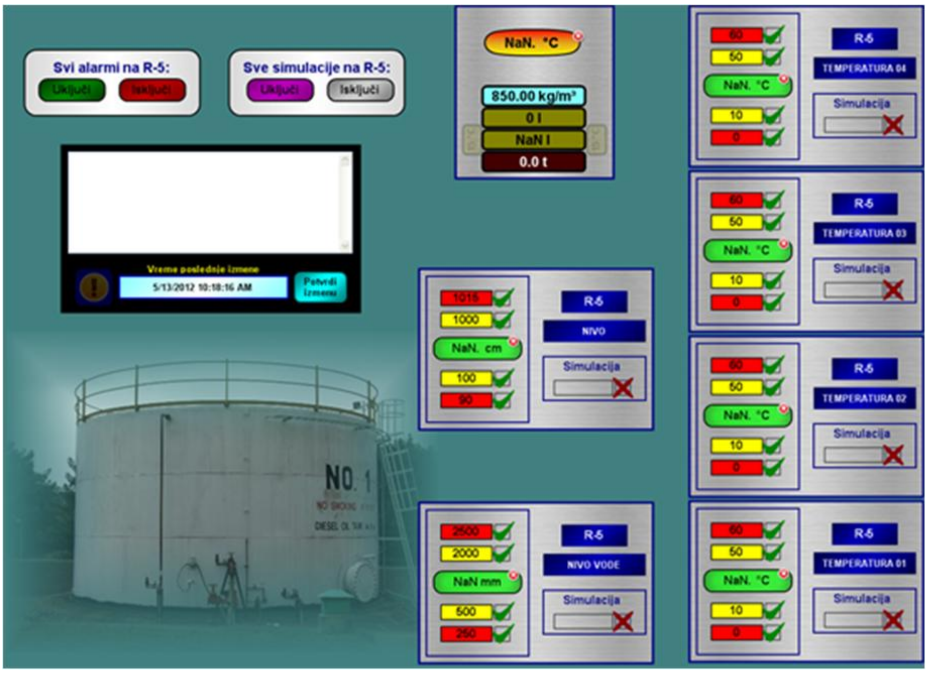


Figure 11. SCADA screen for Alarm setup, simulation

At the top of the view from the flowmeter in Fig. 12, we can see the name / function (eg receipt or dispatch). In addition to the image of the instrument and its name (ordinal number), there is a thumbnail of a note that clicks on the note window for that instrument. The notes work the same way as the tank notes.

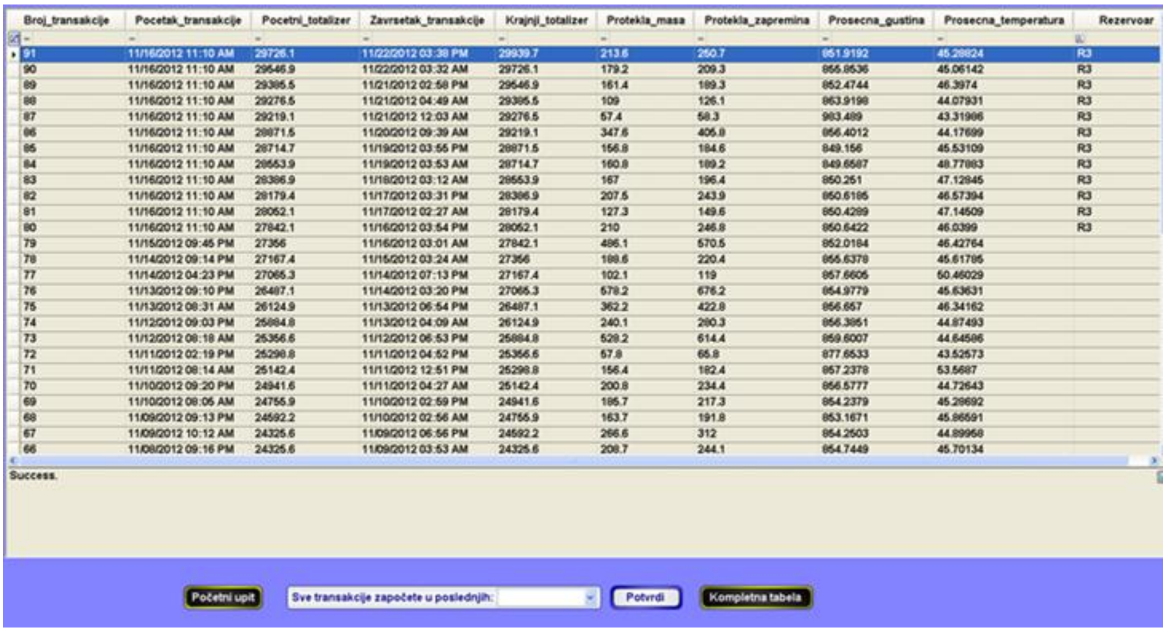
Current Flow Values Current density and temperature displays alarms if activated (yellow for high and low, red for critically high and critically low). If there is flow on the gauge, the blue frame around the image is called a circle. The total totalizer, the initial totalizer as well as the current transaction totalizer are displayed in the middle of the symbol (totalizers are displayed in tonnes and cubic meters).

Prior to the start of the shipment (transaction status is “Transaction not in progress”), it is necessary to notify the operators on the TUS TUS to press the START button. The START button is then pressed on the display or in the frame. The START button is visible if the transaction is not in progress and there is no flow. After pressing the button, a window opens for entering the tank from which the shipment is made.

Enter the tank name in the white box (or leave the previous value if appropriate) and press ENTER. Then it is necessary to press the START button and exit the window by pressing the "X" button. After pressing the START button, the transaction status will change to "Transaction in progress" and from that moment it is allowed to start the pump. Upon completion of the transaction it is necessary to press STOP and report to the TUS OUS to do the same. The STOP button is visible if the transaction is ongoing, the mass totalizer is greater than 2t and there is no flow through the pipeline. It is not necessary but desirable that both START and STOP be pressed immediately before and after the transaction. If pumping is interrupted, STOP is pressed only if it is the end of the batch. As soon as the STOP button is pressed, the batch is recorded to the SQL database and to history on the PLC [5]. At the same time, a report for the last transaction will be generated. The principle of receipt is the same as for the shipment with the batch start and end information being obtained from the shipment side.

Figure 12. SCADA screen for flow meters

The transaction history Fig. 13 on a given flowmeter opens by clicking the "Receive History" or "Upload History" button located on the right side of the screen in Fig. 2. The window that opens shows data for all transactions in the last week and this represents the initial query [12]. At the bottom of the screen is a button for displaying the complete table and a field for entering the period in which we are interested in transaction values. There are arrows on the right side of the screen to navigate through transaction history. Data can be sorted in descending / ascending order by a specific parameter (by clicking the column name in the table), and there are also filters (fields below the column name) to show only those transactions that interest us (e.g. if we are only interested in transactions where the total elapsed mass is greater than 500t).



Broj_transakcije	Pocetak_transakcije	Pocetni_totalizer	Zavrsetak_transakcije	Krajnji_totalizer	Protekla_masa	Protekla_zapremina	Prosecna_gustina	Prosecna_temperatura	Rezervoar
91	11/16/2012 11:10 AM	29726.1	11/22/2012 03:38 PM	29939.7	213.6	250.7	851.9192	45.28824	R3
90	11/16/2012 11:10 AM	29546.9	11/22/2012 03:32 AM	29726.1	179.2	209.3	855.8536	45.06142	R3
89	11/16/2012 11:10 AM	29385.5	11/21/2012 02:58 PM	29546.9	161.4	189.3	852.4744	46.3974	R3
88	11/16/2012 11:10 AM	29276.5	11/21/2012 04:49 AM	29385.5	109	126.1	863.9198	44.07931	R3
87	11/16/2012 11:10 AM	29219.1	11/21/2012 12:03 AM	29276.5	57.4	58.3	983.489	43.31986	R3
86	11/16/2012 11:10 AM	28871.5	11/20/2012 09:39 AM	29219.1	347.6	405.8	856.4012	44.17699	R3
85	11/16/2012 11:10 AM	28714.7	11/19/2012 03:55 PM	28871.5	156.8	184.6	849.156	45.53109	R3
84	11/16/2012 11:10 AM	28553.9	11/19/2012 03:53 AM	28714.7	160.8	189.2	849.6587	48.77883	R3
83	11/16/2012 11:10 AM	28386.9	11/18/2012 03:12 AM	28553.9	167	196.4	850.261	47.12845	R3
82	11/16/2012 11:10 AM	28179.4	11/17/2012 03:31 PM	28386.9	207.5	243.9	850.6185	46.57394	R3
81	11/16/2012 11:10 AM	28052.1	11/17/2012 02:27 AM	28179.4	127.3	149.6	850.4289	47.14509	R3
80	11/16/2012 11:10 AM	27842.1	11/16/2012 03:54 PM	28052.1	210	246.8	850.6422	46.0399	R3
79	11/15/2012 09:45 PM	27356	11/16/2012 03:01 AM	27842.1	486.1	570.5	852.0184	46.42764	
78	11/14/2012 09:14 PM	27167.4	11/15/2012 03:24 AM	27356	188.6	220.4	855.6378	45.61795	
77	11/14/2012 04:23 PM	27065.3	11/14/2012 07:13 PM	27167.4	102.1	119	857.6606	50.46029	
76	11/13/2012 09:10 PM	26487.1	11/14/2012 03:20 PM	27065.3	578.2	676.2	854.9779	45.63631	
75	11/13/2012 08:31 AM	26124.9	11/13/2012 06:54 PM	26487.1	362.2	422.8	856.657	46.34162	
74	11/12/2012 09:03 PM	25884.8	11/13/2012 04:09 AM	26124.9	240.1	280.3	856.3851	44.87493	
73	11/12/2012 08:18 AM	25356.6	11/12/2012 06:53 PM	25884.8	528.2	614.4	859.6007	44.64586	
72	11/11/2012 02:19 PM	25298.8	11/11/2012 04:52 PM	25356.6	57.8	65.8	877.6533	43.52573	
71	11/11/2012 08:14 AM	25142.4	11/11/2012 12:51 PM	25298.8	156.4	182.4	857.2378	53.5687	
70	11/10/2012 09:20 PM	24941.6	11/11/2012 04:27 AM	25142.4	200.8	234.4	856.5777	44.72643	
69	11/10/2012 08:05 AM	24755.9	11/10/2012 02:59 PM	24941.6	185.7	217.3	854.2379	45.29692	
68	11/09/2012 09:13 PM	24592.2	11/10/2012 02:56 AM	24755.9	163.7	191.8	853.1671	45.86591	
67	11/09/2012 10:12 AM	24326.6	11/09/2012 06:56 PM	24592.2	266.6	312	854.2503	44.89958	
66	11/08/2012 09:16 PM	24326.6	11/09/2012 03:53 AM	24326.6	208.7	244.1	854.7449	45.70134	

Figure 13. SCADA screen for transaction history

RESULTS AND DISCUSSION

Sometimes there may be a loss (or poor status) of communication between computers and devices in the field [3], [9]. The most common causes of such problems are malfunctioning devices in the field, cabinet equipment, problems with connections (cables), and possible problems with the operation of the computer itself (eg after a violent reset or loss of power). Poor communication status is displayed on SCADA by "screwing" a field that shows a given value. It does not matter whether the value is given in the alarm (red or yellow field), whether it is simulated (purple field), or whether it is a regular value (green field). In some cases, the field may display the correct value, but in most cases it is the wrong value (due to poor communication status).

Loss of communication, as well as a problem or error in communication, are displayed on SCADA by special graphic symbols that are invisible during normal communication. The communication error symbol is a small red circle with a white X sign in the middle. The symbol appears next to the field that shows the given value. Instead, a question mark, a wrench, an hourglass and some others may be heard in less frequent cases. The only good communication is when none of these signs are seen next to the value field.

CONCLUSIONS

Directions for further development of the application of SCADA are the creation of a unique dissemination center from which data in tank management system will be available. Contemporary data processing involves real-time data collection and storage, and information on each control process parameter can be obtained at any time from any location on the cloud storage. SCADA associated with automated processes enables the graphical display of data on the screen, along with numerical values, in a format suitable for the operator. In addition to the graphical representation of the application's user interface, SCADA system also allows display of certain alarms if some of the parameters go outside of the specified range.

ACKNOWLEDGMENTS

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REFERENCES

[1] Biazon, CL, VCBM Jesus, and EC De Oliveira, Metrological analysis by measurement uncertainty of water and sediment in crude oil, Petroleum Science and Technology Vol. 33, No. 3, pp. 344-352, 2015.
[2] Demirbas, A, H Alidrisi, and MA Balubaid, API gravity, sulfur content, and desulfurization of crude oil. Petroleum Science and Technology Vol.33, No. 1, pp. 93-101, 2015.
[3] Goldenberg, N. and Wool, A., Accurate modeling of Modbus/TCP for intrusion detection in SCADA systems, International Journal of Critical Infrastructure Protection, Vol. 6, No. 2, pp.63-75, 2013.
[4] Hentea, M., Improving security for SCADA control systems, Interdisciplinary Journal of Information, Knowledge, and Management, Vol. 3, No. 1, pp.73-86, 2008.
[5] Kover-Dorco, M., SCADA system creation by using java applications and PLC, In Control Conference (ICCC), 15th International Carpathian, IEEE, pp. 264-267, 2014.
[6] Li, Z., Deng, J.S. and Zou, X.J., Analysis and application of general call strategy of SCADA system, Power System Protection and Control, Vol. 41, No.2, pp.103-106, 2013.
[7] McCrady, S.G., Designing SCADA application software: a practical approach. Elsevier, 2013.
[8] Morsi, I. and El-Din, L.M., SCADA system for oil refinery control. Measurement, Vol. 47, pp.5-13, 2014.
[9] Naduvathuparambil, B., Valenti, M.C. and Feliachi, A., Communication delays in wide area measurement systems. In Proceedings of the Thirty-Fourth Southeastern Symposium on System Theory (Cat. No. 02EX540), IEEE, pp. 118-122, 2002.
[10] Perišić, J., Milovanović, M., Petrović, Ž., Ristić, M., Prokolab, M., Tank management and crude oil transport solutions using BPMN and SCADA application, IV International Conference Industrial Engineering And Environmental Protection (IIZS 2014), Technical faculty "Mihajlo Pupin" Zrenjanin, University of Novi Sad,October 15th, 2014, Zrenjanin, Serbia, pp. 252-260, 2014. ISBN: 978-86-7672-234-1.
[11] Paolucci, M., Sacile, R. and Boccalatte, A., Allocating crude oil supply to port and refinery tanks: a simulation-based decision support system, Decision Support Systems, Vol. 33, No. 1, pp.39-54, 2002.
[12] Redmond, D., McDaniel, R. and Sallee, D., eLynx Tech LLC, Classification and web-based presentation of oil and gas SCADA data. U.S. Patent 8,301,386, 2012.

[13] Salihbegovic, A., Marinković, V., Cico, Z., Karavdić, E. and Delic, N., Web based multilayered distributed SCADA/HMI system in refinery application, Computer Standards & Interfaces, Vol. 31, No. 3, pp.599-612, 2009.

[14] Timmons, M.B., Summerfelt, S.T. and Vinci, B.J., Review of circular tank technology and management, Aquacultural engineering, Vol. 18, No. 1, pp.51-69, 1998.

[15] Wenkai, L., Hui, C.W., Hua, B. and Tong, Z., Scheduling crude oil unloading, storage, and processing, Industrial & engineering chemistry research, Vol. 41, No. 26, pp.6723-6734, 2002.

[16] Wicaksono, H., SCADA Software dengan Wonderware InTouch-Dasar-Dasar Pemrograman, 2011.

EXPERIENCE IN THE USE OF OIL-MINERAL AGGREGATION FOR LIQUIDATION OF EMERGENCY OIL SPILLS IN ICY SEAS

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Abstract: The influence of the process of oil-mineral aggregation on the emulsification of oil and dark oil products in world practice has been known since the end of the last century. Despite a significant number of studies indicating the applicability of this process for cleaning coastlines from accidental spills, the effectiveness of oil-mineral aggregation in the elimination of oil slicks in open water and in ice conditions of the shelf zone is not well understood. Of particular interest is the study and evaluation of the effectiveness of this process from the point of view of bioremediation, hydrometeorological conditions, physico-chemical properties of the spilled product and the technology of work. This paper provides a brief overview of world studies on the study of the oil and mineral aggregation process to assess its applicability as a response to emergency oil spills in ice seas.
Key words: oil-mineral aggregation process, oil spill response, icy seas, clay-oil flocculation

INTRODUCTION

Since the widespread use of dispersants as a means of responding to emergency oil spills in ice seas is constrained by a number of factors [1, 2], there are few examples in the world practice of using the oil-mineral aggregation process for these purposes [3].
The process of oil-mineral aggregation (OMA) involves the interaction of oil globules and fine particles of sedimentary rocks, which leads to the formation of new compounds - microaggregates, the structure of which prevents the re-coalescence of oil. Thus obtained oil-mineral microaggregates (OMM) allow, under certain conditions, to disperse oil spills to concentrations below threshold toxic levels, as well as accelerate the natural processes of their biodegradation.
In theory, with sufficient wave energy of mixing, the oil slick disperses in the aqueous phase in the form of micron-sized oil globules (Fig. 1), stabilized, as a rule, on the surface with finely dispersed mineral particles.

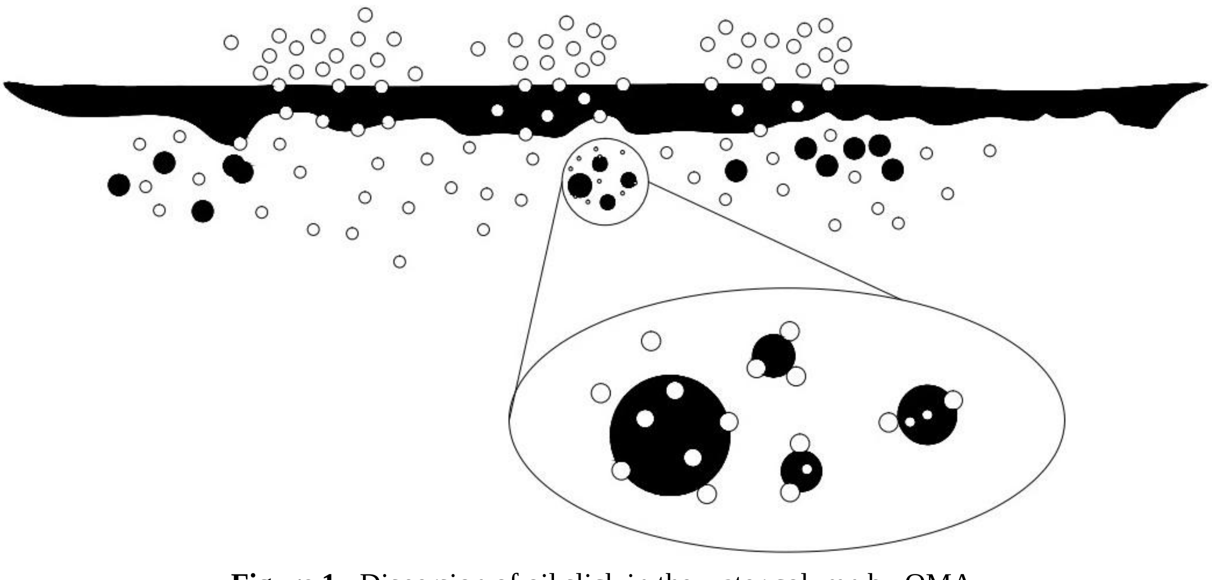

Figure 1. Dispersion of oil slick in the water column by OMA

The resulting petemineral microaggregates reduce the adhesion of oil to solid surfaces, promote the formation of stable globules, preventing re-coalescence of oil, which leads not only to its dispersion in

the liquid column, but also to an increase in the rate and degree of microbiological degradation due to an increase in the oil-in-water interface compared to oil slick [4].
The most common type of OMM is an oil globule stabilized over the surface of fine particles of sedimentary rocks. However, the authors of [5] described OMMs, which are a core covered by a layer of oil from a rock particle, as well as large OMMs of a membrane structure. Observed by the authors of the OMM oil-covered clay had an oblong, curved or even branched shape. Membrane OMMs reached several millimeters in length, had a flaky shape (Fig. 2) and positive or neutral (zero) buoyancy.

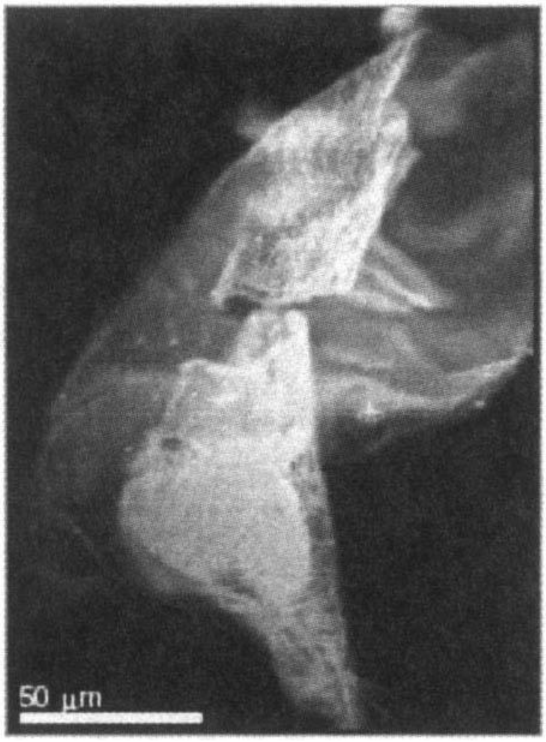

Figure 2. Flake-type membrane OMM [5]

MATERIAL AND METHODS

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Clay-oil flocculation

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A prerequisite for using the OMA-process as a response to emergency oil spills in offshore areas was the Exxon Valdez tanker accident in March 1989.
As a result of the release of oil from an Exxon tanker off the coast of Alaska, about 260 thousand barrels of oil spilled into the water of the Prince William Strait with the formation of a spot with an area of 28 thousand square kilometers. The inaccessibility of the accident area made it impossible to timely localize the oil spill, which led to the spread of the stain to the prince Wilhelm Strait. A day after the accident, a spot on the surface of the water was treated with dispersant sprayed from an airplane, but due to the lack of disturbance at sea, there was no significant effect (only 1% of the volume of spilled oil was transferred to the bottom layer). Incineration measures also did not take effect due to weather conditions. The work of skimmers was limited by the thickness of the slick film and by the fact that the oil managed to mix with brown algae in the water per day. Thus, about two thousand kilometers of the coastline were polluted.
A few years after observing the ecosystems of contaminated territories, researchers [6] found that some of the methods and tools used after the Exxon Valdez tanker accident to eliminate the oil spill on the coastline could be more harmful to the environment than their lack of. At the same time, the researchers for the first time noted the effect of “self-cleaning” of beach areas composed of sedimentary rocks.

A similar effect was observed and was used in response to the emergency spill in Tampa Bay (USA), when on August 10, 1993, as a result of the collision of the ocean-255 tanker barge, the B-155 tanker barge and the Balsa 37 cargo ship South of the Mullet Key Island in the Gulf of Mexico, about 1,000 barrels of diesel fuel and 10,500 barrels of fuel oil were dumped into the water. Most of the resulting hydrocarbon mixture, drifting along the surface of the water along the coast, contaminated almost 21 km of the sandy beaches of Pinellas Park (Florida). [7]
A probable explanation for this “natural self-cleaning” was given by the authors [8, 9] at the XVII Arctic and Marine Oilspill Program (AMOP) in 1994, and the process of the interaction of oil and fine particles of sedimentary rocks was originally called “clay-oil flocculation“.

Wave washing

When liquidating a spill on the coast of the Tampa Bay, an attempt was first made to use the “clay-oil flocculation” process as an additional measure to combat pollution. After excavating 39827 cubic yards of oil-contaminated sand, the remaining soil was mixed and transferred from the upper littoral and supralittoral zone to the lower. Since during the operations the wave action in the surf zone was minimal (breakers with a height of less than 10 cm), the recorded accelerated removal of oil from the soil was associated with the interaction of oil and mineral particles, and not with physical abrasion [7]. These observations were correlated with the results of field tests previously carried out by researchers [10, 11] on beaches with low wave energy surfs, as a result of which it was found that mechanical mixing procedures increase the rate of dispersion of oil from contaminated soils.
Thus, the prerequisites were created for the emergence of a new approach to the elimination of emergency oil spills in coastal environments with insufficient hydraulic energy, which could be used in addition to the traditionally used excavation and mechanical mixing and on rocky beaches.
This method, which consists in transferring oil-soaked soil forming a coastal surface to the surf zone, where a wave action stimulates the formation of oil globules, resuspension of sedimentary rock particles and the formation of OMM (Fig. 3), was called “wave washing” (or “washing of beaches”) and was successfully tested in the aftermath of the See Empress tanker accident. [12-14]

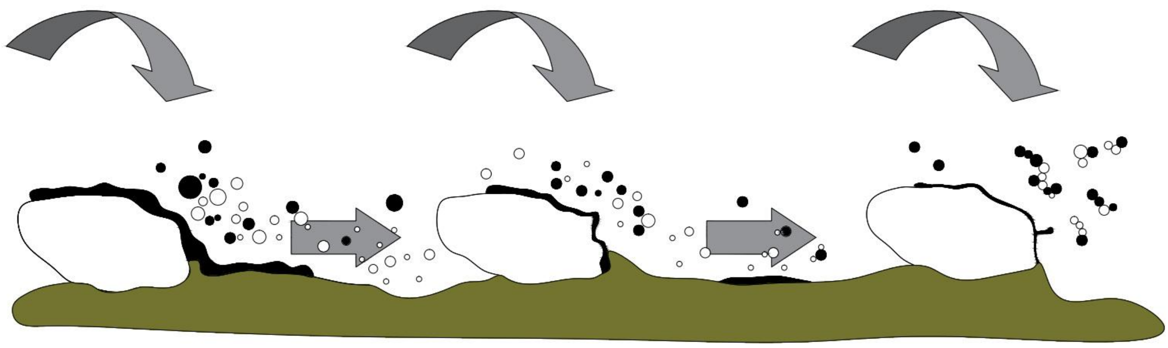

Figure 2. “Wave washing” of pebble contaminated with oil while moving it to the sandy bottom in the surf zone

On February 15, 1996, the Sea Empress tanker ran aground off the southwestern coast of Wales (UK). As a result of the accident, about 73 thousand tons of crude oil spilled onto the water surface and, after the drift of the spot, 201 km of the coastline were polluted, including the territory of the Pembrokeshire National Park and the resort beach Amrot.

Studies of water samples from rocky beaches contaminated during the Sea Empress tanker accident confirmed the presence of natural oil and mineral aggregation. Active wave washing operations on Amroth Beach helped to remove oil not only due to abrasion associated with high waves and surf, but also by stimulating the interaction between oil and fine mineral particles under pebble, which was mechanically mixed excavator and transfer to the surf zone.

The results were so significant that after four days of treatment, the cleaning operations were stopped, since the concentration of the oil emulsion on the pebble was reduced from 15.2 g / kg to 0.94 g / kg. Visual observations showed [13] that 50% of the oil was extracted from the pebble in the form of dispersed drops of oil stabilized by mineral fine particles. The rest of the oil was extracted in the form of a condensed mass, according to the authors [13], obtained due to physical abrasion, weathering and, possibly, with the assistance of some mineral particles in the oil emulsion.

After achieving such significant positive results when cleaning the Amrot beach from oil using the “wave washing” method, it was approved for use on a more environmentally vulnerable and difficult to restore territory - Marros Beach of the Pembrokeshire Coast National Park, where the contaminated soil was transferred to the surf zone manually without application of technology [13, 14].

In the summer of 1997, in the course of field trials to assess the effectiveness of the selected methods for cleaning the coastline with a mixed soil type (sandstone, clay, and pebble) from accidental spills on the Spitsbergen archipelago (Svalbard), Norway, an IFO 30 fuel oil spill was conducted. In total 5500 l of fuel oil was applied to a preformed soil roll 3 m wide in the upper littoral zone of the three experimental sections of the coastline.

A week after the spill, the soil of the contaminated areas was subjected to mechanical mixing (plowing) and “wave washing” for bioremediation. The tests were carried out at water temperatures of 0 ° C - 2 ° C during the absence of ice and low wave energy (the wave height during the tests was less than 0.3 m).

Monitoring of the amount of oil remaining in the soil samples taken from the experimental plots was carried out six times, the latter was carried out 60 days after the “wave wash”. The authors of [15, 16] noted that a sharp decrease in the amount of fuel oil was observed during the first five days after soil transfer to the surf zone, as well as the presence of oil-mineral microaggregates in the samples.

Accelerated biodegradation of oil

Since the total oil-water interface in oil-mineral microaggregates significantly exceeds the same slick area of the same oil volume, the authors of [17, 18] made an assumption about an increase in the rate and degree of microbiological degradation of oil in the presence of oil-mineral aggregation.

Confirmation of an increase in the degree of biodegradation of oil in the presence of fine particles of sedimentary rocks was obtained from field observations of both the natural restoration of contaminated beaches [8, 9] and the results of “wave washing” [12], while monitoring was carried out, including in arctic conditions.

Thus, according to the results of observations in May 1980 - August 1983, after the pilot oil spill response of the BIOS project in the area of Baffin Island, Canada, it was found that in the long term, in most cases, natural cleansing of the coastline of Arctic beaches is observed [19]. It is worth noting here that the author has not yet associated the observed effect with the influence of oil-mineral aggregation. However, the Svalbard field trials, during which “wave washing” was tested under arctic conditions, confirmed the presence of intangible organic matter and its effect on increasing the rate of oil biodegradation [15, 16].

Within the framework of exploratory research under the Canadian Coast Guard program (CCG), aimed at developing methods and means of eliminating spills in the water area of the mouth of the St. Lawrence River, the authors of [20] evaluated the effect of oil-mineral aggregation on the biodegradation rate of oil emulsified using OMM.

The finely dispersed mineral particles used in the experiment were separated in sedimentation columns from sedimentary rocks taken from the Laurentian Depression at the mouth of the St. Lawrence River. X-ray diffraction analysis revealed the main composition of the selected particles: 90% clay with a size of less than 2 nm) and 10% sludge with a size of 2 to 63 nm (including 38% quartz, 22% feldspars, 20% illite and 10% chlorite). Prior to testing, Terra Nova crude oil produced from a research well off the Atlantic coast of Canada was pre-weathered by evaporation for 18 hours.

500 ml Erlenmeyer flasks were filled with 300 ml of seawater with a salinity of 28 ‰, taken from the St. Lawrence River in the area of the proposed OSR works. Then, equal amounts of weathered oil and Bushnell Haas broth were added to each flask (the broth was introduced weekly throughout the experiment). Then, in all flasks, except for the control ones, finely dispersed mineral particles were introduced in a ratio of 1 to 3 with respect to oil, after which the flasks were placed on a horizontal shaker to break the surface tension and ensure the formation of oil-mineral microaggregates. Shaking lasted 24 hours.
Then the flasks were incubated in the dark at a constant temperature of 10 ° C on a rotary shaker. The experiment lasted fifty six days, with oil biodegradation control samples taken from Erlenmeyer flasks on the first, seventh, fourteenth, twenty-eighth and last day of the experiment. For each sampling interval, the flasks of both groups (with and without finely dispersed mineral particles) were randomly selected for detailed chemical analysis. To assess the effect of the interaction of oil with mineral particles on the adhesion of oil to solid surfaces, such as laboratory glassware, samples from each sampling were divided into the fraction of the aqueous phase (dispersed oil, free-floating oil and OMM suspended in the water column) and solid phase fraction (oil particles and / or mineral particles adhering to the surface of glassware).
Changes in the concentration and composition of the aliphatic and aromatic fractions of residual hydrocarbons were determined by gas chromatography and mass spectrometry (GC-MS). Samples were introduced into a Hewlett-Packard 5890 Series II gas chromatograph equipped with an HP 5972 mass selective detector (MSD). The device worked in selective ion monitoring mode for the quantitative determination of specific components of saturated hydrocarbons and polycyclic aromatic hydrocarbons (PAHs). The concentration of specific compounds was determined by comparing the peak heights with the values of the recovery standards during extraction.

RESULTS AND DISCUSSION

Direct observations of samples from experimental flasks using UV-epifluorescence microscopy confirmed the presence of oil-mineral microaggregates consisting of oil droplets stabilized by mineral fine particles. The decrease in the adhesion of oil to the surface of glassware observed during the experiment was not taken into account by the authors of [20] when evaluating the results of chemical analysis, and they note that such dynamics can be explained by the presence of finely dispersed mineral particles in the flask.
Analysis of samples of the aqueous phase showed that mineral particles scattered oil into the aqueous phase (components > n-C25) and enhanced biodegradation (components < n-C25), and analysis of the dynamic series of samples during the experimental period showed that the addition of mineral fine particles increased the rate biodegradation of common aliphatic components.
As a result of analysis of samples on the seventh day of the experiment, the researchers found that the interaction between oil and mineral particles contributes to the start of the biodegradation of oil: 42.2% of the total amount of n-alkanes (from n-C13 to n-C35) decomposed in flasks with oil, treated with fine mineral particles. In the corresponding control flasks (without mineral particles), the same degree of biodegradation was achieved only on the twenty-eighth day.
During the experimental period, the authors of [20] found that the interaction between oil and mineral particles enhances both the rate and degree of biodegradation of oil.
The authors of [20] propose a quantitative increase in the biodegradation rate by statistical analysis, since oil concentrations exponentially decreased over time, but note that a significant increase in the overall rate of loss of n-alkanes was observed only in flasks with oil-mineral microaggregates.
In addition, the authors of [20] note that, contrary to the results of studies conducted earlier [4], the degree of biodegradation of oil during oil-mineral aggregation is not limited to aliphatic components, because their analysis of GC-MS revealed a similar trend in biodegradation and aromatic components.

CONCLUSION

Despite the fact that a number of laboratory studies and field observations indicate a positive effect of oil-mineral aggregation on the removal of oil from contaminated coastlines, including in the Arctic latitudes, the use of this physicochemical process as a separate measure to combat open water spills

and with the presence of ice in the ice seas of the Arctic region, it remains today a matter requiring detailed study.
Of particular interest is the study and evaluation of the effectiveness of this process from the point of view of bioremediation, hydrometeorological conditions, physico-chemical properties of the spilled product, production technology, as well as solving the question of the potential for controlling the oil-mineral aggregation process to obtain the required efficiency under certain conditions.

REFERENCES

[1] Salnikov A.V., Gribov G.G. Problems of Localization and Liquidation of Oil Spills in the Arctic Seas, Construction of Oil and Gas Wells on Land and at Sea, No. 5, pp. 30-34, 2016.
[2] Salnikov A.V., Tskhadaya N.D. Determining the Effectiveness of Dispersants for the Elimination of Oil Spills in the Arctic Seas, Oil Industry, No. 4, pp. 104-107, 2018. DOI: 10.24887/0028-2448-2018-4-104-107
[3] Salnikov A.V. Use of the oil-mineral aggregation for oil spill elimination in icy seas: background and presuppositions, Environmental Protection in Oil and Gas Complex, No. 4, pp. 43-48, 2019. DOI: 10.33285/2411-7013-2019-4(289)-43-48
[4] Weise, A. M., Lee, K. The Effect or Clay-Oil Flocculation on Natural Oil Degradation, Proceedings of the International Oil Spill Conference, American Petroleum Institute Washington, D. C., No 4651, pp 955-956, 1997.
[5] Stoffyn-Egli, P., Lee, K. Formation and Characterization of Oil-Mineral Aggregates, Spill Science & Technology Bulletin, Vol. 8, No.3, pp. 31-44, 2002.
[6] Lees, D.C., Houghton, P., Driskell W.B. Effects of Shoreline Treatment Methods in Intertidal Biota in Prince William Sound, Proceedings of the International Oil Spill Conference, American Petroleum Institute, Washington. D.C., No. 4130, pp. 345-354, 1993.
[7] Owens E.H., Davis, R. A, Michel, Jr. J., Stritzke K. Beach Cleaning and the Role of Technical Support in the 1993 Tampa Bay spill, Proceedings of the International Oil Spill Conference, American Petroleum Institute Washington. D. C., No. 4620, pp. 627-634, 1995.
[8] Bragg, J.R., Owens, E.H. Clay-oil flocculation as a natural cleansing process following oil spills : Part 1-Studies of shoreline sediments and residues from past spills, Proceedings of the 17th Arctic and Marine Oil Spill Program (AMOP) Technical Seminar, Environment Canada, Ottawa, Ontario, pp. 1-23, 1994.
[9] Owens, E. H., Bragg, J.R. Clay-Oil Flocculation as a Natural cleaning process following oil spills: Part 2 - Implications of Study Results in Understanding Past Spills and for future Response Decisions, Proceedings of the 17th Arctic and Marine Oilspill Programme (AMOP) Technical Seminar, Environment Canada. Edmonton. Alberta, pp. 25-37, 1994.
[10] Miller, J.A. Beach Agitation for Crude Oil Removal from Intertidal Beach Sediments, Proceedings of the International Oil Spill Conference, American Petroleum Institute Washington. D. C., No. 4452, pp. 85-90, 1987.
[11] Benson, R. L., LeGore, R.S., Pascoe, D. A Mechanized Approach to Beach Cleanup in Saudi Arabia, Proceedings of the 1993 International Oil Spill Conference, American Petroleum Institute. Washington. D.C., No. 4580, pp. 123-126, 1993.
[12] Lee, K., Lund, T., Wood, P., Swannel1, R., Stoffyn-Egli, R. Shoreline Cleanup by Acceleration of Clay-Oil Flocculation, Proceedings of the International Oil Spill Conference, American Petroleum Institute. Washington. D.C., No. 4651, pp. 235-240, 1997.
[13] Colcomb, K., Bedborough, D., Lunel, T., Swannell, R., Wood, P., Rusin, J., Bailey, N., Davies, L., Sommerville, M., Dobie, A., Mitchel, D., Shimwell, S., Davies, B., Harries, D., Lee, K. Shoreline Cleanup and Waste Disposal Issues During the Sea Empress incident. Proceedings of the International Oil Spill Conference, American Petroleum Institute. Washington. D.C., No. 4651, pp. 195-203, 1997.
[14] Lunel, T., Lee, K., Swannell, R., Wood, P., Rusin, J., Bailey, N., HalliwelI, C., Davies, L., Sommerville, M., Dobie, A., McDonagh, M. Shoreline Clean Up during the Sea Empress Incident: The Role of Surf Washing (Clay-Oil Flocculation), Dispersants and Bioremediation. Proceedings of the 19th Arctic and Marine Oilspill Programme (AMOP) Technical Seminar, Environment Canada, Ottawa, Ontario, pp. 1521-1540, 1996.

[15] Lee, K., Stoffyn-Egli, P., Tremblay, G. H., Owens, E.H., Sergy, G.A., Guenette, C.C., Prince, R.C. Oil-Mineral Aggregate Formation on Oiled Beaches: Natural Attenuation and Sediment Relocation, Spill Science & Technology Bulletin, Vol. 8, No.3, pp. 285-296, 2003.
[16] Garrett, R.M., Rothenburger S.J., and Prince, R.C. Biodegradation of Fuel Oil under Laboratory and Arctic Marine Conditions, Spill Science & Technology Bulletin, Vol. 8, No.3, pp. 297-302, 2003
[17] Bragg, J. R, Prince, R. C., Harner, E., Atlas, R.M. Effectiveness of Bioremediation for the Exxon Valdez Oil Spill, Nature, Vol. 368, No. 6470, pp. 413-418, 1994.
[18] Owens, E. H., Sergy, G. A. Application or Recent Technical Advances to the Decision Process for Shoreline Treatment, Proceedings of the International Oil Spill Conference, American Petroleum Institute Washington. D. C., No 4651, pp 289-295, 1991.
[19] Dickins, D.F. Ice Conditions at Cape Hatt, Baffin Island. Arctic, Vol. 40, Supp. 1, pp. 34-41, 1987.
[20] Lee K., Weise A.M., St-Pierre S. Enhanced oil biodegradation with mineral fine interaction, Spill Sci. Technol, Bull. 3, pp. 263-267, 1996.

BIOGAS - A SUBSTITUTE FOR NATURAL GAS

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Abstract: Biogas is a combustible mixture of gases and consists mainly of methane (CH4) and carbon dioxide (CO2) and is formed from the anaerobic bacterial decomposition of organic compounds, i.e. without oxygen. The gases formed are the waste products of the respiration of these decomposer microorganisms and the composition of the gases depends on the substance that is being decomposed. If the material consists of mainly carbohydrates, such as glucose and other simple sugars and high-molecular compounds (polymers) such as cellulose and hemicellulose, the methane production is low. However, if the fat content is high, the methane production is likewise high. This paper presents an overview of biogas in terms of production, composition, and use.
Key words: biogas, origin, composition, cleaning, applications, the future

INTRODUCTION

As the need for the replacement of fossil fuels as energy sources continues to grow, gases products from other sources (such as biomass) will continue to grow in importance. In fact, biomass will play an increasingly important role in the future global energy infrastructure for the generation of power and heat, but also in the production of gaseous and liquid products for the production of fuels and chemicals and fuels. Biomass is a source of alternative energy insofar as it can be used for fuel substitution and is (unlike the fossil fuels sources) a non-depleted resource which can be renewed and o annual basis.

The dominant biomass conversion technologies will be anaerobic digestion, gas from landfills, pyrolysis gas, and gasification of biomass, with gasification processes likely to supersede anaerobic digestion for the production of gases as intermediates for high-efficient power production or for the synthesis of chemicals and fuels. Isolation of the gas produced from the organic waste in a landfill will also be of extremely high interest. Furthermore, in the discussion on the production of gases from biomass (other forms of organic feedstocks, such as organic waste are also included here), it is important to understand that the composition of the produced gas is very dependent on the type of gasification process and especially the gasification temperature and the predominance of the various reactions [1,2,3,4,5].

BIOGAS

Biogas is a combustible mixture of gases and consists mainly of methane (CH_4) and carbon dioxide (CO_2) and is formed from the anaerobic bacterial decomposition of organic compounds, i.e. without oxygen. The gases formed are the waste products of the respiration of these decomposer microorganisms and the composition of the gases depends on the substance that is being decomposed. If the material consists of mainly carbohydrates, such as glucose and other simple sugars and high-molecular compounds (polymers) such as cellulose and hemicellulose, the methane production is low. However, if the fat content is high, the methane production is likewise high.

Methane – a colorless and odorless gas with a boiling point of -162°C (-260°F) and it burns with a blue flame – is the major combustible constituents of biogas. Methane is also the main constituent (77 to 90%) of natural gas. Chemically, methane belongs to the alkane series of hydrocarbons and is the simplest possible member of this series (C_nH_{2n+2}) form of these. At normal temperature and pressure, methane has a density of on the order of 0.66 to 0.72 g/L in the gas phase or 0.42 g/L in the liquid phase. Due to carbon dioxide being somewhat higher density, biogas has a slightly higher density than methane and is on the order of 1.15 g/liter. If biogas is mixed with 10 to 20% air, there is the high probability of an explosion – explosive air is the name often applied to such a mixture.

ORIGIN

Biogas originates from the metabolic activities of bacteria in the process of biodegradation of organic material under anaerobic conditions (conditions without air and sometime referred to as fermentation). Thus, the natural generation of biogas is an important part of the biogeochemical carbon cycle, which is a pathway by which a chemical substance moves through the biosphere and lithosphere, atmosphere, and hydrosphere of the Earth. In addition to natural systems, biogas is produced in different anthropogenic environments such as landfills, waste water treatment plants (WWTP), and biowaste digesters during anaerobic degradation of organic material.

Biogas is typically produced by anaerobic digestion (also called anaerobic fermentation) of various feedstocks (Table 1, Table 2), although other processes are known, which involves the activities of three different bacterial communities. In the biogeochemical cycle, methanogens (methane-producing bacteria) are the final link in a chain of micro-organisms which degrade organic material and return the decomposition products to the environment. It is in this process that biogas is generated and the constituents of biogas – methane, hydrogen, and carbon monoxide – can be combusted or oxidized with oxygen and it is this energy release which allows biogas to be used as a fuel. Biogas can be used as a low-cost fuel in any country for any heating purpose, such as cooking, and it can also be utilized in modern waste management facilities where it can be used to run any type of heat engine, to generate either mechanical or electrical power [6,7,8].

Table 1. Composition of Various Biogas Samples

Source:	**Household waste**	**Wastewater treatment plant sludge**	**Agricultural waste**
Component			
Methane, % v/v	50 - 60	60 - 75	60 - 75
Carbon dioxide, % v/v	38 - 34	33 - 19	33 - 19
Nitrogen, % v/	5 - 0	1 - 0	1 - 0
Oxygen, % v/v	0 - 1	< 0.5	< 0.5
Water, % v/v	6	6	6
Hydrogen sulfide, mg/m^3	100 - 900	1000 - 4000	3000 - 10 000
Ammonia, mg/m^3	-	-	50 - 100
Aromatics mg/m^3	0 - 200	-	-
Properties:			
Density*	0.93		0.85
Wobbe index**	6.9		8.1

*Natural gas: 0.57
**Natural gas: 14.9

The process of biogas-production depends on various parameters [9,10,11]. For example, changes in ambient temperature can have a negative effect on bacterial activity. The microbes that produce biogas microbes consist of a large group of complex and differently acting microbe species, notably the methane-producing bacteria. The whole biogas-process can be divided into four steps: hydrolysis, acidification, acetogenesis, and methane formation. As a result of these four steps, biogas typically from different digestible sources contains constituents that can range considerably – up to 70% v/v methane and as much as 45% v/v carbon dioxide when the methane contact is lower. Depending on the source, biogas can also contain, e.g., nitrogen, hydrogen sulfide, halogenated compounds and organic silicon compounds.

Table 2. Simplified Illustration of the Generation of Biogas

Substrate	Stage 1 products	Stage 2 products	Stage 3 products*
Organic waste	Carbon dioxide		Carbon dioxide
	Acetic acid		Methane
	Propionic acid	Carbon dioxide	Carbon dioxide
		Acetic acid	Methane
		Carbon dioxide	Carbon dioxide
	Butyric acid	Acetic acid	Methane
		Carbon dioxide	Carbon dioxide
		Acetic acid	Methane
Stage 1 catalyst: fermentive bacteria			
Stage 2 catalyst: acetogenic bacteria			
Stage 3 catalyst: methanogenic bacteria			
* Hydrogen is also produced in minor quantities in each stage			

COMPOSITION

The composition of biogas is highly variable, especially when compared to the composition of natural gas (Table 3). For example, biogas from sewage digesters usually contains from 55 to 65% v/v methane, 35 to 45% v/v carbon dioxide, and < 1 % nitrogen whereas biogas from organic waste digesters usually contains from 60 to 70 % methane, 30 to 40 % carbon dioxide and <1% v/v nitrogen, while in biogas from landfills typically from 45 to 55% v/v methane, 30 to 40 % v/v carbon dioxide, and 5 to 15% v/v nitrogen. Besides the main components, biogas also contains hydrogen sulfide and other sulfide compounds, aromatic compounds, and halogenated compounds, and siloxane derivatives. The latter compounds (i.e. halogenated compounds, and siloxane derivatives) are more common in landfill biogas than in biogas from the anaerobic digestion of manure (unless the livestock have been on a very mysterious diet).

Table 3. Ranges of Composition of Biogas Compared to Landfill Gas (also a biogas) and Natural Gas.

	Anaerobic digester gas	Landfill gas	Natural gas
Density	1.1	1.3	0.82
Relative density (air = 1.0)	0.9	1.1	0.63
Wobbe index	27	18	55
Methane number*	>135	>130	73
Methane, % v/v	60-70	35-65	85-92
Heavy hydrocarbons	0	0	9
Hydrogen, % v/v	0	0-3	-
Carbon dioxide, % v/v	30-40	15-40	0.2-1.5
Nitrogen, % v/v	-	5-40	0.3-1.0
Oxygen, % v/v	-	0-5	-
Hydrogen sulphide, ppm v/v	0-4000	0-100	1.1-5.9
Ammonia, ppm v/v	100	5	-
Total chlorine, ppm v/v	0-5	20-200	-

*A measure of the gas resistance to knocking in an internal combustion engine; see Malenshek, M., and Olen, D.B. 2009. Methane Number Testing of Alternative Gaseous Fuels. Fuel, 88: 650-656.

Although the amounts of trace compounds are low compared to methane, they can have environmental impacts such as stratospheric ozone depletion, the greenhouse effect and/or the reduction in local air quality. In addition, some compounds cause engine damage leading to engine failure if the gas is used as an energy source. Many volatile organic compounds (VOCs) with high vapor pressure and low solubility, which can occur in biogas from some sources, are harmful to the environment and/or to human health. For example, aromatic derivatives, heterocyclic compounds, ketone derivatives, aliphatic derivatives, terpene derivatives, alcohol derivatives, and halogenated aliphatic derivatives, for example, occur in particular in landfill gas [12,13,14,15,16]. Also, many toxic volatile organic compounds are formed from household waste which includes cleaning compounds, plastics, synthetic textiles, coatings, pesticide derivatives, and pharmaceutical derivatives, [17].
The predominant sulfur compound in biogases is hydrogen sulfide (H2S) but other sulfur compounds such as sulfide derivatives (-S-, including hydrogen sulfide, disulfide derivatives (-S-S-), and thiol derivatives (-SH, also called mercaptans) can also occur in biogas. In the presence of water, sulfur compounds can cause corrosion to compressors, gas storage tanks and engines and, thus, these compounds need to be removed before biogas can be utilized as energy. Under anaerobic conditions hydrogen sulfide and other sulfide compounds originate along several different pathways [18]. For example, methanethiol (CH_3SH) and dimethyl sulfide (DMS, CH_3SCH_3) are formed by the degradation of sulfur-containing amino acids such as cysteine ($HO_2CCH(NH_2)CH_2SH$) that may be present in manure.

CLEANING

Biogas cleaning, which is the first step in the biogas upgrading process, has gained increased attention due to the recognition that as conventional fossil fuel sources of gas are being depleted the sources of biogas – the various forms of biomass – offer an unlimited supply of feedstocks for the production of the gas. It is therefore important to have an optimized upgrading process in terms yielding high methane content in the upgraded gas [11,19,20,21]. It is also very important to minimize, or if possible avoid, emissions of methane during the upgrading process, since methane has a greenhouse gas effect that is twenty three times greater than the greenhouse gas effect of carbon dioxide.
Biogas can be cleaned in a conventional gas processing facility with the recognition that the main difference in the composition between biogas and natural gas relates to the carbon dioxide content. Carbon dioxide is one of the main components of biogas, while natural gas contains lower amounts carbon dioxide. In addition, natural gas also contains higher levels of hydrocarbons other than methane. These differences result in a lower energy content of biogas per unit volume compared to natural gas and by separating carbon dioxide from the biogas in an upgrading process, the energy content of upgraded biogas becomes comparable to natural gas.
Biogas from anaerobic digestion and landfills consists primarily of methane (CH_4) carbon dioxide (CO_2) (Table 3). Trace components that are often present in biogas are water vapor, hydrogen sulfide, siloxanes, hydrocarbons, ammonia, oxygen, carbon monoxide and nitrogen. The end result is that the biogas for use must be very clean to reach pipeline quality and must be of the correct composition for the gas distribution network to accept – any carbon dioxide, water, and hydrogen sulfide.
In order to transfer biogas into biomethane, two major steps are performed: (i) a cleaning process to remove the trace components and (ii) an upgrading process to adjust the calorific value (Table 4). Upgrading is generally performed in order to meet the standards for use as vehicle fuel or for injection in the natural gas grid. Different methods for biogas cleaning and upgrading are used. They differ in functioning, the necessary quality conditions of the incoming gas, the efficiency and their operational bottlenecks. Condensation methods (demisters, cyclone separators or moisture traps) and drying methods (adsorption or absorption) are used to remove water in combination with foam and dust.

APPLICATIONS AND THE FUTURE

Biogas is considered to be a renewable resource because its production-and-use cycle is continuous, and it generates no net carbon dioxide. The gas is copious and is available from sources such as landfills, wastewater treatment facilities, and animal and agricultural waste. If fully consumed, the yield from existing organic waste streams could satisfy about 20% v/v of current natural gas use.

Biogas is currently applied as a heating and electricity fuel but is expected to find more advanced applications as a vehicular fuel gradually. The developing technology should not be viewed as a competition to the already existing conventional energy sources but rather a compliment to what is already existing and a sustainable environmental management scheme for the future. Additionally, to improve the awareness of a sustainable fuel, more demonstration plants should be set up.

In future investigations, analyses of synchronized process of co-digestion with substrates are needed to be executed and also researchers need to concentrate on multi stage anaerobic co-digestion with reduced cost through the selection of appropriate expertise. Purification of biogas is the major task behind the fixation of cost level, which should be analyzed in detail with methods like cryogenic upgradation and In situ methane enrichment. Further, the developing methods for upgrading and refinement of the produced biogas will receive major attention due to rapid increment in the price of fossil fuels.

Biogas production in the agricultural sector is a very fast growing market in Europe and finds increased interest in many parts of the world. In the next few decades, bioenergy will be the most significant renewable energy source, because it offers an economical attractive alternative to fossil fuels. The success of biogas production will come from the availability at low costs and the broad variety of usable forms of biogas for the production of heat, steam, electricity, and hydrogen and for the utilization as a vehicle fuel. Many sources, such as crops, grasses, leaves, manure, fruit, and vegetable wastes or algae can be use, and the process can be applied in small and large scales. This allows the production of biogas at any place in the world.

Finally, in order to improve the economic benefit of biogas production, the future trend will go to integrated concepts of different conversion processes, where biogas production will still be a significant part.

REFERENCES

[1] Speight, J.G. 2013a. The Chemistry and Technology of Coal 3rd Edition. CRC-Taylor and Francis Group, Boca Raton, Florida.
[2] Speight, J.G. 2013b. Coal-Fired Power Generation Handbook. Scrivener Publishing, Beverly, Massachusetts.
[3] Speight, J.G. 2014a. The Chemistry and Technology of Petroleum 4th Edition. CRC-Taylor and Francis Group, Boca Raton, Florida.
[4] Speight, J.G. 2014b. Gasification of Unconventional Feedstocks. Gulf Professional.
[5] Luque, R., and Speight, J.G. (Editors). 2015. Gasification for Synthetic Fuel Production: Fundamentals, Processes, and Applications. Woodhead Publishing, Elsevier, Cambridge, United Kingdom.
[6] Bove R., and Lunghi P. 2005. Electric Power Generation from Biogas Using Traditional and Innovative Technologies. Energy Conversion & Management; 47, 1391- 1401, 2005.
[7] Budzianowski W. 2011. Sustainable Biogas Energy in Poland: Prospects and Challenges. Renewable and Sustainable Energy Reviews, 2011.
[8] Niemczewska, J. 2012. Characteristics of Utilization of Biogas Technology. Nafta-Gaz, LXVIII(5): 293-297.
[9] Weiland, P. 2010. Biogas Production: Current State and Perspectives. Appl. Microbiol. Biotechnol., 85(4): 849-60.
[10] Nasir, I.M., Mohd, Ghazi. T.I. and Omar, R. 2012. Anaerobic Digestion Technology in Livestock Manure Treatment for Biogas Production: A Review. Eng. Life Sci., 12(3): 258-69.
[11] Speight, J.G. 2019b. Biogas: Production and Properties. Nova Science publishers, New York.
[12] Allen, M. R., Braithwaite, A. & Hills, C. C. 1997. Trace Organic Compounds in Landfill Gas at Seven U.K. Waste Disposal Sites. Environ. Sci. Technol. 31: 1054-1061.

[13] Spiegel, R. J., Preston, J. L. & Trocciola J. C. 1997. Test results for fuel-cell operation on landfill gas. Energy 22: 777-786.
[14] Eklund, B., Anderson, E. P., Walker, B. L. & Burrows, D. B. 1998. Characterization of landfill gas composition at the fresh kills municipal solid-waste landfill. Environ. Sci. Technol. 32: 2233-2237.
[15] Shin, H-C., Park, J-W ., Park, K. & Song, H-C. 2002. Removal characteristics of trace compounds of landfill gas by activated carbon adsorption. Environ. Pollut. 119: 227-236.
[16] Jaffrin, A., Bentounes, N., Joan, A. M. & Makhlouf, S. 2003. Landfill Biogas for Heating Greenhouses and Providing Carbon Dioxide Supplement for Plant Growth. Biosyst. Eng. 86: 113-123.
[17] Reinhart, D. R 1993. A review of recent studies on the sources of hazardous compounds emitted from solid waste landfills: A U.S. experience. Waste Manage. Res. 11: 257-268.
[18] Wilber, C., and Murray, C. 1990. Odor Source Evaluation. Biocycle, 31(3): 68-72.
[19] Mokhatab, S., Poe, W.A., and Speight, J.G. 2006. Handbook of Natural Gas Transmission and Processing. Elsevier, Amsterdam, Netherlands.
[20] Persson M., Wellinger A. 2006. Biogas Upgrading and Utilization, IEA Bioenergy. International Energy Agency, London, United Kingdom.
[21] Speight, J.G. 2019a. Natural Gas: A Basic Handbook 2nd Edition. GPC Books, Elsevier, Gulf Publishing Company, Elsevier, Cambridge, Massachusetts.

RESIDUAL FATIGUE LIFE ESTIMATION OF OIL RIG PIPES WITH AN AXIAL SURFACE CRACK

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Abstract This work represents residual fatigue life estimation of high-frequency (HF) welded oil rig pipes made of API J55 steel. Experimental tests of base metal mechanical properties, including fatigue properties, were conducted on pipes after 70.000 hours of service in an oil drilling rig. The fatigue crack growth rate and fatigue threshold are obtained using the pre-cracked Charpy specimens. The number of cycles to the final fracture is then calculated using initial and critical crack depths. Based on the number of cycles to the final fracture the remaining fatigue lifetime of pipes with axial outer surface crack is determined.
Keywords: fatigue life, oil rig pipes, axial surface crack, number of cycles to failure N_f.

INTRODUCTION

The pipelines are the most economical and safest way for oil and gas transport. They may consist of welded or seamless pipes. Standard API 5CT generally specifies pipes and fittings dimensions and their mechanical properties. However, the majority of failures of welded steel pipelines are due to insufficient resistance to crack initiation and growth, poor quality of welded joints and reduced capacity due to corrosion damage, [1].
During its life cycle, welded casing pipes used for oil rigs are exposed to corrosion effects, augmented with high pressure and high temperature environment. That is why the casing pipes are very sensitive to degradation of the material, which is often preceded by errors in their design and construction, production and installation defects, unforeseen exploitation conditions and working environment conditions.
The reliability of the oil rigs system is very important for the continued exploitation and for environmental protection as well. Therefore, the standards and recommendations for assessing the effects of cracks on the integrity of welded pipes were developed. Some of them deal with the effect of through-wall cracks on the integrity of the pipes that are loaded by the internal pressure and bending [2]. However, welded casing pipes can also have an axial surface crack on the inside and/or outer surface, and be subjected to different loads, including external and internal pressure and axial loads (e.g. due to structure weight).
In order to keep the pipeline safe and reliable in operation, its integrity assessment is of utmost importance [3-5]. The essential part of integrity assessment is to estimate precisely the maximum allowed pressure, as well as to evaluate fracture mechanics parameters, like stress intensity factor and J integral. Contrary to inner circumferential and axial semi-elliptical cracks [4-9], there are only a few papers dealing with the outer cracks [8].
It is important to notice that the environment potentially has a significant effect on structural integrity. The low-alloyed steels are nowadays widely used for pipelines, due to the optimal combination of mechanical properties and weldability, but their application for oil and gas pipelines is still related to failures. Thus, specific models for residual life have been developed, like [10]. Many laboratory studies, as well as recent experience, have shown that work environment containing water can significantly influence the rapid development of fatigue cracks in ferrite steels, [11].
This paper presents the assessment of the residual lifetime of welded casing pipes with axial surface crack, made of API J55 steel. The analyzed pipe was in operation at an oil rig and was withdrawn during the process of reparation, after a period of about 70,000 hours (about 8 years). This period is much shorter than the projected service lifetime, which is up to 30 years.
In order to evaluate the residual life of pipes with an axial surface crack the values of coefficients C_p and m_p are determined, as well as fatigue crack growth rate (da/dN), by testing pre-cracked Charpy specimens in three-point bending. The number of cycles to the final fracture were then calculated

using initial and critical crack depths. Based on the number of cycles to the final fracture and the number of stress cycles (determined by the number of working hours per year) the number of remaining fatigue lifetime years of pipes with an axial surface crack at the outer pipe surface was determined.

EXPERIMENTAL PROCEDURE FOR THE FATIGUE CRACK GROWTH

The pressured welded pipes can be very sensitive to cracks and their stable or unstable growth. Therefore, it is important to identify reliable criteria for assessing the remaining lifetime of pressured pipes with cracks in base material and weld. In order to understand better the crack initiation and crack growth in casing pipes exposed to high pressures, high temperatures and chemically aggressive work environment in oil rigs, the material behavior control parameters at the crack tip and the fracture resistance should be expressed quantitatively. Therefore, the critical stress intensity factor K_{Ic}, the crack growth resistance curve (J-Δa), the fatigue crack growth rate, da/dN and the stress intensity factor range at the fatigue threshold, ΔK_{th}, are experimentally tested and determined.

ASTM Standard E647, [12], provides procedures for fatigue crack growth rate, da/dN, testing and measurement, as well as the calculation of stress intensity factor range, ΔK. Standard Charpy specimens with fatigue crack in the base material (2 mm) and with the foil RUMUL RMF A-5 for the continuous monitoring of crack length were used. Tests were conducted at room temperature with three-point bending in load control, and a high-frequency resonant pulsator CRACKTRONIC is used. The diagram of a-N dependence is shown in Figure 1, [13].

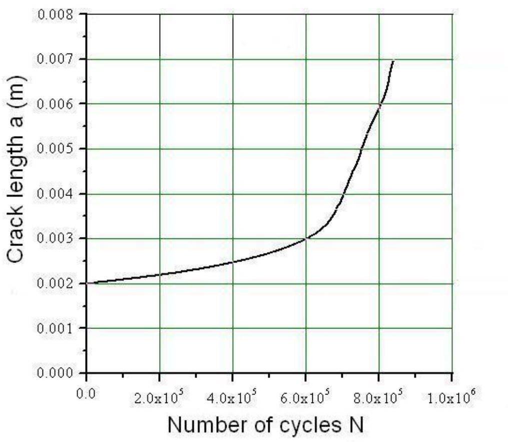

Figure 1. Crack length a – number of cycles N dependence

Diagram of changes in fatigue crack growth rate, da/dN - depending on the stress intensity factor range, ΔK, for specimens with a fatigue crack tip in BM, is shown in Figure 2.

Obtained parameter values from Paris equations, are: coefficient C_p=2.11·10^{-15} [m/cycles·MPa·m$^{1/2}$], exponent m_p=6.166, fatigue threshold ΔK_{th}=9.5 [MPa·m$^{1/2}$], and fatigue crack growth rate, da/dN=3.75·10^{-8} [m/cycles], [13].

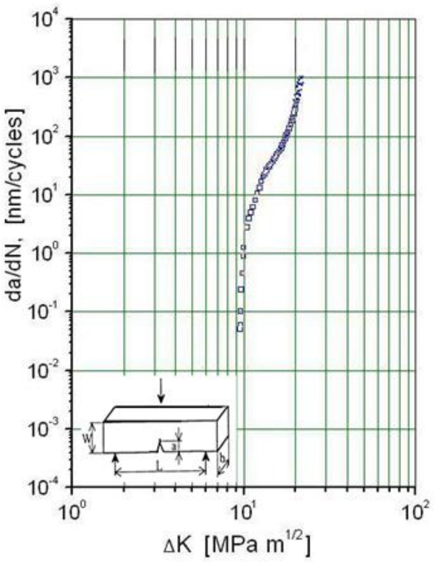

Figure 2. Curve *da/dN-ΔK*

RESIDUAL FATIGUE LIFE ESTIMATION

Main technical characteristics of the oil rigs from which the pipe was withdrawn after 70,000 hours are as follows:

- the layer pressure (Kp-31):
  p_{max}=10.01 [MPa], p_{min}=7.89 [MPa].
- the layer temperature: *T*=65 [°C],
- the number of strokes of the pump rod: n_{PR}=9.6 [min^{-1}]
-

The pipe with diameter Ø139.7 mm and nominal wall thickness 6.98 mm is with axial outer surface crack length *a*=200 mm and depth c= 3.5 mm, (Figure 3).

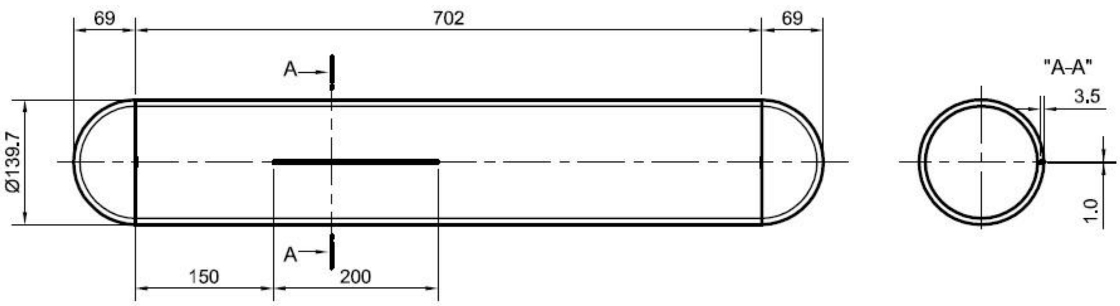

Figure 3. The test pipe with an axial outer surface crack

The working stresses and the stress amplitude in circumferential direction are:

$$\sigma_{max} = \frac{2p_{max}R}{t} = \frac{2\cdot 10.01\cdot 66.36}{6.98} = 190[MPa] \tag{1}$$

$$\sigma_{min} = \frac{2p_{min}R}{t} = \frac{2\cdot 7{,}89\cdot 66{,}36}{6.98} = 150[MPa] \tag{2}$$

$$\Delta\sigma = \sigma_{max} - \sigma_{min} = 40[MPa] \tag{3}$$

where: R is the pipe radius, t - pipe wall thickness, p - layer pressure, 2 - correction factor due to cross-section weakening (crack depth c=3.5 mm - 50% of wall thickness).

Crack growth under variable loading of machine parts and construction has a crucial influence on their lifetime. Therefore, to estimate the number of cycles to fracture occurrence and for implementation of complex control procedures in production and exploitation monitoring of practical importance is to determine the relationship between the present stress state at the crack tip, which is at a variable load determined by the stress intensity factor range *ΔK*, and the crack growth rate *da/dN* (Fig.2) The crack growth to its critical size primarily depends on external loads and crack growth rate. Paris equation for metals and alloys, establishes the relationship between fatigue crack growth *da/dN* and stress intensity factor range ΔK, using the coefficient C_p and the exponent m_p:

$$\frac{\mathrm{d}a}{\mathrm{d}N} = C_p(\Delta K)^{m_p} = C_p\left(1{,}12 \cdot \Delta\sigma \cdot \sqrt{\pi \cdot a}\right)^{m_p} \tag{4}$$

By the integration of Paris equation from the initial crack length a_0 to a critical crack length a_{cr} the total number of cycles, *N* is obtained, from initiation of a fatigue crack to its critical development, [14].

$$N = \frac{2}{(m_P - 2)\cdot C_P \cdot (1{,}12 \cdot \Delta\sigma)^{m_P} \cdot \pi^{\frac{m_p}{2}}}\left(\frac{1}{a_0^{\frac{m_P-2}{2}}} - \frac{1}{a_{cr}^{\frac{m_P-2}{2}}}\right) \tag{5}$$

The specimens fatigue crack tip was: a_0=2 mm (initial crack length (standard 3PB specimen, Fig. 2), and calculated critical crack length a_{cr} was :

$$a_{cr} = \frac{1}{\pi}\left[\frac{K_{IC}}{\Delta\sigma \cdot f\left(\frac{a}{W}\right)}\right]^2 = \frac{1}{\pi}\left[\frac{91{,}4}{1.12 \cdot 380}\right] = 14{,}4mm \tag{6}$$

where K_{Ic} is the fracture toughness, and σ_c is the critical stress, i.e. the yield strength.
Dependence of the stress intensity factor on crack angle φ is given for different crack shapes and crack depths c/t=0.2÷0.8, for 2a/c=3 and a_{cr}=14.4 mm, the critical crack depth in pipe wall is c_{kr}=4.8 mm [15].
The fracture toughness has been evaluated by using the J-R curve, obtained by testing CT specimens, i.e. by using the formula:

$$K_{Ic} = \sqrt{\frac{J_{Ic} \cdot E}{1 - \nu^2}} \tag{7}$$

For J_{Ic}=35.8 [kN/m], it follows KIc=91.4 [MPa·m$^{1/2}$].
By applying Eqn (3) the one can get:

$$N = 17.66 \times 10^6 \text{ cycles}$$

For annual working hours, $T_y = 8760$ h, a number of cycles are:

$$N_y = 60 T_y n_{PR} = 60 \times 8760 \times 9{,}6 = 5{,}046 \times 10^6 \text{ cycles/year.}$$

The remaining fatigue life, *n*, as given in years of exploitation, for a pipe with initial axial surface crack is:

$$n = \frac{N}{N_y} = \frac{17.66 \times 10^6}{5.046 \times 10^6} = 3.5\, years$$

The remaining fatigue life is 3.5 years of exploitation. Having in mind that the analyzed pipe had been in operation at an oil rig for a period of about 70,000 hours (about 8 years), in total fatigue life is about 11.5 years of service. This period is much shorter than the projected service lifetime (for about 62%).

CONCLUSION

The reliability of the oil rigs system is very important for the continued exploitation and for environmental protection as well. During its life cycle, welded casing pipes used for oil rigs are exposed to corrosion effects, augmented with high pressure and high temperature. That is why the casing pipes are very sensitive to degradation of the material, which is often preceded by errors in their design and construction, production and installation defects, unforeseen exploitation conditions and working environment conditions. The pressured welded pipes can be very sensitive to cracks and their stable or unstable growth which has a crucial influence on their lifetime.

The remaining fatigue life was calculated assuming that welded casing pipes in oil rigs had been damaged on the outer surface. It was calculated that, after 8 years of operation, the residual lifetime of damaged pipes was about 3.5 years. From a fatigue point of view, this remaining life is much shorter than the projected service lifetime, which is up to 30 years. That is about 62% less than the projected lifetime. Moreover, having in mind the predicted severe exploitation conditions, significantly shorter remaining fatigue lifetime of welded casing pipes is expected.

Results presented here show a significant influence of axial outer surface crack on the residual lifetime of damaged oil rig pipe.

REFERENCES

[1] Arsić M.: Choice of steel for welded tubes production, Welding Weld Struct., 47, pp 33-37, 2002.
[2] Sanjeev S, Ramachandra M.: On the accuracy of ductile fracture assessment of through-wall cracked pipes, Engineering Structures, 29, pp 789–801, 2007.
[3] Kumar V. and German M.D.: Elastic-plastic fracture analysis of through-wall and surface flaws in cylinders, EPRI Report, NP-5596, 1988.
[4] API RP579 - Recommended Practice for Fitness-For-Service, American Petroleum Institute, 2000.
[5] Miller A.G.: Review of limit loads of structures containing defects, International Journal of Pressure Vessels and Piping, 32, pp 191-327, 1988.
[6] Jones M.R., Eshelby J.M.: Limit solutions for circumferentially cracked cylinders under internal pressure and combined tension and bending, Nuclear Electric Report TD/SID/REP/0032, 1990.
[7] Delfin P.: Limit load solutions for cylinders with circumferential cracks subject to tension and bending, SAQ/FoU Report 96/95, SAQ Kontroll AB, Stockholm, Sweden, 1998.
[8] Raju I.S. and Newman J.C.: Stress-intensity factors for internal and external surface cracks in cylindrical vessels, Journal of Pressure Vessel Technology, 104, pp 293-298, 1982.
[9] Bergman M.: Stress intensity factors for circumferential surface cracks in pipes, Fatigue and Fracture of Engineering Materials and Structures, 18, pp 1155-1172, 1995.
[10] Pavankumar T., Samal M., Chattopadhyay J., Dutta B. and Kushwaha E.: Transferability of fracture parameters from specimens to component level, International Journal of Pressure Vessels and Piping, 82, pp 386–399, 2005.
[11] Erent Eason D, Edward Nelson E. and Gilman D.: Modeling of fatigue crack growth rate for ferrite steels in light water reactor environments, Nuclear Engineering and Design, 184, pp 89-111, 1988;
[12] ASTM E647-95, Standard test method for constant-load-amplitude fatigue crack growth rates, Annual Book of ASTM Standards, Vol. 03.01, 1995.

[13] Šarkoćević Ž, Arsić M, Medjo B, Kozak D, Rakin M, Burzić Z, Sedmak A.: Damage level estimate of API J55 steel for welded seam casing pipes, Strojarstvo: J Theory Appl. Mech. Eng, 51, 303-311, 2009.
[14] Lazić Vulićević Lj.: Fatigue fracture resistance of welded pipes made from high strength steels, Doctoral dissertation, University of Belgrade, Belgrade, Feb. 2015.
[15] Sedmak, A., Berković, M., Savović, N.: Numerical analysis of surface crack problems in pressure vessels, Structural Integrity and Life, Vol. 4, No 2, pp. 91-100. 2004.

SOME ASPECTS OF CRUDE OIL PIPELINE TRANSPORT

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Abstract: This paper discussed with the basic problems of transportation of crude oil by pipelines. Due to its properties and tendency to gel at lower temperatures, the oil is preheated before being introduced into the pipeline. This prevents the deposition of paraffin on the pipe walls. The following is given in the paper: Influence of paraffin content on the pour point, pressure drop in a pipeline with different paraffin content at different flow temperatures, pressure drop in the pipeline depending on transport capacity, as well as structural solutions for heating the pipeline.
Key words: oil, paraffin, heating, transport

INTRODUCTION

Problems and difficulties during transportation occur in crude oil with a high paraffin content. Paraffin content has an effect on the physical properties of the oil flow. This is the most often the case for high-paraffin oil with a paraffin content above 15%. Such oils are called heavy oils. Oil gelling occurs when oil is cooled. The pour temperature occurs with a further decrease in temperature, and then the oil passes from the glaze structure to a semi-solid state, a gel. [1, 2].
Cooling the oil below the flow temperature causes the entire mass of the oil to gel. This can occur during pipeline outage. Because of this problem, it is necessary to design such operating conditions of the oil pipeline so that oil is always would be above the pour temperature [10], [12, 13].

ANALYSIS OF INFLUENTIAL PARAMETERS IN CRUDE OIL PIPELINE TRANSPORT

High-paraffinic oils have high pour points, ranging from 15 to 45^oC. At temperatures between the pour temperature and the temperature 8^oC higher than the pour temperature, these oils act as non-Newtonian fluids. This means that the dynamic viscosity depends on both the temperature and the tangential shear stress [6], [8].
The properties of high-paraffin oils are significantly influenced by the paraffin content into the oil. Oils with different paraffin content have a pour point, as shown in Table 1 [3], [7].

Table 1. Oil pour points with different paraffin content

Paraffin content in mass %	Pour point in ^oC
12,7	23
15,4	27
18	29
23	33
29,3	36

Dependence of the pour point on the paraffin content of crude oil, based on Table 1, is shown in Figure 1.

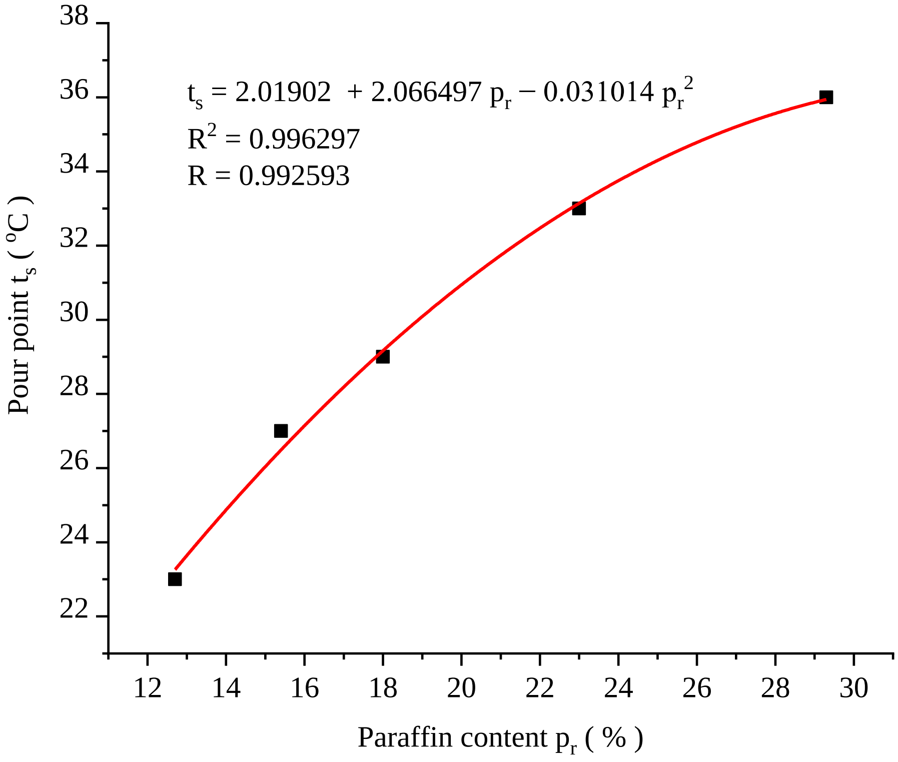

Figure 1. Dependence of the pour point on the paraffin content of crude oil

The dependence of the shear stress on the paraffin content and temperature is shown in Figure 2 [3].

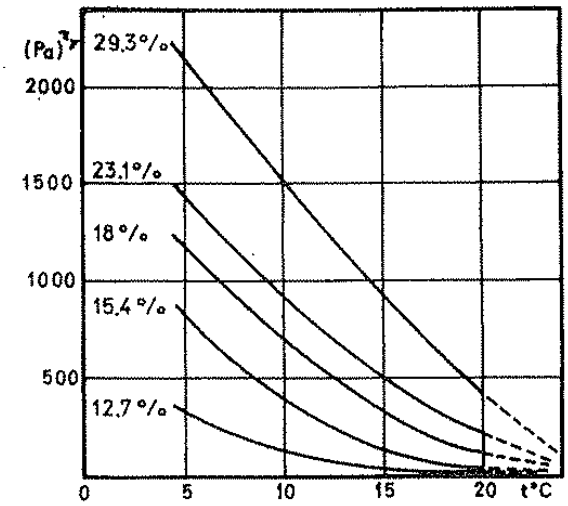

Figure 2. Dependence of the shear stress on the paraffin content and temperature

The dependence of the pressure drop at an oil flow of Q = 200 m^3/h, with different paraffin content and at different temperatures, for a pipeline with a diameter of D_u = 303 mm, is shown in Figure 3 [7].

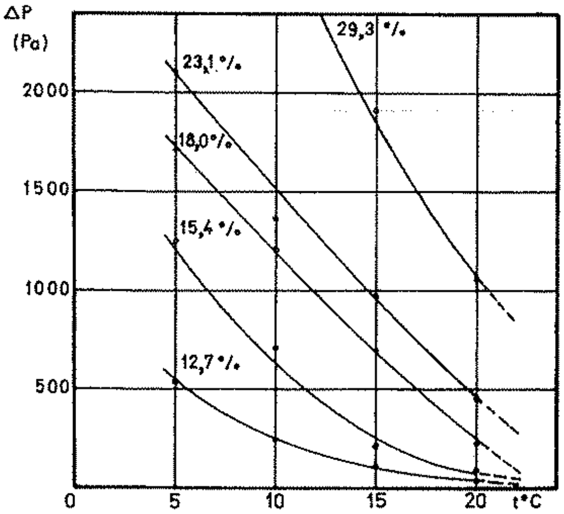

Figure 3. Pressure drop in a pipeline with different paraffin content at different flow temperatures

For this reason, for each type of high-paraffin oil, the flow characteristics are determined and depending on the flow conditions (climatic conditions), suitable transportation solutions are found. Due to the large number of factors affecting the flow properties of high-paraffin oils, there is no universal solution for their transport [9].

There are several possible technical solutions for the transportation of high-paraffin oil:

- transport of oil in the heated state,
- transportation of dilute oil,
- transportation of treated oil with rheological properties modifiers, etc.

Oil pipelines for the transportation of heated oil can be constructed in such a way that oil heating takes place along the entire oil pipeline, or only at certain locations: at the beginning of the pipeline and at interstations. When oil is heated over the entire length of the pipeline, its temperature does not change along the pipeline. When the oil is heated only in certain locations, the temperature along the pipeline after the place of heating, decreases. [4].

When installing an oil pipeline for transporting heated oil, care must be taken that there may be a change in the amount of oil (pipeline flow) to be transported. Based on this, the minimum and maximum oil flow and pipeline characteristic should be determined for each pipeline so that the pump operates in the area of optimal efficiency [11].

The pressure drop due to friction in the pipeline depending on the transport capacity is shown in Figure 4 [3].

When transporting heated oil, care should be taken to restore flow if unforeseen delays and failures occur. If the oil flow delay is shorter, it will be easier to restore re-flow in the oil pipeline because less initial pump pressure is also required [9].

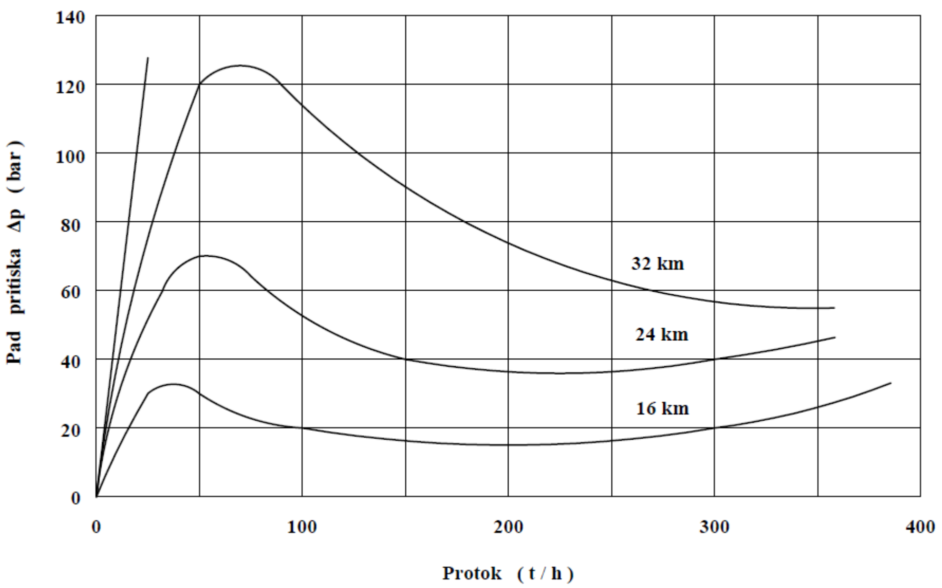

Figure 4. Pressure drop in a pipeline with a diameter of 324 mm, for different flows

There are various construction solutions for heating and maintaining the temperature along the pipeline during transportation. Some of these solutions are given in Figure 5 [3, 4, 5].

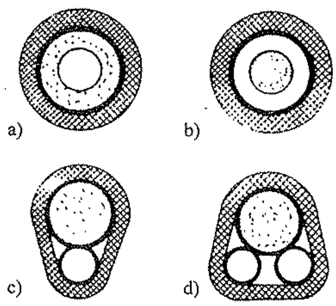

Figure 5. Design solutions for heating oil pipelines

Viscosity increases with decreasing temperature. Increasing the flow rate and reducing the crude oil temperature results in an increase in pump power. When transporting crude oil with higher viscosity, higher pressure drop and pump power are required [4, 5].

When transporting paraffin oil, at a temperature below the flow point, higher pumping pressure is required. If it is ensured that the fluid is kept in motion, no major problems or delays will occur [1, 2, 3].

For the transportation of oil and oil products, the choice of the power of the pump aggregates is of great importance. According to the total pressure drop ie. pump power capacity, the layout and number of pumping stations on the pipeline route are planned [9], [13].

CONCLUSION

The paper analyzes the relevant parameters of crude oil transportation by pipeline. An analysis of the paraffin content at the pour point was performed, the pressure drop in the pipeline was analyzed with different paraffin content at operating temperatures and flows. It also shows the pressure drop in the pipeline, depending on the transportation capacity, as well as the design solutions for heating the pipeline.
It was found that:

- The content of paraffin in crude oil has a dominant influence on the pour point

- Oils with lower paraffin content have a lower pour point and vice versa.
- The pressure drop due to friction losses depends on the temperature and viscosity of the crude oil. An increase in flow and a decrease in the temperature of crude oil lead to an increase in pressure drop due to friction.
- When transporting crude oil with a higher viscosity, a higher pressure drop and pump power is required.
- When transporting crude oil with high paraffin content, at a temperature below the pour point, higher pressure is required for pumping - pushing.
- Due to its properties and tendency to precipitate paraffin at lower temperatures, the oil is preheated before being introduced into the pipeline.

The results presented here can be useful for determining the optimal operating parameters for the crude oil pipeline transport.

REFERENCES

[1] Danilovic, D., Karovic-Maricic, V., Ivezic, D., Batalovic, V., Zivkovic, M., Lekovic, B., Crnogorac, M., Analysis of applied heating systems for heating well pumps for the transport of paraffin oil in the fields of oil industry of Serbia, Technique, No.67, pp.919-923, 2012.
[2] Secerov-Sokolovic, R., Bjelovic, Z., Sokolovic, S., Influence of solid paraffin content on the rheology of model oil, Chemical industry, No.60, pp.10-14, 2006.
[3] Prstojevic, B., Pipeline transport of oil and gas, Faculty of Mining and Geology, Belgrade, 2012.
[4] Sasic, M., Transport of fluids and solid materials by pipes, Scientific book, Belgrade, 1980.
[5] Prvulovic, S., Tolmač, D., Transportation Systems - Collection of Solved Tasks, Technical Faculty "Mihajlo Pupin", Zrenjanin, 2012.
[6] Sun Guangyu, Zhang Jinjun, Me Chenbo, et al., Start-up flow behavior of pipelines transporting waxy crude oil emulsion, Journal of Petroleum Science and Engineering, No.147, pp.746-755, 2016.
[7] Skrbic, B., Oil and gas transport, Faculty of Technology, Novi Sad, 2006.
[8] Jie Sun, Jiaqiang Jing, Cheng Wu, Fei Xiaoa, Xiaoxuan Luo, Pipeline transport of heavy crudes as stable foamy oil, Journal of Industrial and Engineering Chemistry, No.44, pp.126-135, 2016.
[9] Tanaskovic, P., Transportation of Crude Oil and Gas, Part I,II, Faculty of Mining and Geology, Belgrade, 1998.
[10] Chang, C., Nguyen, Q.D., Rningsen, H.P., Isothermal start-up of pipeline transporting waxy crude oil, J. Non-Newton. Fluid Mech., No.87, pp.127-154, 1999.
[11] Davidson M.R., Nguyen Q.D., Chang C., Rningsen H.P., A model for restart of a pipeline with compressible gelled waxy crude oil, J. Non-Newton. Fluid Mech., No.123, pp.269-280, 2004.
[12] Hussain H. Al-Kayiem, Wong Ning, Nassir Dhamin Mokhlif, Characterisation of paraffinic compositions in crude oils, International Journal of Oil, Gas and Coal Technology, No.2, Vol.15, pp.152-165, 2017.
[13] Tolmač, J., Prvulović, S., Nedić, M., Aleksić, A., Tolmač, D., Analysis of the influence of physical characteristics of crude oil in pipeline transport, International Congress on Process Industry, No.1, Vol.32, pp.105-109, May 30-31, 2019, Belgrade, ISBN 978-86-81505-94-6.

SESSION 5. ENGINEERING MANAGEMENT

STATISTICAL INDICATORS FOR ACCIDENTS AT WORK IN EUROPEAN UNION AND THE REPUBLIC OF NORTH MACEDONIA

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Abstract: In this paper the statistical indicators concerning non-fatal and fatal accidents at work in the European Union (EU-28) and in the Republic of North Macedonia in period from 2010 to 2016 were presented. The performed statistical analysis shows that the number of non-fatal and fatal accidents at work in EU-28 in 2016 was decreased in comparison with 2010. In the Republic of North Macedonia in 2016 there was an increase in the number of non-fatal and was decrease in the number of fatal accidents at work in comparison to the number of accidents at work in 2010. Nevertheless, in the Republic North of Macedonia the value of incidence rate for fatal accidents at work in 2016 is much higher compared to the average value in EU-28.
Key words: non-fatal accidents, fatal accidents, incidence rate.

INTRODUCTION

According to the European Agency for Safety and Health at work, occupational diseases and accidents at work, that is a consequence of inadequately organized system for safety and health at work, cost the European Union 3.3% of its GDP [1]. That's €476 billion every year which could be saved with the right occupational safety and health strategies, policies and practices [1]. In 1990 the Eurostat harmonization project of European statistics was initiated on accidents at work (European Statistics on Accidents at Work - ESAW) to develop methodologies for the collection of comparable and significant data within the European Union [2]. In European Statistic for Accidents at Work methodology an 'Accident at work' is defined as 'a discrete occurrence in the course of work which leads to physical or mental harm'. The phrase 'in the course of work' means while engaged in an occupational activity or during the time spent at work [2]. The following types of accidents are included: cases of acute poisoning, wilful acts of other persons, accidents that occurred on the premises of an employer other than that which employs the victim, accidents in public places or public means of transport during a journey in the course of works. According to this methodology, accidents in workplace do not include: commuting accidents (accidents that occur during the normal journey to or from home and place of work), deliberate self-inflicted injuries, accidents from strictly natural causes (accidents caused solely by a medical condition, e.g., cardiac or cerebral incidents), accidents to members of the public, even if such an accident is due to a work activity within a company, [2]. In the European methodology a ''fatal accident'' is defined as an accident which leads to the death of a victim within one year of the accident, while Non-fatal accidents at work are defined as those that imply at least four full calendar days of absence from work (they are sometimes also called 'serious accidents at work'). It should be emphasized that according to the European methodology, in the statistical analysis of data in order to provide comparative data, only injuries at work that has caused an absence from work for more than three calendar days, are analyzed. In the Directive 89/391/EEC, [3] on the safety and health of workers at work is contained provision for the employer to keep records of accidents at work resulting in an inability to perform their duties for more than three days. In accordance with national law regulations, employer is obliged to drawn up reports for occupational accidents suffered by his workers. In Macedonia this area is regulated by the Rulebook on keeping records of Occupational Safety and Health at Work (Official Gazette of R.M., No. 136/2007) [4]. In this paper, some statistical indicators for non-fatal and fatal accidents at work in the European Union and in the Republic of North Macedonia were given.

MATERIAL AND METHODS

In these paper two main types of statistical indicators on accidents at work: number of accidents and incidence rate were used. For the values of the number of accidents at work (non-fatal or fatal) in the EU-28, Eurostat database were used, while for the Republic of North Macedonia data from relevant institutions were used. While for the calculation of the values of the incidence rate the methodology of the European Statistics on Accidents at Work (ESAW) was used [2].

RESULTS AND DISCISSION

Statistical indicators for non-fatal and fatal accidents at work in the European Union

In the EU-28 there were over 3.29 million non-fatal accidents that resulted in at least four calendar days of absence from work in 2016 and 3 549 fatal accidents (Table 1) [5], a ratio of approximately 925 non-fatal accidents for every fatal accident. In the total number of non-fatal accidents at work in the EU-28 between 2010 and 2016 [5], there was decrease for 926.6 accidents i.e. equivalent to a reduction of 8.3 % (Fig.1). During on 2016, in the Member State on EU-28 there were 900 fatal accidents at work fewer when compared with 2010 i.e. equivalent to on decrease of 20.2 % (Fig.2). From Table 1 it is evident that the smallest number of non-fatal accidents at work was recorded in 2013 (3,127.5 persons), while the smallest number fatal accidents is recorded in 2016 (3,549 persons).

Table 1. Total number of non-fatal and fatal accidents at work, EU-28, 2010-2016 (persons)

All NACE Activities	thousands						
	2010	2011	2012	2013	2014	2015	2016
Non-fatal accidents	3,581.6	3,414.7	3,165.4	3,127.5	3,221.1	3,212.0	3,285.0
Fatal accidents	4,449	4,141	3,918	3,674	3,774	3,876	3,549

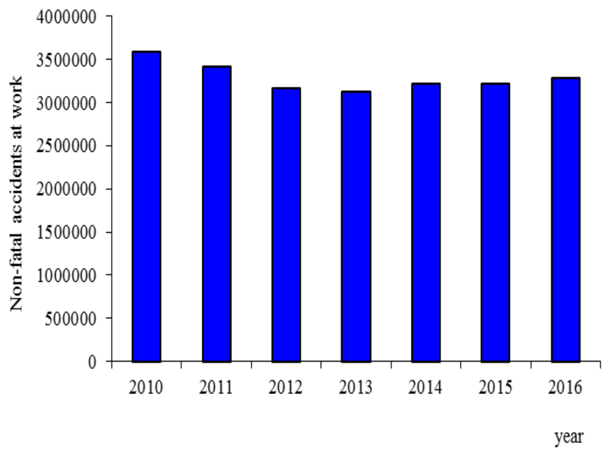

Figure 1. Non-fatal accidents at work, 2010-2016

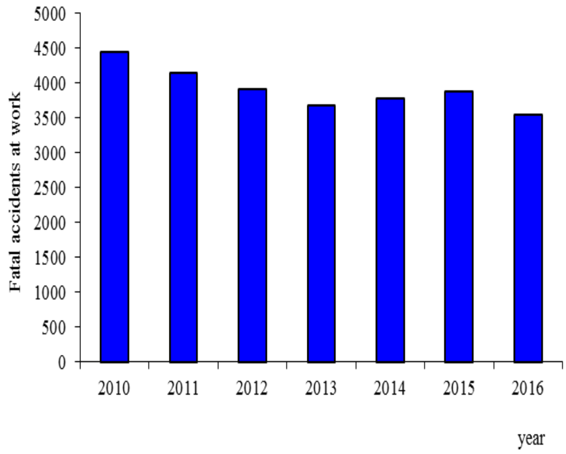

Figure 2. Fatal accidents at work, 2010-2016

In Table 2 the number of non-fatal and fatal accidents at work in the EU-28 Member States is given [5]. From Table 2 evident is that the highest number of non-fatal accidents at work in 2016 was recorded in Germany (862.963), followed by France with (749.670), and Spain with (432.052) [5].
On the other hand in Latvia (1810), Malta (1818) and the Cyprus (1900), were recorded the lowest number of non-fatal accidents at work. In 2016, the highest number of fatal accidents at work was recorded in France (595), Italy (481) and Germany (413). By far the lowest number of fatal accidents was reported in Cyprus (5), Malta (7), and Slovenia (14) [5].

Table 2. Number of non-fatal and fatal accidents at work, EU-28, 2016 (persons)

	Accidents at work involving at four calendar days absence from work			Fatal accidents at work
	Total	Men	Women	Total
EU-28	3.285.032	2.190.367	1.008.398	3.546
Belgium	70.674	49.071	21.599	64
Bulgaria	2.188	1.482	706	78
Czech Republic	45.282	31.325	13.957	106
Denmark	49.439	29.196	19.039	34
Germany	862.983	639.044	223.187	413
Estonia	6.354	4.618	1.736	26
Ireland	14.088	9.196	4.841	43
Greece	3.987	2.895	1.092	33
Spain	432.052	297.845	134.208	296
France	749.670	418.492	247.009	595
Croatia	13.263	8.758	4.504	33
Italy	295.967	215.049	80.918	481
Cyprus	1.900	1.374	526	5
Latvia	1.810	1.150	660	38
Lithuania	3.541	2.197	1.344	44
Luxembourg	7.152	5.612	1.540	22
Hungary	27.434	17.564	9.870	83
Malta	1.818	1.466	352	7
Netherlands	81.165	46.241	34.924	36
Austria	62.902	49.203	13.699	109
Poland	84.037	52.637	31.400	243
Portugal	135.033	93.846	41.187	138
Romania	4.188	3.070	1.118	236
Slovenia	12.162	9.059	3.103	14
Slovakia	9.814	6.499	3.315	45
Finland	41.106	27.652	13.454	35
Sweden	37.858	21.281	16.578	37
United Kingdom	227.165	144.544	82.533	252
Iceland (:)	:	:	:	:
Norway	10.150	6.004	4.147	45
Switzerland	87.386	68.419	18.967	79

(:) not available

In Table 3 the incidence rates for non-fatal and fatal accidents at work in period from 2010 to 2016 in the EU-28 are given [5]. Across the whole of the EU-28 there were, on average, 1.71 fatal accidents per 100 000 persons employed, and on average, 1 587 non-fatal accidents per 100 000 persons employed in 2016.
Obviously is that in 2016 there is a decrease of incidence rates for non-fatal and fatal accidents at work in comparison with 2010. The smallest incidence rate for non-fatal accidents at work was recorded in 2015 (1,513), while for fatal accidents at work was recorded in 2016 (1.71).

Table 3. Incidence rates for non-fatal and fatal accidents at work, EU-28, 2010-2016

All NACE Activities	2010	2011	2012	2013	2014	2015	2016
Non-fatal accidents	1698	1690	1576	1533^p	1554	1513	1587
Fatal accidents	2.11	2.05	1.95	1.80^p	1.82	1.83	1.71

p (provisional)

In Figures 3 and 4 the incidence rates are shown, relating the number of accidents to the overall number of persons employed [5]. The range for incidence rates among the EU-28 Member States was from less than 100 accidents per 100 000 persons employed in Bulgaria and Romania to more than 2 750 per 100 000 persons employed in Spain, Portugal and France (Figure 3). The highest incidence rate was recorded in France, at 3 458 non-fatal accidents per 100 000 persons employed. According to explanation of Eurostat the phenomenon of low non-fatal incidence rates can be considered to reflect under-reporting following the assumption that many accidents remain unreported.

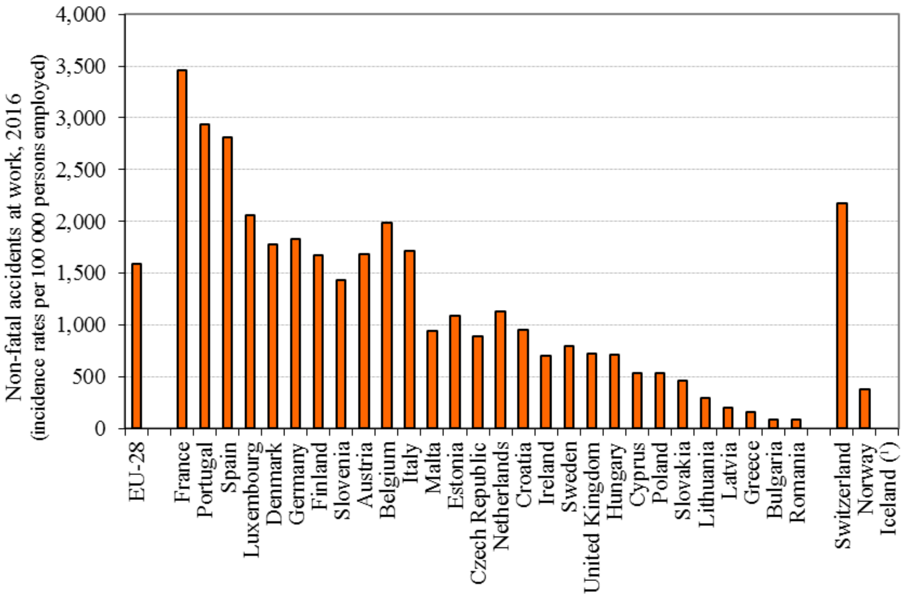

Figure 3. Non-fatal accidents at work, 2016 (incidence rates per 100 000 persons employed)

In 2016, the number of fatal accidents per 100 000 employed persons ranged from less than 1.00 in the Netherlands, Sweden, United Kingdom and Germany, and to more than 3.50 fatal accidents per 100 000 persons employed in Malta, Lithuania, Latvia, Estonia, Romania and Luxembourg (Figure 4) [5]. The highest rate among the EU Member States was recorded in Luxembourg, at 6.32 fatal accidents per 100 000 persons employed. The situation for incidence rates of fatal accidents is different from non-fatal accidents at work because it is much more difficult to avoid reporting fatal accidents.

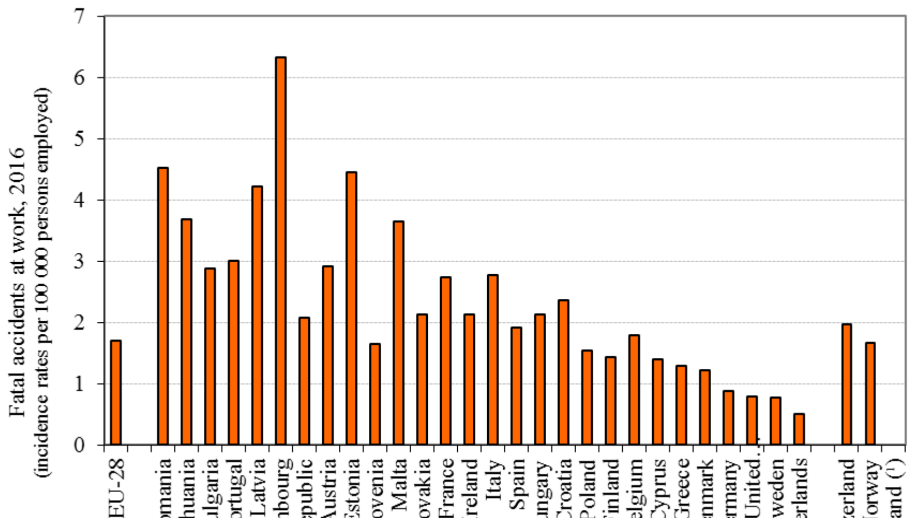

Figure 4. Fatal accidents at work, 2016 (incidence rates per 100 000 persons employed)

Statistical indicators for non-fatal and fatal accidents at work in the Republic of North Macedonia

In the Republic of North Macedonia there are several organizations and institutions dealing exclusively with working conditions. These include State statistical office, the Labour inspectorate, Institute for public health, the Macedonian Occupational Safety and Health Association, Organization of the employers of Republic of Macedonia and the Trade unions. The data on the number of accidents at work in the Republic of North Macedonia is not confidential for the reason that different relevant institutions published various statistical data [6].
In this paper, the statistical indicators related to the number of non-fatal and fatal accidents at work in the Republic of North Macedonia in the period 2010÷2016 are based on the data of the Macedonian Occupational Safety and Health Association [7-13], because in the statistical reports of the other relevant institutions that register a work injury, no distinction is made between the number of non-fatal and fatal accidents at the workplace. In the Republic of North Macedonia in 2016 there were 94 non-fatal accidents that resulted in at least four calendar days of absence from work and 19 fatal accidents (Table 4) [13]. In the total number of non-fatal accidents at work in the Republic of North Macedonia between 2010 and 2016, there was increase for 10 accidents i.e. equivalent to enlargement of 11.9 % (Figure 5),[7-13]. During on 2016, there were 26 fatal accidents at work fewer when compared with 2010 i.e. equivalent to on decrease of 42.2 % (Figure 6) [7-13]. From Table 4 it is evident that the smallest number of non-fatal and fatal accidents at work was recorded in 2013.

Table 4. Total number of non-fatal and fatal accidents at work, Republic North Macedonia, 2010-2016 (persons)

All NACE Activities	2010	2011	2012	2013	2014	2015	2016
Non-fatal accidents	84	79	118	70	88	105	94
Fatal accidents	45	44	44	28	42	39	19

Source: Macedonian Occupational Safety and Health Association

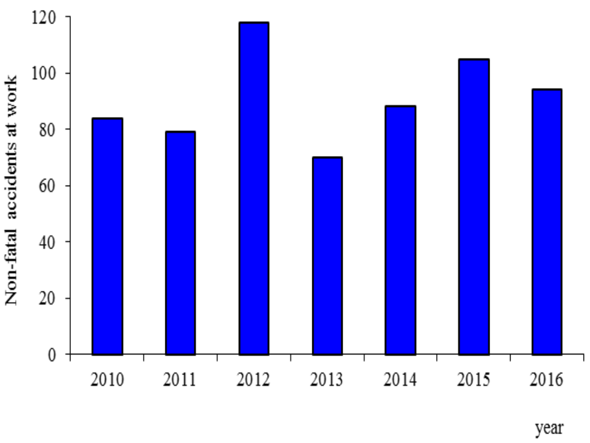

Figure 5. Non-fatal accidents at work, 2010-2016

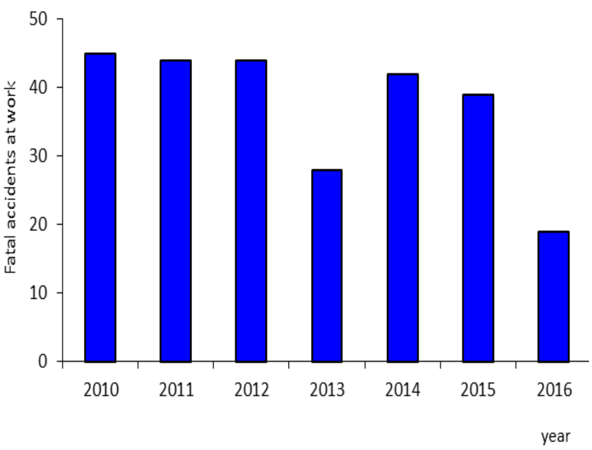

Figure 6. Fatal accidents at work, 2010-2016

In Table 5 the incidence rates for non-fatal and fatal accidents at work in period from 2010 to 2016 in the Republic of North Macedonia are given [7-12]. In the period between 2010 and 2016, there is an increase in the incidence rate for non-fatal accidents at work for 11.2%. In comparison with the values of incidence rates of EU-28 Member States, the Republic of North Macedonia can be classified in the country with incidence rates less than 100.

Table 5. Incidence rates for non-fatal and fatal accidents at work, Republic of North Macedonia, 2010-2016

All NACE Activities	2010	2011	2012	2013	2014	2015	2016
Non-fatal accidents	12.74	11.98	17.89	10.61	13.34	15.92	14.25
Fatal accidents	6.82	6.67	6.67	4.25	6.37	5.91	2.88

From Table 5 evident is that the smallest incidence rate for non-fatal accidents at work was recorded in 2013 (10.61). There is an equivalent decrease in the incidence rate for fatal accidents at work for 57.7% in the period between 2010 and 2016, while the smallest incidence rate for fatal accidents at work was recorded in 2013 (4.25). The incidence rate of fatal accidents at work in 2016 in the Republic of North Macedonia was 2.88 deaths cases from accidents at work per 100 000 persons employed. In comparison with the mean value of the incidence rates in EU-28 (1.71), the incidence rate in the Republic of North Macedonia is the higher for 68.4%.

CONCLUSION

In this paper the statistical indicators for non-fatal and fatal accidents at work in EU-28 Member States and in the Republic of North Macedonia from 2010 to 2016 were presented. From the statistical indicators for the number of fatal accidents at work in the EU-28 Member States and in the Republic of North Macedonia in 2016, may be concluded that there is considerable reduction of number of accidents at work in relation to 2010. But the high value of incidence rate of fatal accidents at work (2.88) ranks the Republic of North Macedonia as the country above the European average (1.71). From the value of the incidence rate (14.25 non-fatal accidents per 100 000 persons employed), may be concluded that the Republic of North Macedonia can be classified in the group of EU-28 countries that have less than 100 non-fatal accidents at work. But, for more accurate and more comparable statistical indicators it is necessary to harmonize the Macedonian legislation with the methodology of ESAW.

REFERENCES

[1] European Occupational Safety and Health Agency (EU-OSHA) Work-related accidents and injuries cost EU €476 billion a year according to new global estimates, Published on Safety and health at work, Available at https://osha.europa.eu/en/about-eu-osha/press-room/eu-osha-presents-new-figures-costs-poor-workplace-safety-and-health-world.

[2] European Statistics on Accidents at Work (ESAW), 2013, Summary methodology.

[3] Council Directive 89/391/EEC of 12 June 1989 on the introduction of measures to encourage improvements in the safety and health of workers at work, OJ L183, 29.06.1989.

[4] Rulebook on keeping records of Occupational Safety and Health at Work (Official Gazette of R.M., No.136/2007).

[5] Eurostat, Accidents at work statistics, 2018, Published on https://ec.europa.eu/eurostat/statisticsexplained/ index.php?title=Accidents_at_work_statistics. Last update of: 06.02.2019.

[6] Mitrevski, V., Geramitcioski, V., Mijakovski, V., Mitrevska, C., 2014, Situation regarding of accident at work in the European Union and in the Republic of Macedonia, IV International Conference Industrial Engineering And Environment Protection 2014 (IZZS 2014), October 15st, Zrenjanin, Serbia.

[7] Annual Report for fatalities, injuries and accidents at work 2010, Macedonian Occupational Safety and Health Association, 2010.

[8] Annual Report for fatalities, injuries and accidents at work 2011, Macedonian Occupational Safety and Health Association, 2011.

[9] Annual Report for fatalities, injuries and accidents at work 2012, Macedonian Occupational Safety and Health Association, 2012.

[10] Annual Report for fatalities, injuries and accidents at work 2013, Macedonian Occupational Safety and Health Association, 2013.

[11] Annual Report for fatalities, injuries and accidents at work 2014, Macedonian Occupational Safety and Health Association, 2014.
[12] Annual Report for fatalities, injuries and accidents at work 2015, Macedonian Occupational Safety and Health Association, 2015.
[13] Annual Report for fatalities, injuries and accidents at work 2016, Macedonian Occupational Safety and Health Association, 2016.

ANALYSIS OF NON-FATAL AND FATAL ACCIDENTS AT WORK BY ECONOMIC ACTIVITIES IN EUROPEAN UNION AND THE REPUBLIC OF NORTH MACEDONIA

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Abstract: In this paper some statistical analysis for non-fatal and fatal accidents at work in the European Union (EU-28) and in the Republic of North Macedonia in period from 2010 to 2016 according to economic activities were presented. The performed statistical analysis shows that the activities in manufacturing, activity in wholesale and retail trade, human health and social work activities and construction are the economic sectors in which were recorded the most number of non-fatal accidents at work. The activities in mining and quarrying, construction, transportation and storage and agriculture, forestry and fishing are the economic sectors in EU-28 where prevention of injuries at work caused by fatal accidents must be addressed. Non-fatal accidents in the Republic of the North Macedonia were most common in public administration and defense, while the activities of households as employers and construction accounted more than one tenth of all non-fatal accidents at work. Fatal accidents in were most common in unknown NACE activity and construction sector, while the activity in transportation and storage is the next in the scale.
Keywords: non-fatal accidents, fatal accidents, economic activities.

INTRODUCTION

Health and safety at work, in particular issues relating to accidents at work in the European Union (EU-28), are one of the most important areas of action of the European Union’s social policy [1]. An accident at work is defined in (European Statistics on Accidents at Work – ESAW) methodology as a discrete occurrence during the course of work which leads to physical or mental harm. Fatal accidents at work are those that lead to the death of the victim within one year of the accident taking place, while non-fatal accidents at work are defined as those that imply at least four full calendar days of absence from work. Non-fatal accidents at work often involve considerable harm for the workers concerned and their families and they have the potential to force people, to live with a permanent disability, to leave the labor market, or to change job [2]. In 2016 in EU-28 there were registered 3.29 million non-fatal accidents that resulted in at least four calendar days of absence from work and 3,549 thousand fatal accidents at work. Recently published statistics from EuroStat shows that a “fifth of all workplace accidents happened in the construction industry”, but that accidents are occurring in every economy activities [2]. In the Republic of North Macedonia in 2016, there were registered 94 non-fatal and 19 fatal accidents at work [3]. In this article a set of main statistical findings in relation to indicators concerning non-fatal and fatal accidents at work by economic activity in the EU-28 and in the Republic of North Macedonia were presented.

MATERIAL AND METHODS

The European Statistics on Accidents at Work (ESAW) methodology considers two main types of indicators on accidents at work: the number of accidents and the incidence rate. To define the frequency of accidents i.e. incidence rate, it is necessary to define the relationship between the number of accidents and the reference population which ideally is the number of persons in employment (persons exposed to the risk of accident at work). The incidence rate is defined as the number of accidents at work per 100 000 persons in employment, [4]

$$\text{Incidence rate} = \frac{\text{Number of accidents (fatal or nonfatal)}}{\text{Number of employed persons in the covered population}} \text{x}100000 \quad (1)$$

This rate can be based on the variables that classify the victims of an accident (e.g. economic activities, age, etc.), it could be calculated for the whole European Union, for a Member State or any other subdivision of the population, and the type of injury (injured body part, etc.). For an more than-three-day injury which results in the injured person being away from work or unable to do their normal work for more than three days'; or for fatal accidents, the incidence rate are calculated separately.

RESULTS AND DISCUSSION

Non-fatal and fatal accidents at work in the European Union-Statistical indicators by economic activity

In the Member State on EU-28 in 2016 there were over 3.29 million non-fatal accidents that resulted in at least four calendar days of absence from work in 2016 (Table 1). From Table 1 it is evident that in absolute terms, non-fatal accidents in the EU-28 were most common in manufacturing, where 633 thousand people had non-fatal accidents in 2016, i.e. (19.3 %) of the total. While the activity in wholesale and retail trade (12.7 %), human health and social work activities (11.5 %) and construction (11.3%) also accounted more than one tenth of all non-fatal accidents at work [5].

Table 1. Total number of non-fatal and fatal accidents at work, by economic activity EU-28, 2010-2016

NACE (Section)	(thousands)						
	2010	2011	2012	2013	2014	2015	2016
Total (all NACE activities)	3,581.6	3,414.7	3,165.4	3,127.5	3,221.1	3,212.0	3,285.0
Agriculture, forestry and fishing (A)	163.5	164.9	150.9	157.8	177.1	169.8	168.4
Mining and quarrying (B)	16.2	14.4	12.5	12.0	10.6	9.7	9.4
Manufacturing (C)	770.7	723.8	673.7	649.6	627.1	625.4	633.4
Construction (F)	504.5	479.9	418.4	378.3	376.6	372.3	371.7
Wholesale and retail trade (G)	481.0	451.2	416.8	426.3	410.8	412.6	416.0
Transportation and storage (H)	313.5	286.2	268.7	283.6	269.5	273.1	269.5
Accommodation and food service activities (I)	169.6	168.0	159.6	161.8	157.1	163.4	170.4
Administrative and support service activities (N)	255.9	279.9	246.2	245.5	239.7	244.9	262.8
Public administration and defense (O)	150.9	128.5	123.9	141.5	207.6	202.0	196.2
Human health and social work activities (Q)	323.5	319.5	305.6	321.7	369.0	369.8	378.3
NACE (Section)	(incidence rate)						
	2010	2011	2012	2013	2014	2015	2016
Total (all NACE activities)	1698	1690	1576	1533	1559	1513	1586
Agriculture, forestry and fishing (A)	1293	1704	1694	1675	1919	1894	2011
Mining and quarrying (B)	2188	1934	1697	1739	1610	1257	1457
Manufacturing (C)	2366	2227	2090	2020	1949	1869	1952
Construction (F)	3214	3425	3067	2821	2934	2852	3010
Wholesale and retail trade (G)	1545	1501	1373	1416	1384	1396	1444

Table 1. Total number of non-fatal and fatal accidents at work, by economic activity EU-28, 2010-2016 (continue)

Transportation and storage (H)	3004	2776	2590	2724	2533	2461	2447
Accommodation and food service activities (I)	1752	1818	1699	1696	1633	1652	1734
Administrative and support service activities (N)	2342	2390	2159	2200	2165	2274	2205
Public administration and defense (O)	1248	1035	1062	1130	1444	1392	1352
Human health and social work activities (Q)	1531	1571	1473	1503	1629	1540	1634

However, given that the workforces of the activities are different in size, the incidence rate gives a clearer impression of where workers are more likely to encounter non-fatal accidents [2]. In 2016, the highest incidence of non-fatal accidents at work in the EU-28 was observed in construction, with 3010 such accidents per 100000 persons employed. Transportation and storage (2447 per 100000) administrative and support service activities (2205 per 100000) and agriculture, forestry and fishing (2 011 per 100000) were the only other NACE sections with incidence rates above 2000 per 100 000 persons employed. Among the activities shown in Table 1, the lowest incidence rate was for public administration and defense (1 352 per 100 000), which also recorded the largest decrease in the incidence rate between 2010 and 2016. While incidence rates for non-fatal accidents at work were lower in 2016 than in 2010 for most activities, a relatively small increase was observed for human health and social work activities (6.7 %), a larger increase for public administration and defense (8.3 %) and a particularly large increase for agriculture, forestry and fishing (55.5 %). Note that for some EU Member States some of these changes may be linked to changes in coverage of specific activities linked to the end of derogations or voluntary data collection [5].

In Fig. 1 shows the change in the incidence rate in the EU-28 Member States in the period from 2010 to 2016 in the four of the ten activities of the national classification where highest values were recorded [5].

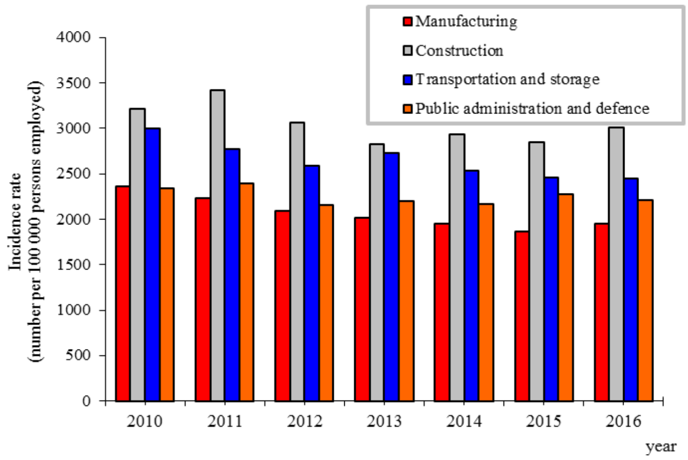

Figure 1. Incidence rate of non-fatal accidents at work, 2010-2016, EU-28

In the Member State on EU-28 there were 3 549 fatal accidents at work in 2016 (Table 2). From Table 2 it is evident that in absolute terms, fatal accidents in the EU-28 were most common in construction, where 716 people had fatal accidents in 2016, 20.2 % of the total. While the activity in transportation and storage (17.7 %), manufacturing (15.5 %) and agriculture, forestry and fishing (14.4 %) also accounted for more than one tenth of all fatal accidents at work [5].

Table 2. Total number of fatal accidents at work, by economic activity EU-28, 2010-2016

NACE (Section)	(thousands)						
	2010	2011	2012	2013	2014	2015	2016
Total (all NACE activities)	4,449	4,141	3,918	3,674	3,774	3,876	3,549
Agriculture, forestry and fishing (A)	583	552	527	484	542	513	510
Mining and quarrying (B)	82	112	78	71	72	73	67
Manufacturing (C)	710	684	651	587	578	659	549
Construction (F)	1,049	958	869	787	791	815	716
Wholesale and retail trade (G)	397	355	345	344	324	321	303
Transportation and storage (H)	680	613	562	549	627	641	628
Accommodation and food service activities (I)	55	49	42	55	72	69	58
Administrative and support service activities (N)	199	217	215	220	199	202	183
Public administration and defense (O)	111	82	76	102	97	110	111
Human health and social work activities (Q)	77	51	69	63	68	70	63
NACE (Section)	(incidence rate)						
	2010	2011	2012	2013	2014	2015	2016
Total (all NACE activities)	2.1	2.1	2.0	1.8	1.8	1.8	1.7
Agriculture, forestry and fishing (A)	4.5	5.7	5.9	5.1	5.8	5.8	6.1
Mining and quarrying (B)	11.2	15.2	10.7	10.4	10.9	9.5	10.5
Manufacturing (C)	2.2	2.1	2.0	1.8	1.8	2.0	1.7
Construction (F)	6.7	6.8	6.4	5.9	6.1	6.2	5.8
Wholesale and retail trade (G)	1.3	1.2	1.1	1.1	1.1	1.1	1.1
Transportation and storage (H)	6.5	6.0	5.4	5.3	5.9	5.8	5.7
Accommodation and food service activities (I)	0.6	0.5	0.4	0.6	0.8	0.7	0.6
Administrative and support service activities (N)	1.8	1.9	1.9	2.0	1.8	1.9	1.5
Public administration and defense (O)	0.9	0.7	0.7	0.8	0.7	0.8	0.8
Human health and social work activities (Q)	0.4	0.3	0.3	0.3	0.3	0.3	0.3

What all these industries have in common is that the employees here are doing mainly physical work, and with large loads of goods and machines, which can present risks in terms of occupational safety. Another observation from Table 2 is that mining and quarrying has a low amount of fatal accidents, only 67 persons. This could be due to the implementation of more safety at work as this is seen as a dangerous industry to work in general. From Table 2 it can see that the decrease in the incidence rate in the period between 2010 and 2016 is 19.1%. In 2016, the highest incidence of fatal accidents at work was observed in mining and quarrying, with 67 fatal accidents, equivalent to 10.4 per 100000 persons employed. The activities in agriculture, forestry and fishing (6.1 per 100000 persons employed), construction (5.8 per 100000), transportation and storage (5.7 per 100000) were the only other NACE sections with incidence rates above 2.0 per 100000 persons employed [5].

Among the activities shown in Table 2, the lowest incidence rate was for human health and social work activities (0.3 per 100 000), which also recorded the constant values of incidence rate between 2010 and 2016. While incidence rates for fatal accidents at work as for non-fatal accidents were lower in 2016 than in 2010 for most activities, a relatively increase was observed in agriculture, forestry and fishing (32.6 %). In Fig. 2 shows the change in the incidence rate in the EU-28 Member States in the period from 2010 to 2016 in the four of the ten activities of the national classification where highest values were recorded [5].

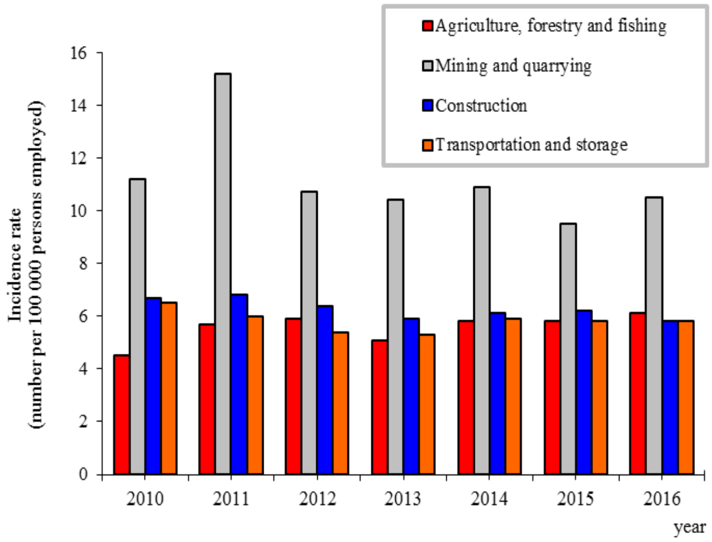

Figure 2. Incidence rate of fatal accidents at work, 2010-2016, EU-28, Source: Eurostat

Non-fatal and fatal accidents at work in the Republic of North Macedonia-Statistical indicators by economic activity

In this paper, the statistical indicators related to the number of non-fatal and fatal accidents at work in the Republic of North Macedonia by economic activities in the period 2010÷2016 are based on the data of the Macedonian Occupational Safety and Health Association [5-11]. In the Republic of North Macedonia in 2016 there were 94 non-fatal accidents that resulted in at least four calendar days of absence from work (Table 3). From Table 3 it is evident that in absolute terms, non-fatal accidents in the Republic of the North Macedonia were most common in public administration and defense, where 46 people had non-fatal accidents in 2016, i.e. (48.9 %) of the total [3]. While the activity in activities of households as employers (14.9 %) and construction (12.8%) also accounted more than one tenth of all non-fatal accidents at work. In 2016, the highest incidence of non-fatal accidents at work was observed in public administration and defense, (7.0 accidents per 100000 persons), which also recorded the highest increase between 2010 and 2016 [3]. The high values of the incidence rate in 2015 and 2016 in this NACE section are the result of the refugee crisis. The manufacturing (1.1 per 100000), transportation and storage (1.2 per 100 000), construction (1.8 per 100000) and activities of households as employers (2.1 per 100000) were the only other NACE sections where observed incidence rates [3, 6-11]. The incidence rates for non-fatal accidents at work were lower in 2016 than in 2010 for most activities, with excluding for relatively increase for transport and storage and activities of households as employers.

Table 3. Total number of non-fatal accidents at work, by economic activity, R.of North Macedonia, 2010-2016

NACE (Section)	(persons)						
	2010	2011	2012	2013	2014	2015	2016
Total (all NACE activities)	84	79	118	70	88	105	94
Agriculture, forestry and fishing (A)	3	4	1	2	0	1	0
Mining and quarrying (B)	6	1	2	5	12	3	1
Manufacturing (C)	8	5	9	2	1	0	7
Construction (F)	18	12	35	13	7	3	12
Wholesale and retail trade (G)	3	7	5	1	3	0	0

Table 3. Total number of non-fatal accidents at work, by economic activity, R.of North Macedonia, 2010-2016 (continue)

Transportation and storage (H)	3	11	7	7	11	2	8
Accommodation and food service activities (I)	0	0	2	0	0	0	0
Public administration and defense (O)	26	24	45	9	42	83	46
Human health and social work activities (Q)	3	2	1	1	4	0	0
Activities of households as employers (T)	6	4	2	21	6	7	14
NACE (Section)	(incidence rate)						
	2010	2011	2012	2013	2014	2015	2016
Total (all NACE activities)	12.7	11.9	17.9	10.6	13.3	15.9	14.3
Agriculture, forestry and fishing (A)	0.5	0.6	0.2	0.3	0.0	0.2	0.0
Mining and quarrying (B)	0.9	0.2	0.3	0.8	1.8	0.4	0.2
Manufacturing (C)	1.2	0.8	1.4	0.3	0.2	0.0	1.1
Construction (F)	2.7	1.8	5.3	1.9	1.1	0.5	1.8
Wholesale and retail trade (G)	0.5	1.1	0.7	0.2	0.5	0.0	0.0
Transportation and storage (H)	0.5	1.7	1.1	1.1	1.7	0.3	1.2
Accommodation and food service activities (I)	0.0	0.0	0.3	0.0	0.0	0.0	0.0
Public administration and defense (O)	3.9	3.6	6.8	1.4	6.4	12.6	7.0
Human health and social work activities (Q)	0.5	0.3	0.2	0.2	0.6	0.0	0.0
Activities of households as employers (T)	0.9	0.6	0.3	3.2	0.9	1.1	2.1

In Fig. 3 shows the change in the incidence rate in the Republic of the North Macedonia in the period from 2010 to 2016 in the four of the ten activities of the national classification where highest values were recorded [3, 6-11].

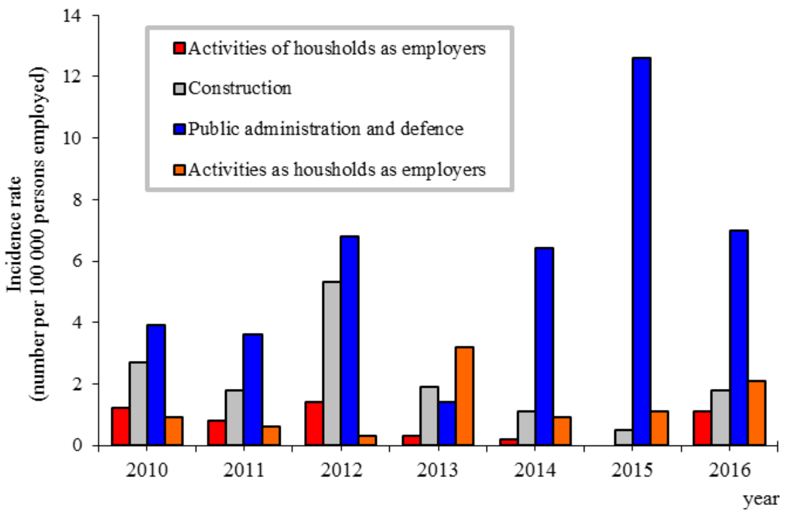

Figure 3. Incidence rate of non-fatal accidents at work, Republic of North Macedonia, 2010-2016

In 2016 in the Republic of North Macedonia were recorded 19 fatal accidents at work [3]. From Table 4 it is evident that in absolute terms, fatal accidents in the Republic of the North Macedonia were most common in unknown NACE activity, 9 people i.e. 47.3% of the total and construction, where 6 people

had fatal accidents in 2016, i.e. 31.6 % of the total, while the activity in transportation and storage is the next in the scale with 3 people i.e. 15.8 % from the total accidents at work [3].
From Table 4 it can see that the decrease in the incidence rate in the period between 2010 and 2016. In 2016, the highest incidence of fatal accidents at work was observed in unknown NACE activity, with 9 fatal accidents, equivalent to 1.4 per 100000 persons employed.
The activities in construction (0.9 per 100000), transportation and storage (0.5 per 100000) and mining and quarrying (0.2 per 100000) were the only other NACE sections where observed incidence rates [3, 6-11]. Incidence rates for fatal accidents at work as for non-fatal accidents were lower in 2016 than in 2010 for most activities, excluding in relatively increase in unknown NACE activity was observed [3, 6-11].
From Table 4 it is evident that the value of incidence rate of all NACE activities in the Republic of North Macedonia in 2016 (2.9 per 100 000 employees) are the bigger than value of incidence rate of all NACE activities in the EU-28, (1.7 per 100 000 employees), see Table 2.

Table 4. Total number of fatal accidents at work, by economic activity, R. of North Macedonia, 2010-2016

NACE (Section)	(persons)						
	2010	2011	2012	2013	2014	2015	2016
Total (all NACE activities)	45	44	44	28	42	39	19
Agriculture, forestry and fishing (A)	2	7	4	0	0	1	0
Mining and quarrying (B)	7	1	2	2	0	3	1
Manufacturing (C)	1	0	0	1	3	0	0
Construction (F)	6	15	9	7	5	4	6
Wholesale and retail trade (G)	1	0	0	0	0	3	0
Transportation and storage (H)	5	3	8	4	7	0	3
Accommodation and food service activities (I)	0	0	0	0	0	0	0
Public administration and defense (O)	0	2	0	0	5	11	0
Human health and social work activities (Q)	1	0	1	0	1	1	0
Activities of households as employers (T)	16	15	17	10	17	8	0
Unknown NACE activity	0	0	0	3	2	5	9
NACE (Section)	(incidence rate)						
	2010	2011	2012	2013	2014	2015	2016
Total (all NACE activities)	6.8	6.7	6.7	4.3	6.4	5.9	2.9
Agriculture, forestry and fishing (A)	0.3	1.1	0.6	0.0	0.0	0.2	0.0
Mining and quarrying (B)	1.1	0.2	0.3	0.3	0.0	0.5	0.2
Manufacturing (C)	0.2	0.0	0.0	0.2	0.5	0.0	0.0
Construction (F)	0.9	2.3	1.4	1.1	0.8	0.6	0.9
Wholesale and retail trade (G)	0.2	0.0	0.0	0.0	0.0	0.5	0.0
Transportation and storage (H)	0.8	0.5	1.2	0.6	1.1	0.0	0.5
Accommodation and food service activities (I)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Public administration and defense (O)	0.0	0.3	0.0	0.0	0.8	1.7	0.0
Human health and social work activities (Q)	0.2	0.0	0.2	0.0	0.2	0.2	0.0
Activities of households as employers (T)	2.4	2.3	2.6	1.5	2.6	1.2	0.0
Unknown NACE activity	0.0	0.0	0.0	0.5	0.3	0.7	1.4

In Fig. 4 shows the change in the incidence rate in the Republic of the North Macedonia in the period from 2010 to 2016 in the four of the eleven activities of the national classification where highest values were recorded [3, 6-11].

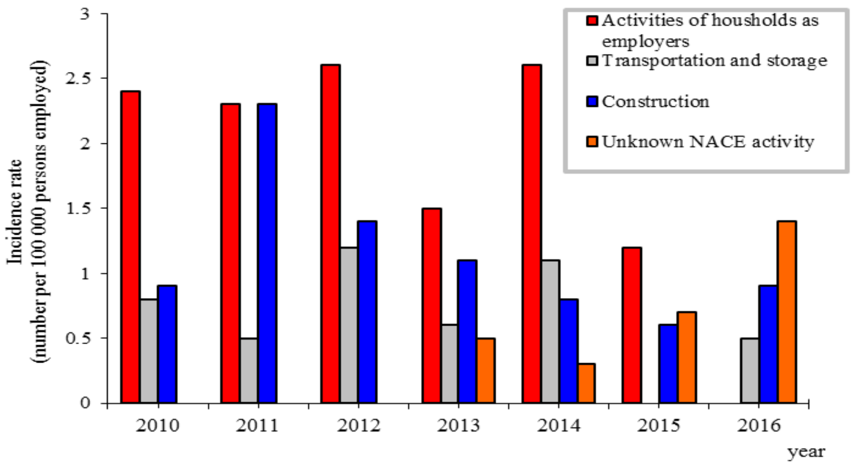

Figure 4. Incidence rate of fatal accidents at work, Republic of North Macedonia, 2010-2016

CONCLUSION

In this paper the statistical indicators for non-fatal and fatal accidents at work by economic activities in EU-28 Member States and in the Republic of North Macedonia from period from 2010 to 2016 were presented. In the EU-28 on the activities in manufacturing, wholesale and retail trade, human health and social work activities and construction were recorded the most of non-fatal accidents at work. The activities in mining and quarrying construction sector, transportation and storage and agriculture, forestry and fishing are the economic sectors in EU-28 in which where recorded most of number the fatal accidents. In the Republic of the North Macedonia public administration and defense, activities of households as employers and construction are the economic sectors were registered the most common non-fatal accidents at work. Fatal accidents in were most common in unknown NACE activity, construction and transportation and storage sector. From the presented statistical indicator it can be concluded that the value of the incidence rate of all NACE activities in the Republic of Northern Macedonia is greater than the value of the incidence rate of all NACE activities in the EU-28. For this reason, the development of a security strategy in industry is one way to reduce work related accidents in any economic activity.

REFERENCES

[1] Eurostat, Causes and circumstances of accidents at work in the EU, 2008, Available at https://ec.europa.eu/eurostat/documents.
[2] Eurostat, Accidents at work statistics, 2018, Available at https://ec.europa.eu/eurostat/statistics-explained/pdfscache/11539.pdf.
[3] Annual Report for fatalities, injuries and accidents at work 2016, Macedonian Occupational Safety and Health Association, 2016.
[4] Mitrevski, V., Geramitcioski, V., Mijakovski, V., Mitrevska, C., 2014, Situation regarding of accident at work in the European Union and in the Republic of Macedonia, IV International Conference Industrial Engineering And Environment Protection 2014 (IZZS 2014), October 15st, Zrenjanin, Serbia.
[5] Eurostat, Accidents at work statistics, 2018, Available at https://ec.europa.eu/eurostat/statisticsexplained/ index.php?title=Accidents_at_work_statistics. Last update of: 06.02.2019.
[6] Annual Report for fatalities, injuries and accidents at work 2010, Macedonian Occupational Safety and Health Association, 2010.

[7] Annual Report for fatalities, injuries and accidents at work 2011, Macedonian Occupational Safety and Health Association, 2011.
[8] Annual Report for fatalities, injuries and accidents at work 2012, Macedonian Occupational Safety and Health Association, 2012.
[9] Annual Report for fatalities, injuries and accidents at work 2013, Macedonian Occupational Safety and Health Association, 2013.
[10] Annual Report for fatalities, injuries and accidents at work 2014, Macedonian Occupational Safety and Health Association, 2014.
[11] Annual Report for fatalities, injuries and accidents at work 2015, Macedonian Occupational Safety and Health Association, 2015.

THE ROLE OF REENGINEERING AND TQM IN IMPROVING THE QUALITY OF BUSINESS IN ORGANIZATIONS

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Abstract: This paper presents the role of the application of reengineering and TQM to improve the efficiency of the company's business. In a situation when we have more competition, where there are many organizations today it is needed request for constant development and innovation. One of the possibilities presented in the paper is used. Reengineering represents a complex operation in which everything, except the final objective, is changing. Total Quality Management (TQM) is presented as the continuous satisfaction of customer needs, wants and requirements. Quality was and still is the key aspect in the process of increasing value for the final user. It is believed that reengineering and TQM represent excellent operational and functional brilliance for companies. But with these two concepts there are certain differences.
Key words: Reengineering, TQM, Business, Quality.

INTRODUCTION

In today's conditions, when many companies are facing market loss, i.e lack of customer confidence, there is a decline in company profits and job losses. In this case, some of the companies to implement reengineering must fundamentally implement a complete reorganization within their company in order to survive at the market. Applying the concept of reengineering is a very complex process where people need to have a good manager with authority and knowledge of the job he is doing. This concept requires great renunciation and great effort for the manager who puts it into action. The reengineering concept is a radical approach to restructuring all business activities and processes within the company in order to innovate new business activities and increase profits by increasing competitiveness and constantly improving the quality of the company's business. Reengineering does not represent a modification of the current business but it starts from the beginning and searches for better ways of business performance, different from the previous one [19].
Total quality management (TQM) is a management approach through which a company can achieve long-term goals. These goals are customer satisfaction, and improved competitiveness on the market [8]. The seven dimensions of TQM are leadership management; employee relationships; reporting, and data quality; training, and skill development of employees; supplier quality management; product, and service design; and process management [16]. The base philosophy of this concept is the utilization in companies regardless of their size, and industry. TQM tools and techniques can improve knowledge gathering from the internal and external environment of the organization [15]. Quality management in the organization plays an important role in the realization of the basic principles of long-term and sustainable development of society [17].

REENGINEERING

The concept of reengineering

The concept of reengineering is one of the most radical processes of managing a company. There are many misconceptions about the essence of reengineering. Many times organizations carry out a major reorganization and call it reengineering. Some other organizations reduce staff, and they call it reengineering. And some others just run an efficiency program, different from the usual ones, and turn it into reengineering [6]. In modern business conditions, changes have become constant and faster organizations are forced to make much more effort to adequately follow them. Businesses need to accept the basic principles of entrepreneurial management based on the following factors: the acceptance of change, innovation and knowledge creation as the main economic resource [7]. The needs of the concept of reengineering today present us with new challenges, which require that the problem within the organization be solved in a new and more efficient way. That is why the need for reengineering just today and now.

The concept of reengineering is related to the name of Michael Hamer, who first used the term in the early 1990s. Reengineering was created in response to the Japanese concept of quality management and represents a pragmatic approach to change in line with the American way of thinking. According to Hamer, reengineering is the fundamental design and radical redesign of business processes to achieve dramatic improvements in performance [1]. New times are challenging for us, seeking to address the problem of the organization in a new way. Hence the need for reengineering just today and now. There are numerous reasons for the need to implement business process reengineering [18].

Reengineering does not represent a modification of the current business but it starts from the beginning and searches for better ways of business performance, different from the previous one [19]. Business processes to date are largely outdated and ineligible because they cannot meet customer expectations as well as company requirements. The concept of reengineering represents a different and completely new form of business process, a new quality of business. In addition to productivity growth, it aims to include a healthy and new workplace, new knowledge and full collaboration of employees at all levels in the organization, problem identification, acceptance of any suggestions and criticisms, teamwork and work discipline of all employees of the company. Reengineering began with the idea that all changes in the environment should be overcome [4]. Changes are caused by the application of new science and technology, the rapid aging of organizations and their business processes [11].

Businesses can achieve radical performance improvements if they use business process reengineering, in other words, if they manage to break the old rules of business and organization [11]. The concept of reengineering is a very difficult and risky business process, but it is still accepted as the best option for companies wishing to take a new path of business, reengineering as such process brings with it new changes, attitudes, ideas, modern technology and new organization of work.

For US and European companies, applying the concept of reengineering is acceptable if the companies: 1. Have problems, 2. they still have no problems, but I can predict, and 3. they are doing well, but they want to move forward [5]. Determined that 50-70% of reengineering business processes did not give the expected results. In the same time, they found out that there was some progress in certain segments: 20% of cost reduction, 50% of time process reduction and 25% of quality rise [21], [19].

There are two types of approach in reengineering:

- Gradual – it is characterized by a small risk, easy management, less turbulence in short time intervals, and
- Radical – based on the idea that when permanent changes or individual corrections do not give results, the only way to change the status is to be exposed to radical changes and the implementation of fresh, new solutions [19].

Radical changes can be achieved by changing organizational performances, such as: price, production time, service, quality, application of different tools and techniques in the realization of certain business activities. Reengineering is a process that contributes to transformation in enterprise's business but the main reason for failure is caused by a tendency to change all processes at once and in the same time [19].

It is wrong to reengineering as a change that applies only to for-profit business. Reengineering does not focus solely on profit or loss in the balance sheets, commodity prices, or value adding in the processes of modern capitalism or globalization. He is engaged in work and is relevant for any organization in which to perform any job, big or small, manufacturing or service, profit or nonprofit, private or public sector [2].

Targeted business in modern business does not always produce the best results. Hammer believes that businesses need to organize their business around processes rather than functions, and that modern Western companies resemble silos - organized vertically, by functions that represent only parts of the process [1]. There are four key words in reengineering: Fundamental, Radical, Dramatic, and Process.

Phases of business process reengineering

The three basic processes of reengineering are entities, objects and activities. Reengineering must be applied to all entities (interorganizational processes, interfunctional processes, and interpersonal processes), facilities (equipment, materials, information) and activities (executive, operational) in the business process [8].
Business process reengineering is a multisector business, which seeks an innovative approach to the problem in an organization. It is implemented through radical changes and through all the functions of the company and involves conceptualizing the project, creating a new business and integrating a new process in the organization. [8] Generally speaking, the circle of business improvement should start from exploring customer needs and analyzing competition, and possibly the bottleneck of the business process. It is necessary to determine the goals and mission for the company and to begin modifying, or completely replacing the process, it must be constantly monitored and evaluated from the population of results, above all production characteristics. Reengineering finally completes the process by re-exploring the needs and demands of the market. The reengineering process consists of six stages:

- Predicting change processes,
- Presentation of the reengineering project,
- Diagnosis
- Redesign,
- Reconstruction,
- Process evaluation [13].

The objective of reengineering is related to satisfying customers' needs and in this particular case the attention should be paid on the following:

- It is necessary to work fast. Reengineering will not be successful if the process is slow because it should be carried out until the resistance in the organization appears,
- Risk is unavoidable. There is no progress without risks. The unknown is always frustrating but the greatest risk comes from unchanged state,
- Imperfection must exist. Mistakes cannot be avoided whenever something new and unknown is done. Mistakes are necessary for learning, and
- Activities mustn't be stopped suddenly. A great number of enterprises stop reengineering process as soon as the results are visible. It is bad because the final objective is important and the process must not be stopped when the first problems appear [19].

The importance of reengineering lies in changing the rules of behavior in the organization so far, rather than on better or more consistent application of existing ones. Instead of custom procedures, reengineering seeks to design and incorporate completely new, inventive solutions that require a different approach and fully capture key processes within the enterprise [20].

TOTAL QUALITY MANAGAMENT

Concept TQM

Modern society requires responsibility and contribution. According to Draker, a knowledge-based organization requires that I take responsibility for the organization's given accomplishments for its contribution and its behavior [8]. All employees belonging to the work organization must fully consider and reflect on the further goal of making and contributing. There are four factors that require public intervention and regulation [10]:

- Protecting the planet,
- Protecting the most vulnerable in the economy,
- Consumer protection,
- The (market economy) system itself has tendencies that destructively affect its functioning.

The essence of the concept of responsibility lies in the following [8]:

- Each individual must be held accountable for their actions,
- Every individual should become a “contributing individual”,
- Action is taken on the basis of an analysis of the factors that prevail in the case.

Total quality management is a concept that completely took shape in the 1980s. as such the concept represents the Japanese and American strategy for improving the quality of business. Basic development occurs in Japan after the Second World War, in the 1950s came from US experts who, in the form of technical assistance, educated Japanese experts, how to manage the company. A significant development of the concept of quality of the Japanese economy, in addition to Deming's teachings on the proper management of a company, on certain achievements of Schuhart, was to some extent the application of the Kaizen philosophical principle. It's about permanent, systematic and organized improvement of the company's products and services, that is, a continuous improvement of the quality of business [8].

One of the goals of modern business is to achieve business excellence and to achieve world-class products and services. It can be successful only on the basis of continuous continuous improvement of the quality of business organization, which refers to the constant growth of productivity of work and knowledge of each individual in the organization. The concept of TQM is specifically targeted at employees, ie man is the most significant resource of an organization's business. Every employee in the organization should become responsible for their contribution to improving the quality of business. Each employee can be evaluated on the basis of improving labor productivity and knowledge.

The Kyoto Declaration, adopted at the 4th International Productivity Symposium in 1990 in Japan, provides five suggestions for improving productivity [8]:

- Human resources care,
- Collaboration of management with employees,
- Mutual understanding,
- Global cooperation,
- Work for a better future.

The situation today in the field of quality in domestic conditions characterized by elaboration of a standard ISO 9000, and a dominant direction in the certification of a system of quality, whereby the quality of the system, i.e. TQM becomes the primary goal [6]. In the business world, the largest companies in the world insist on the use of a systematic approach in the implementation of the TQM concept, as the only correct way of ensuring the quality of business. The application of the modern concept of quality, based on the principles and elements of TQM, is an effective and efficient means of achieving the general goals of the organization (economic efficiency, meeting the needs of the entities of the organization and competitiveness in the market), thus ensuring the survival and development of the organization [6]. The EFQM European Foundation for Quality Managements defines TQM in a company for business excellence, based on customer focus, supplier partnerships, and development and employee involvement [14].

Basic similarities between reengineering and TQM are reflected in the process orientation, the initiative for introduction in both cases is given by top management, and in both cases responsibilities and authorities are delegated, as well as the needs for education and training, as well as the application of quality methods and techniques (quality tools) [6]. TQM is based on product and service quality and excludes innovation and process replacement. Quality management is a monotonous cycle with continuous improvement of quality, while reengineering implies radical changes of process [1].

TQM is a solution focused on quality, not wide enough and does not take into account the speed and innovation of the product. Reengineering involves doing business in a rapid and drastic change, introducing new processes rather than upgrading existing ones [4]. Basic differences of TQM and Reengineering concepts follow in Table1.

Table 1: Comparison of TQM and Reengineering features [8]

	TQM	Reengineering
Trait	Advancement	Innovation
Level changes	Gradual	Radical
Starting point	Starting point	Starting point
Frequency of change	Continuously	Periodically
It takes time	Long	Short
Participation	Bottom up	Top to top
Field of operation	Narrowly, within existing functions	Broadly, through functions
Risk	Moderate	High
Tool	Statistical control	Information Technology

These two concepts are thought to overlap with each other over time over the life cycle of a single process [12]. The best solution for the company is to use both of these concepts, where necessary to insist on the constant improvement of the quality of operations.
It can be concluded that reengineering improves organizational structure, enables rapid and drastic changes, increases quality and reduces costs, reduces process execution time, improves internal and external relations, eliminates unnecessary activities. Makes for a comfortable work atmosphere and defines broad employee responsibility. Unfortunately, because of big costs at applying BPR and a high percentage of failure, it is recommended to enterprises which do not have great problems in their business to implement TQM system [19,22].

CONCLUSION

It can be said that TQM and reengineering are customer oriented. Both concepts seek to improve customer satisfaction, propose and put management in the role of the user, in order to properly understand the advantages, mistakes and disadvantages of what is offered to the user. TQM and BPR concepts are process oriented. Both concepts go towards improving and improving the process, not just the product. These two concepts can be said to have a similar team approach in business.
Companies that opt for one of these techniques will certainly not go wrong. Reengineering is certainly the most radical concept compared to the TQM concept. TQM approaches as a tactical concept, if a company wants slow but secure and stable growth and development, as well as constantly improving processes and products, TQM should be implemented into the company. If a company chooses to implement a reengineering concept, the top management of the company must spend some time thinking and defining processes and how to improve those processes before they undergo radical changes and reengineering business processes. Lessons learned through the process of defining processes and eliminating redundant operations, then teamwork of employees from various functions, improving employee knowledge, applying the principles of "get it right" as well as many other activities are invaluable to the organization. If the job is not characterized by a permanent monitoring of the market and knowledge of appropriate response that will satisfy discerning customers and it is not possible to develop and improve the company [9].

REFERENCES

[1] Adamović, Ž., Sajfert, Z.: Reinženjering, Univerzitet u Novom Sadu, Tehnički fakultet “Mihajlo Pupin”, Zrenjanin, 2009.
[2] Banjanin, M. Reinženjering univerziteta, XI Skup Trenodovi razvoja, Kopaonik, 2005.
[3] Bakator, M., Petrović, N., Stajić, M.: Totalno upravljanje kvalitetom u cloud computing okruženju, Interantional Convention on Quality, Beograd, 2017.
[4] Bennis, W., Mische, M.: The 21st century organization: reinventing through reengineering, Jossey-Bass Inc. Pub, San Francisco, 1995.
[5] Verespej, M.: Reengineering isn’t going away, Industry Week, 244(4), pp. 42-44, 1995.

[6] Đokić, I., Rajković, D.: BPR I TQM – određenja i komparacije, Nacionalna konferencija o kvalitetu, Kragujevac, 2005.
[7] Đorđević, D., Đekić, I.: Osnove upravljanja kvalitetom, Teagraf, Beograd, 2001.
[8] Đorđević, D., Ćoćkalo, D.: Upravljanje kvalitetom, Univerzitet u Novom Sadu, Tehnički fakultet “Mihajlo Pupin”, Zrenjanin, 2007.
[9] Đorđević, D., Ćoćkalo, D., Bogetić. S.: The analysis of marketing concept implementation in domestic enterprises. Journal of engineering management and competitiveness, Vol. 6, No. 2, pp. 120-128, 2016,
[10] Galbraith, J, K.: Dobro društvo, PS Grmeč – Privredni pregled, Beograd, 2001.
[11] Hammer, M.: Reengineering work: Don't automate, Obliterate, Harvard business review, 68(4), pp. 104-112, 1990.
[12] Hammer, M.: Beyond Reengineering, Harper Business, New York, 1993.
[13] Hammer, M.: The Reengineering revolution handbook, Harper Collins Publishers Inc, London, 1993.
[14] Heleta, M.: TQM – Model za poslovnu izvrsnost, Educta, Beograd, 1998.
[15] Love, P. E., Heng, L., Irani, Z., Faniran, O.: Total quality management and the learning organization: A dialogue for change in construction, Construction Management and Economics, Vol.18, No.3, pp. 312-331, 2010.
[16] Oliveira, G. S., Corrêa, J. E., Balestrassi, P. P., Martins, R. A., Turrioni., J. B.: Investigation of TQM Implementation: Empirical Study in Brazilian Iso 9001-Registered Smes. Total Quality Management & Business Excellence, pp. 1-19, 2017.
[17] Petrović, N., Ivin, D., ,Joksimović, D., Sajfert, D., Mjedenjak, M.: The role of implementation of the concept – total quality management in organizations, VIII International Conference Industrial Engineering and Environmental Protection, Zrenjanin, Serbia, 2018.
[18] Sajfert, Z.: Organizacija poslovnih sistema, Univerzitet u Novom Sadu, Tehnički fakultet “Mihajlo Pupin”, Zrenjanin, 2006.
[19] Vorkapić, M., Ćoćkalo, D., Đorđević, D., Bešić, C.: Implementation of 5s tools as a starting point in business process reengineering, Journal of engineering management and competitiveness Vol. 7, No.12, pp. 44-54, 2017.
[20] Šćekić, V., Vučirović, I., Jovanović, D.: Uticaj reinženjeringa na poboljšanje ekonomske efikasnosti, Ekonomija – teorija i praksa, Novi Sad, 2011.
[21] Hall, G., Rosenthal, J., Wade, J.: How to make reengineering really work. Harvard Business Review, 71(6), pp. 119-131. 1993.
[22] McAdam, R.: Radical change: a conceptual model for research agendas. Leadership & Organization Development Journal, 24(4), pp. 226-235. 2003.

THIRD MISSION IN SERBIA – A NEW VIEW ON HIGHER ENGINEERING EDUCATION

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Abstract: Today's higher education is taking place in a changing and dynamic environment. New technologies, demanding market and especially labour market raised awareness of their responsibility and a leading role among academic community. Therefore, higher education institutions (HEIs) have assumed another set of activities along with the traditional ones: education and research. These activities are commonly referred to as *third mission* (TM).This paper discusses all three aspect of the third mission, and the possibilities of students' involvement in these activities as part of their university education process.
Key words: higher education institutions, third mission, students

INTRODUCTION

Encyclopaedia Britannica defines engineering as "The branch of science and technology concerned with the design, building, and use of engines, machines, and structures. The words engine and ingenious are derived from the same Latin root, *ingenerare*, which means *to create.* [1] Dictionaries of English language offer more or less similar definition of engineering and define it as "The branch of science and technology concerned with the design, building, and use of engines, machines, and structures" [2]
Having in mind these definitions on the one hand and a fast advancement of technology on the other hand, engineering education is nowadays regarded as very dynamic combination of various disciplines. Apart from studying their core disciplines, modern engineers face a growing competition so they also need to be skilful in promotion of their products, marketing and financial aspects of production.
Acquiring these new skills require changes in study programmes at HEIs as well as additional engagement of students' time in extra-curricular activities. Moreover, new demanding environment in which engineers work today impose a necessity for them to constantly deepen their knowledge and upgrade their professional skills.

REASONS FOR DEVELOPMENT OF THIRD MISSION IN SERBIA

Not long ago higher education institutions were focused on two main activities: education and research. They created study programmes to generate qualified labour force for industry and economy. In addition, they organized research work the results of which were available mainly to scientific community. However significant, the research results rarely found their way to practical application in industry.
Similarly, although HEIs have education as their main activity, it seems that regardless of the frequency of their upgrading, curricula and syllabuses did not manage to cover a wide enough range of courses to meet the needs of contemporary labour market. Besides, upgrading of curricula was sometimes led by reasons other than necessity to become more competent in the higher education offer. Consequently, graduate students who wanted to advance and develop their professional knowledge and skills in a short time and in an effective way had to turn to other centres of education.
Finally, no matter how important the role of HEIs may be for the wellbeing of society and economy in general, academic community seemed rather distant from the main social and economic developments. Any contributions to them, whether as a result of research or cooperation with industry, are not a frequent and regular activity of HEIs and seem visible only to those directly involved.

THE PROJECT INSTITUTIONAL FRAMEWORK FOR DEVELOPMENT OF THE THIRD MISSION OF UNIVERSITIES IN SERBIA – IF4TM

As a member of the Bologna Process and the European higher education area since 2003, the relevant ministries and authorities in the Republic of Serbia have adopted a series of laws and regulations in the process of harmonization with the regulations in force in the EU. Among others, new *Law on higher education* was adopted in 2005 and it introduced a reformed higher education with three-cycled system of studying including a new system of valuation using the European Credit Transfer and Accumulation System (ECTS) and diploma supplement among other novelties.
Wishing to continue the process of harmonization with the European higher education area, the University of Kragujevac applied for a grant for the project entitled *Institutional framework for development of the third mission of universities in Serbia – IF4TM* [3] which was selected for EU co-financing and was implemented from December 2015 until June 2019. Beside the University of Kragujevac as a lead partner, the project gathered five public universities in Serbia (University of Kragujevac, University of Belgrade, University of Novi Sad, University of Niš, State University of Novi Pazar), one privately owned university - Belgrade Metropolitan University and one college - Technical College of Applied Sciences in Zrenjanin. Other Serbian partners were the Ministry of Education of the Republic of Serbia, Intellectual property Office, Business Innovation Centre Kragujevac, Business Technology Incubator of Technical Faculties Belgrade**,** Business Incubator Novi Sad, Intranea Solutions, Serbia. The consortium also included five European universities (University of Brighton, Danube University Krems, **I**nstituto Superior Técnico Lisboa, University of Maribor**,** University of Bari Aldo Moro**)** whose experience and assistance in third mission preparation and development was highly appreciated.
The project objective was “to contribute to the establishment of institutional framework for the third mission of the universities in Serbia, encompassing three dimensions: technology transfer and innovation, continuing education and social engagement” [3] In other words, IF4TM implementation was aimed at filling the gaps between randomly organized activities within these three dimensions at Serbian HEIs described in the previous section and the systematic and institutionally regulated third mission activities of the EU universities.
In this regard, specific objectives included legal framework on both national and institutional level to support development and implementation of third mission, creating conditions for implementation of technology transfer and innovation dimension through INNO platforms, Proof-of-concept programme, national competitions for the best student idea, mobilazing university resources to society and indurstry, establishment of creativity centres, open-innovation campaigns and integrative university approach in the continuing education dimension.

DEVELOPMENT OF THIRD MISSION IN SERBIA

Since the term third mission was introduced, there have been many documents which analysed its aims, purpose and implementation. They all have in common a student-oriented dimension and underline that third mission in all its aspects rely on students’ participation. All three TM dimensions involve an active participation of students, not only to play their traditional role of learners, but to assume a new role and new tasks and duties as initiators of actions. Therefore, students, along with their teachers are the most valuable resource in TM implementation and special attention should be given to their capacity building as well as motivation and encouragement.
All three dimensions first need an institutional framework which would include bylaws based on legal framework on the national level which incorporated measures developed by the project IF4TM, such as the Law on higher education [4] or Strategy of Scientific and Technological Development of the Republic of Serbia 2016 to 2020, [5]
The aspects of all three dimensions of third mission which could improve and supplement education of graduate engineers and engineering students implemented at seven Serbian HEIs as results of IF4TM project [6] are here described to show some of the possible actions which HEIs may consider undertaking in this regard.

Technology transfer and innovation

Innovation platforms – a kind of collaborative support tool for all existing and forthcoming activities related to the technology transfer and innovation, designed primarily for students to exchange ideas during preparation for the Competition for best student ideas, but may be used for any other purpose by students and teachers. They are user-friendly and help students collect material for further discussion.
Workshops and trainings for capacity building – Methodology guide for innovation, Intellectual property (IP) protection and management, Market strategy and Start-up trainings. They were all organized for both teachers and students as their topics can be rarely seen included in study programs, especially those concerning IP protection. Entrepreneurship was also one of the topics within Start-up trainings although a mapping conducted at the beginning of the project implementation showed that most HEIs in Serbia had already included it in their study programmes. The said training was organized within preparation of students for the Competition for best student ideas and it familiarized students with business model development using CANVAS method, business model validation, finance for start-ups, elevator pitch
Competition for best student ideas – was organized in 2017, 2018 and 2019 and each year a large number of students took part in it. They applied with their ideas as two- three- or four-member teams and after the best teams were selected at local competitions, national competitions were organized where the best teams competed for valuable awards. The competitions were aimed at developing entrepreneurial and competitive spirit and innovativeness among students.
Proof-of-concept programme - is based on support to research teams with promising technologies in developing their research, valuating IP and developing the commercialization strategy. The Program for raising Technology Readiness Level and its validation (PoC Program) supports the researchers from Serbian HEIs who develop technologies with the potential for commercialization and who need additional support for validation of their research results, technologies and laboratory prototypes, with the aim to raise their Technology Readiness Level and get closer to the market.
Furthermore, the project also suggested establishment of specialized offices/centres/units to ensure a professional management of the whole technology transfer process which would identify scientific and research results with commercialization potential, help in IP protection, facilitate the research results into marketable products and services, ensure cooperation with business, participate in establishment of spin-offs and start-ups, and other

Continuing education

Although there is a range of activities organized as lifelong learning (LLL) or continuing education (CE) courses, with existing strategies and policies at some Serbian HEIs, these activities need appropriate institutionalization in terms of "umbrella" law and regulations, internal and external accreditation and procedures followed in its implementation. In this regard, beside amended *Law on higher education* [4] and introduction of short-cycle courses, the IF4TM offered a document Guidelines for establishment of integrative approach in continuing education at the university level [7] to help HEIs regulate these activities which include development of bylaws, establishment of a separate CE unit, types and scopes of CE, accreditation procedure quality assurance and assessment, incentives for participants in CE and promotion.

Social engagement

Social engagement involves a whole set of activities aimed at improvement of social life in general, economy, and local, regional and national community. It is not always easy to institutionally regulate them with exception of the *Law on higher education* [4] which includes provisions and the recommendations to establish the Committee of Employers at all higher education institutions as a mechanism for creating sustainable links with industry. Certain documents may also be prepared to conduct these activities in a systematic and organized way.

Above all, those are *social engagement plans* which should clearly describe the HEIs efforts to become more socially involved and responsible institutions. Short-term and long-term priorities and objectives need to be established and a set of actions defined in order to achieve these objectives.

Creativity centres, established during the IF4TM project implementation, present yet another place for students where all sorts of activities may be organized, those in connection with innovation and technology transfer, continuing education and cooperation with external stakeholders.

Student volunteering in different actions initiated either by themselves or external partners should be properly valuated and encouraged in order to create students as socially responsible members of society. This activity also needs to be organized in such a way so that its rules for application, performance and reports are clear and available to all students.

As for the institution itself, it should *unlock its resources* (classrooms, laboratories, academic and staff in general) to a wider community and offer itself as an active participant in all sorts of actions.

Open-innovation campaigns are another channel which can enable connection and cooperation between companies or other stakeholders and HEIs. During the projects implementation, the companies with any kind of problems which needed to be solved were invited to present that problem and offer students and their research teams a chance to solve them and thus enter the world of work even before they graduate.

CONCLUSION

The mentioned IF4TM project has laid the groundwork for all HEIs in Serbia to further develop third mission concept in accordance with their own needs, resources and community requirements. In this regard, the project delivered a set of manuals, guidelines, instructions and other supporting documents to help HEIs establish the third mission activities as part of their regular and continuous work.

Although it comprises three dimensions, it is quite obvious that their activities are overlapping and complementary. Thus, when considering engineering education, they all contribute to it in different forms but with the same aim – to offer engineering students and graduates an opportunity to enlarge their knowledge and professional profile by attending up-to-date programmes, courses, workshops and trainings. Moreover, they are invited to take an active part in development of new technologies, cooperation with industry and community and to obtain business experience from the very beginning of their studying.

Regardless of the recommendations proposed by the project, all HEIs are welcome to create their own methods, models, regulations and procedures when setting their goals regarding third mission activities and to offer them to a wider academic community.

REFERENCES

[1] Internet source: https://www.britannica.com/technology/engineering
[2] Internet source: https://www.lexico.com/en/definition/engineering
[3] Institutional framework for development of the third mission of universities in Serbia – IF4TM funded by Erasmus+ Programme of the European Union, Project No. 561655-EPP-1-2015-1-RS-EPPKA2-CBHE-SP http://www.if4tm.kg.ac.rs
[4] Law on Higher Education (Official Gazette of the Republic of Serbia, No. 88/2017, 27/2018-other law and 73/2018)
[5] Strategy of Scientific and Technological Development of the Republic of Serbia 2016 to 2020 http://www.mpn.gov.rs/wp-content/uploads/2015/08/Strategija-engleski-jezik.pdf
[6] Internet source: http://www.if4tm.kg.ac.rs/pub/download/15620514805146_D2.5%20v2.pdf
[7] D4.1 Guidelines for establishment of integrative approach in continuing education at the university level .http://www.if4tm.kg.ac.rs/pub/download/15386518227916_D%204.1.pdf

QUALITY MANAGEMENT FOR COMPUTERIZED PHARMACEUTICAL SYSTEMS

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Abstract: Product (medicine) quality management in the pharmaceutical industry is a very important process because of pharmaceutical products are directly introduced into the body of the user, so the composition, purity, stability and appropriate quality of the product are extremely important. To maintain the quality of pharmaceutical products, a quality management system should be followed. One of the indispensable elements for quality management in the pharmaceutical industry represent the qualifications of computerized and KGH systems. Giving importance to qualifications has been increasing in recent years, so qualifications are an integral part of quality assurance and represent a systematic approach to data collection and analysis which will provide documented evidence that the system is functioning properly and continuously gives the expected results. Through this paper the basic terms of qualifications of computerized and KGH systems are defined, process stages are established, potential risks are identified, it was evaluated which risks were acceptable and risk reducing actions have been proposed from their impact on computerized and KGH systems. The focus of this paper is on the application of risk analysis to the qualifications of computerized systems.
Keywords: Quality, pharmaceutical industry, qualification, risk analysis

INTRODUCTION

GMP Annex 15 [1] describes the qualification principles applicable to the premises, equipment, ancillary systems and processes used to manufacture drugs. GMP's requirement is that throughout the product and process life cycle, through qualification, controls the critical points of certain procedures. Any planned changes to space, equipment, ancillary systems and processes which can affect the quality of the product, should be formally documented and the estimated impact on qualification principles or evaluated strategy. Computerized systems used for drug production should be qualified in accordance with the requirements of Annex 11 [2]. Significant concepts should also be taken into account and the recommendations presented in the guidelines ICH Q8, Q10 i Q11 [3].

The quality risk management approach should be applied throughout the drug life cycle. Decisions about the scope and degree of qualification and qualifications, as part of the quality risk management system, should be based on a justified and documented risk assessment in the space, equipment, ancillary systems and processes. Data supporting qualification studies, obtained from sources outside the manufacturer's own qualification program, can be used under condition that this approach is justified, and that there is an adequate guarantee of the performed controls during the acquisition of this information.

One of the basic requirements for drug production is the pharmaceutical quality system, which involves the administration of GMP at all stages of the drug life cycle. GMP requires from the pharmaceutical industry to implement a control program, qualifications of the computerized system. The paper will be focused on quality management during the qualifications of computerized systems during construction or reconstruction of pharmaceutical facilities.

GMP requirements require manufacturers to identify the qualifications to be implemented, to prove that critical points in production processes are under control. All modifications to the space, equipment and production process that affect the quality of the product must be qualified. It is necessary for any change on a computerized or KGH system, or change that affects the systems listed (installation of additional components, software changes, defining new alarms, changing room dimensions, changing the number of air changes and the like) carry out a risk assessment to determine the extent of the qualification required.

According to [5], the qualification of pharmaceutical facilities plays a major role, whether or not it has contact with the product, because an adequate facility is a prerequisite for obtaining a quality product.

In their paper they give a short overview of the qualification of pharmaceutical facilities, in which he describes the planning of qualifications, qualification, methodology for execution, as well as change control and a re-qualification plan. Unlike the mentioned paper, in this paper a detailed account of quality management will be given during the qualifications of computerized and KGH systems, as well as done risk analysis to evaluate the scope of testing.

Qualification presents a proven security for an efficient and solid manufacturing process and presents a tool for measure of quality in the pharmaceutical industry. Qualification reduces the costs associated with monitoring, sampling and process testing. [6]

Render N et al (2006) present research results that have been gathered from numerous case studies and have been used to test and inform about the best practical model of the qualifications of pharmaceutical facilities. The aim of the study was to investigate the method and the way by which validation activities are represented in the process of construction of pharmaceutical facilities; as well as to compare the obtained results with what needs to be done to arrive at a best practice model. It comes to the conclusion that the criteria for evaluating the success of any construction project are time, cost and quality. Time and cost are easily measurable, but the meaning and sense of quality was unattainable, and this is at the root of the problem of successful qualification of pharmaceutical plants. During the research it became clear that construction project heads probably tend to understand quality as a measure of production, while pharmaceutical project heads view it as safety and regulatory compliance. This difference in the understanding and importance of qualification activities has been neglected, or in the best case underestimated. [7]

However, some authors and researchers do not attach much importance to qualifications and [8] and consider that the quality system in the pharmaceutical industry can be viewed from four aspects: through quality planning, quality assurance, quality control and quality improvement. Until the application and importance of qualifications they do not mention.

QUALIFICATION PLANNING METHODOLOGY

Projects for construction and / or reconstruction of pharmaceutical facilities are different from many projects because of the complexity of the production process within the plant itself, as well as the critical nature of the drugs which are produced. As early as 1995, the paper [9] showed that the subject costs such as finishing works, installations, ancillary systems, support systems and other hardware far larger in the pharmaceutical industry than non-pharmaceutical facilities of the same size.

In doctoral dissertation, Render (2006) monitors participants in the construction of pharmaceutical facilities and conducts companies surveys, and in his doctoral dissertation presents evidence of a "conflict of cultures and approaches" between contractors (constructors and designers) and users. As a result of non-compliance, reprocessing, postponement or delay is common, and this leads to late plant start-up, production delays, customer dissatisfaction and litigations. [10]

In order to avoid such problems, it is very important and essential that the qualification is properly planned. For significant efforts during validation which involving complex equipment and ancillary systems, validation master plan should be developed at early-stage of project, ie. in the conceptual engineering design phase, in order to define the overall philosophy and methodology of the qualifications that will be used throughout the whole project. This allows the qualification team to plan resources, schedule requirements, and ensure that specifications designed by the engineer are suitable for validation.

Qualification activities should consider all phases from initial development from customer specification requirements or initial process development to end use of equipment, space or process. The main stages and some of the proposed criteria (although this depends largely on the individual circumstances of the project) that may be included at each stage are listed in following: **URS** (User requirements specification), **Change Control**; **DQ** (Design Qualification); **RA** (Risk Analysis; **SAT** (Site acceptance testing) / **FAT** (Factory acceptance testing); **IQ** (Installation Qualification); **OQ** (Operational Qualification); **PQ** (Performance Qualification); **Tests conducted report**. The focus of this paper is on the application of risk analysis to the qualifications of computerized systems.

Risk management

Papers that have a similar approach are listed below and used in the preparation of the risk analysis that follows. In [11] the authors present the qualification of the control (BMS) system, in [12] the qualification of the KGH system is presented, while in [13] the risk management of the KGH system is presented. In practice, it is rare for KGH and BMS qualifications to be analyzed together, although they are inseparable entities. Therefore, the qualification of the computerized system operating the KGH system will be presented below, applying the FMEA method to determine the scope of testing required to qualify the system properly and in accordance with regulations.

The essence of the problem is to evaluate the scope of testing in detail, depending on the change initiated on the system. Effective risk analysis should be performed by an expert team with sufficient knowledge of system design and implementation, and as such an evaluation of the test should be given, after which the system with high confidence will continuously produce the expected results.

Risk management is a systematic process for assessing, controlling, communicating, and reviewing risks for the quality of medications during the product life cycle. In ICQ 9, a recommended risk assessment methodology is provided, of course, other models may be used, but the competent authorities (inspections) recommend this type of methodology, to make risk management as uniform as possible. For systems with very high and high levels of risk, the hazards associated with the process managed by the computerized system should be determined and reduced through the application of the FMEA model.

When these steps are completed, the FMEA method requires an evaluation of the severity level (Severity) assigned to each of the potential effects (FM). Severity is the assessment of the potential effect of FM on the process stages, in accordance with the intended application of the procedure and / or product quality, and is performed using the following rules:

Table 1. Severity of Effects

Severity	Criteria for Evaluation
High	Failure mode might jeopardize process intended use and/or product quality and the controlled process has no alternative methods to perform operations
Medium	Failure mode might jeopardize process intended use and/or product quality but manual operations/additional control can be adopted to ensure the process execution
Low	Failure mode may not jeopardize process intended use and/or product quality

The Probability of Failure (Likelihood) represents the frequency of the risk root cause occurring. The approach requires to consider the probability of the risk root cause occurring within a given time period (day, month, year) or per a quantity of transactions, and assigning a value to that estimate according to the criteria reported in following Table 2:

Table 2. Likelihood of Failure

Classification	Criteria for Evaluation
High	A standard system function or business process that has been customized by custom coding or by configuration of non-standard system parameters and/or options
Medium	A standard system function or business process that has been significantly modified solely by configuration of standard system parameters and/or options
Low	A standard system feature or business process that has not been significantly modified by configuration or coding

The Risk Class for each Risk Scenario identified has been evaluated as a combination of the Severity and of the Likelihood, as reported in the following Table 3, where 1 = High; 2=Medium and 3=Low.

Table 3. Risk Class

		Likelihood		
		Low	Medium	High
SEverity	High	2	1	1
	Medium	3	2	1
	Low	3	3	2

Table 4. Risk Priority

		Detectability		
		Low	Medium	High
Risk Class	1	High	High	Medium
	2	High	Medium	Low
	3	Medium	Low	Low

By combining the Risk Class with the Detectability, it is possible to priorities the fault conditions associated with each risk scenario based upon those areas of greatest vulnerability. The Table 4 provides the model to evaluate the Risk Priority.

The purpose of this phase has been to identify if the risk event could be recognized or detected (Detectability) by other system controls. The Detectability of a risk has been evaluated as reported in the following Table 5:

Table 5. Detectability of failure

Classification	Criteria for Evaluation
Low	No Additional checks and/or Process Downstream Controls aimed to detect the ***Potential Cause of Failure or Failure Mode*** are available
Medium	Information for Additional checks and/or Process Downstream Controls aimed to detect the ***Potential Cause of Failure or Failure Mode*** by an operator are available
High	Additional checks and/or Process Downstream Controls aimed to detect the ***Potential Cause of Failure or Failure Mode*** automatically are available

Based on the risk priorities of each Scenario, appropriate Mitigation Actions have been determined (e.g. Testing effort, SOPs emission, automated operational check's implementation) in order to mitigate the risk, according to the following Table 6:

Table 6. Risk Mitigation Actions

Risk Priority	Mitigation Action
High	User Training; Relevant SOPs; Testing activities in normal conditions; Challenge Testing activities where applicable (e.g. negative test) or Procedure Implementation/Verification; Redesign could be reconsidered.
Medium	User Training; Relevant SOPs; Testing activities in normal conditions
Low	User Training; Relevant SOPs

Table 7 presents the risk analysis. The methodology of this analysis is taken from the ISPE and ICH guidelines. The set-up of the analysis was obtained by combining the ISPE and ICH guidelines, while the description of risks, potential effects and causes were determined depending on the computerized system.

Table 7. Risk analysis

Functionality	Description	Potential Effect of failure	Risk root cause	S	L	Risk Class	D	Risk Priority
Data Integrity	No data backup and/or archiving foreseen on system.	No storage of GxP relevant data. Lack of data traceability.	Unadequate Control System	H	L	2	H	**L**
	The system does not allow to obtain correct and complete copies of data.	Copies of GxP relevant data cannot be submitted in an appropriate format to the authorities.	System Failure	H	L	2	M	**M**
	Data can be corrupted and falsified, with no trace.	Original data loss.	Wrong System Configuration	H	L	2	M	**M**
	The system is not able to detect an invalid record.	Invalid data are stored.	System Failure	H	L	2	M	**M**
	Backup and restore activities are not specified in an adequate procedure.	Possible GxP relevant data loss.	SOP missing	H	L	2	H	**L**
	Stored data are not periodically checked for accessibility, readability and accuracy.	Possible GxP relevant data loss.	Responsible person mistake	H	L	2	H	**L**
	The data are not retained for an appropriate time after backup.	GxP relevant data loss and cannot be submitted to the authorities.	SOP missing	H	L	2	H	**L**
Time manage-ment	The system allows uncontrolled change of the system date and time.	The date and time reliability of the system results is compromised.	Wrong Configuration	H	L	2	M	**M**
	Time clock is not correct.	All GMP records are invalid.	System Failure	H	L	2	M	**M**

Functionality	Description	Potential Effect of failure	Risk root cause	S	L	Risk Class	D	Risk Priority
System & Data Security	The system allows the access to unauthorized user to use system and application.	Unauthorized use of the system and application software.	Access to system and applicaton without control	H	L	2	M	**M**
	The system allows the access to unauthorized user to use data acquired.	Unauthorized use of the data acquired.	Access to data without control	H	L	2	M	**M**
	Wrong user profiles / privileges assignment provide unauthorized access to system and application software parts	Unauthorized use of the system and application software parts.	Incorrect Configuration	H	L	2	H	**L**
	The system allows same username / password to be assigned to multiple users.	Wrong use of the system and application software and operator actions traceability.	Control System Failure	H	L	2	M	**M**
	System doesn’t lock after period of inactivity.	Unauthorized use of the system and application software.	Unauthorized Access to system	H	L	2	M	**M**
Device / Equipment Status	The system does not allow to control/monitor the status of the devices.	Impossibility to control/monitor the device	System Failure	M	M	2	H	**L**
	The system does not allow forcing connected devices statuses.	Connected device status is not controlled by the system.	System Failure	M	M	2	M	**M**
	The system does not trace the forcing condition in Audit Trail.	Device forcing not traced.	System Failure	M	M	2	M	**M**
Process Parameters Monitoring and Trends	The monitored environmental parameters are not correctly displayed.	Impossibility to record/monitor the environmental values/conditions.	System Failure	H	L	2	M	**M**

Functionality	Description	Potential Effect of failure	Risk root cause	S	L	Risk Class	D	Risk Priority
Alarm Manage-ment	The system does not generate the alarms if equipment failure occurs.	Production process potential impact.	System Failure	H	L	2	H	**L**
	The system does not generate alarms if the values of the process parameters under alarm control are out of designed ranges.	Process parameters out of specified range cannot be detected.	System Failure	H	L	2	M	**M**
	The system does not allow to set alarm thresholds for the values of the process parameters under alarm control.	Invalid alarm configuration.	System Failure	H	L	2	M	**M**
	The system does not allow to display alarms properties.	Alarms cannot be inquired.	System Failure	H	L	2	M	**M**
	The system does not allow to acknowledge the alarm conditions.	Impossibility to restart the process.	System Failure	H	L	2	M	**M**
	The system does not keep alarm history after alarm condition disappear.	GMP important record missing.	System Failure	H	L	2	M	**M**
Data Tracea-bility	The system audit trail doesn’t generate.	Missing data traceability.	System Deficiency	H	L	2	H	**L**
	The Audit Trail is not kept over the retention time.	Missing data traceability.	SOP lack	H	L	2	H	**L**
	The information contained in system audit trail can be modified.	Missing data traceability.	System Failure	H	L	2	M	**M**

CONCLUSION

The qualification proves security for an effective and robust quality management process in the case of changes to systems in the pharmaceutical industry. Also, the qualification of pharmaceutical plants plays a very important role in quality assurance, because an adequate facility is a prerequisite for obtaining a quality product. Risk rankings, and the scales used in risk analysis, are difficult to define so they need constant review and improvement. How risk management is based largely on the scientific knowledge and and expert evaluations of participants in the process, active involvement of all relevant parties is necessary for the effective implementation of all prescribed activities and a measure to reduce or accept risk. Focusing on risk management and segregation of research funds, unnecessary efforts for qualification can be eliminated. Risk analysis, as an indispensable part of qualifications, is not only a means of compliance with GMPs rather, it demonstrates real advantages in the process of qualifying computerized systems by identifying risks and providing control of critical parameters. Qualification is an activity where prevention is achieved, as well as an important companion to all projects. This paper presents a detailed account of quality management in the qualification of computerized systems in the pharmaceutical industry, conditioned by changes to the system.

REFERENCES

[1] European Commission (2015) “Good Manufacturing Practice Medicinal Products for Human and Veterinary Use” Annex 15, Qualification and Validation, Brussels.
[2] European Commission (2011). “Good Manufacturing Practice Medicinal Products for Human and Veterinary Use” Annex 11, Computerised Systems, Brussels.
[3] US FDA (2006). Guidance for Industry “Q9 Quality Risk Management.
[4] ISPE Pharmaceutical Engineering (2005). “Positioning Paper: Use of Building Management Systems and Environmental Monitoring Systems in Regulated Environments”.
[5] Kashid V.A., Nikam V.K., Somwanshi S.B., Dolas R.T., Dhmak K.B., Gaware V.M., Kotade K.B., (2014). Brief Overview of Pharmaceutical Facility Validation. Journal of Current Pharma Research.
[6] Nandhakumar L., Dhramamoorty G., Rameshkumar S., Chandrasekaran S. (2011). An overview of pharmaceutical validation: Quality assuramce view point, International Journal of research in pharmacy and chemistry.
[7] Render N., Greenwood D., Edge J. (2006). The validation of pharmaceutical facilities. School of the Built Environment.
[8] Priyambada P., Goyal A. (2018). Quality Management System in Drug Industry: A Review. Journal of Scientific & Technical Research.
[9] Tedesco J.L., Titus M.J. (1995). Revealing hidden costs in building biopharmaceutical facilities. Pharmaceutical engineering.
[10] Render N. (2006). The Validation of Pharmaceutical Buildings. Doctoral thesis. Northumbria University.
[11] Tabašević I., Milanović D.D., Misita M. (2018). Assessment of the scope of testing required to qualification the BMS using FMEA methods. International symposium on industrial engineering.
[12] Shukla1 A., Katole A., Jain N., Karthikeyan1 C., Mehta F., Trivedi P. (2011). A Risk Assessment Approach: Qualification of a HVAC System in Aseptic Processing Area Using Building Management System. The Quality Assurance Journal.
[13] Kamakshi, Sharma RB. (2015). Risk Management of HVAC System in Pharma Industries. International Journal for Pharmaceutical Research Scholars.

INDUSTRY 4.0, DOMESTIC ECONOMY AND THE CHALLENGES OF GLOBAL COMPETITIVENESS

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Abstract: The globalization of markets and the emergency of heavy competition requires organizations to conduct business in way that will achieve competitiveness on the market. Convergence in technology is evident in the modern economy. In order to improve their competitiveness within the framework of Industry 4.0, countries have to accept innovation and new ideas faster and to be more effective in acting on those ideas. For many years, domestic enterprises face difficulties with improving their competitive ability in a global scale. Some of the reasons behind this are low product quality, insufficient investment in quality, and insufficient investment in innovative activity. In order to increase productivity and competitiveness of domestic enterprises, it is necessary to improve the technical and technological basis of conducting business, and to more efficiently apply modern management methods and techniques.
Key words: globalization, competitiveness, industry 4.0, organization, management, knowledge

INTRODUCTION

Enterprises in the modern business environment are struggling to obtain a competitive advantage over competitors. Competitiveness is hard to gain and easy to lose. The main reason for this is the fast advancement of technology and its widespread application. Additionally, fast technological development resulted in appearance of new industries, new clusters, new enterprises, and new competition. The essence of new technologies is the increase in productivity which further improves competitiveness. The globalization of markets, and globalization overall, has led to an increase in the number of international competitors. This further results in a more intense, more active and more visible competition on the market [1]. In addition, globalization has had an impact on changes in understanding and achieving competitive advantage. Somewhat thirty years ago, the main competitors in the international market were the United States, Great Britain, the Netherlands, West Germany, France and Japan. The relations on the international market were formed between the United States, Japan and West Germany. Currently, several additional countries are involved in the formation of competitive relationships on a global scale. The most influential of these new countries are China and India. Globalization made it possible for every country to take part on the global market and to become competitive. India and China are becoming world economic powers. More countries in Asia, such as South Korea, Indonesia, Singapore, Taiwan and others have an important role in the world economy. Corporations form developed countries face new challenges as corporations from emerging economies are more and more competitive. The economic development of newly industrialized countries has strongly affected the thinking of business people from developed countries, especially when it comes to improving productivity. The biggest chance for economic development is developing entrepreneurship. Implementing the entrepreneurial concept in every organization, regardless of size and industry, is crucial for strengthening the competitive ability of that organization. Entrepreneurial behavior is a type of thinking, which includes a creative and innovative approach to conducting business. In the entrepreneurial economy, every individual has to behave in an entrepreneurial way. Entrepreneurial innovation has to be the central element of every activities of managers.
On the global market, enterprises have to overcome challenges that relate to the development of a competitive advantage. Before, it used to be enough for enterprises to offer a market a new product or service. Today, competitiveness can't be obtained only through innovation, but also on the price component and standardized product quality. Surely, consumers expect from the product to have standard quality, with, of course, a globally acceptable price. Furthermore, market turbulence has

become a new business reality. According to some studies [2], strategic challenges over the next ten years will come from the simultaneous integration and fragmentation of the world. In the midst of the fourth industrial revolution, transformations are happening and they change the way how companies, governments and individuals develop relationships. Society enters a new phase of global cooperation - globalization 4.0.

The importance of new technologies is best observed on the strategic development of China as it choose ten priority sectors which are intensively developed till the year 2025. These sectors/industries are information-communication technologies, robotics, cosmic and airline equipment, equipment for ocean research, high-tech ships, traffic equipment, energy savings, new energy vehicles, new materials, new medical technologies and agricultural machines [3]. The Chinese government is determined to become a world leader in developing and applying artificial intelligence. The Chinese government's plan is to achieve an essential breakthrough onto the global top till the year 2025. China has managed to connect the necessity of fast technological development with globalization. The strategic plan of China can be presented as the "new silk road". The main interest of China is the development of the global economy. The Chinese president Xi Jinping on the beginning of this political leadership in 2013 launched the idea of a "new silk road", which was actually his foreign trade policy on how to energize the integration process of Chine into the global economy and political sphere.

Furthermore, this paper analyzes the competitiveness of domestic enterprises in the domain of Industry 4.0. The main goal is to present the current and future trends in globalization and competitive ability of domestic enterprises.

INDUSTRY 4.0 AND GLOBAL COMPETITIVENESS

Modern economies operates in a global context in the conditions of Industry 4.0. The economy was focusing on production, while it evolved through focus on consumers to the convergence of all participants in the economic process. This convergence is conducted with new advances of technology development. According to the definition of the World Economic Forum [4], the fourth industrial revolution is a cyber-physical system, or more precisely, it presents the connection of peoples' skills, and the possibilities of machines. The modern way of conducting business implies an ever growing number of digitalized manufacturing enterprises, cloud computing, cyber-physical systems, big data analytics which are important for Industry 4.0 development. Further, this implies the digitalization of every process and the implementation of the mentioned digital technologies during the creation of production processes, product control and offering of services which are paired with the new products.

Technology is one of the most dynamic factors of economic development. Additionally, enterprise competitiveness also plays a crucial role in economic prosperity. New technologies have a tremendous potential to increase business productivity which can further improve the competitiveness. The implementation and application of a new technological solution increases production capacity of the enterprise. Also, it can reduce the use of human labor and operating costs per unit of a product.

Kotler noted [5] that an enterprises' competitiveness will no longer be determined by its size or country of origin or advantages from the past. Smaller, younger and local enterprises will have the chance and the potential to compete with larger, older and global corporations. Globalization made the markets inclusive while social media enhances communication between businesses and consumers.

The speed with which countries generate innovations and adopt new ideas is key to improving competitiveness in the Industry 4.0 framework. Germany is the leader in the world, when it comes to generating and applying innovations [6]. Next comes USA and Switzerland hold the third place.

Further, the application of ICT and the overall quality of available education can determine the country's ability to develop innovations. As mentioned before, the China, or more precisely, the Chinese minister noted that China will be more focused and engaged into stimulating and creating innovation and to fully commit to innovation. This means encouraging high-tech institutions and research institutes to develop and apply innovations [7].

Table 1. Ranking the top 10 countries in the world according to their competitiveness in 2018 [8]

Country	Rank
USA	1
Singapore	2
Germany	3
Switzerland	4
Japan	5
Netherland	6
Hong Kong	7
United Kingdom	8
Sweden	9
Denmark	10

Table 1 presents the top ten most competitive countries in the world (according to the list of World Economic Forum (WEF) for the year 2018). After these countries Finland, Canada, Taiwan, Australia, South Korea, Norway, France, New Zealand, Luxembourg and Israel are among the most competitive countries in the world. China moved up a rank from the 27th last year to the 28th position. In contrast, India moved down from the 40th place to the 58th.. Further, Russia is placed 43rd (from the 38th), Brazil is ranked 72nd (moved up from the 80th), South Africa is placed 71st (dropped down from 61st). During the Global Competitiveness Report in 2018 creation a new and improved methodology was used compared to previous years. This new approach takes into consideration the requirements and trends of Industry 4.0. Additionally, this new and improved global competitiveness index focuses on factors which determine productivity and long-term growth in the era of Industry 4.0. Competitiveness requirements of the global competitiveness index 4.0 include the following indicator groups:

1. **Human capital**, with indicators: employee health, employee skills;
2. **The environment**, that includes the analysis of institutions, ICT acceptability, infrastructure, and macroeconomic stability;
3. **Market**, which includes the following indicators: labor market, product market, financial system and market size;
4. **Innovation and ecosystem**, which includes the following indicators: business dynamics, innovation capacity.

Further, the most significant areas of change in global transformation in relation to Industry 4.0, are:

1. Agile management,
2. Innovation and productivity,
3. Integration of technologies,
4. The need for leaps in business,
5. The need for jumps in relation to existing jobs and skills,
6. Improving ethical action and identity, [9].

Additionally, it is important to conduct changes regarding inequality and improving security aspects and reducing overall conflict. These measures are crucial for effective transition and adaption to Industry 4.0.

INDICATORS OF DOMESTI ECONOMY COMPETITIVENESS

The domestic economy of Serbia has a long-standing and persistent problem regarding competitiveness. This problem in the international context has been evident since the late 1980s. Further, it was even more noticeable at the beginning of the transition in 2001. After the global economic crisis, it negative effects have tremendously affected the weakening of competitive ability of domestic enterprises. The main issue of competitive ability are particularly evident in domestic enterprises where the main or dominant type of capital is domestic capital, or more precisely, autochthonous domestic capital. Further, the non-competitiveness of enterprises is primarily related to non-productivity. Another reason is that the domestic enterprises can't invest into the revitalization of production capacities, as they don't have the financial ability. The importance of productivity comes from the notion that quality and productivity are interconnected, so are cost advantage and productivity. Now, the problem of productivity can be observed from the aspect of low employee, especially executives/managers. In addition, outdated technical and technological basics of business also negatively affect productivity.

Business productivity is severely affected by the age of equipment used in the enterprise. Unfortunately, domestic enterprises use equipment with the average age between 20 and 30 years. In addition, modern management methods and techniques are inadequately applied by the managers in the domestic enterprises.

Even though there is a somewhat a decrease in unemployment over the last three years, there is practically no improvement in productivity. Foreign investors come to the domestic market primarily for the financial incentives which are given by the Republic of Serbia. The cheap and qualified labor force is also tempting for foreign investors. This further implies that foreign investors don’t bring new technologies and state-of-the-art industrial equipment. These foreign investors focus on construction factory buildings and facilities, and their goal is not to equip them with modern technology equipment, as the business activities are mainly labor-intensive. Development and innovation is not included in these business activities of foreign investors.

In the new report of the World Economic Forum for 2018, Serbia ranked 65th (out of 140 countries) in the domain of competitiveness which is a few places higher compared to the previous year where it placed 78th. Table 2 gives the ranking of the countries of the Western Balkans in the period 2018.

Table 2. Ranking of Western Balkans countries according to competitiveness in 2018 [8]

Country	Rank in 2018.
Bosnia and Herzegovina	91
Montenegro	71
Croatia	68
Macedonia	84
Slovenia	35
Serbia	65

Now, as for the neighboring countries, Hungary ranked 48th, Austria 22nd, Romania 51st, Greece 57th,, Bulgaria 52nd and Albania took the 75th place. With the exception of Austria which ranked 19th the previous year, the other countries have managed to improve their rank.

Table 3 presents the data for competitiveness of the Western Balkan countries in relation to the main indicators of competitiveness in 2018. The Republic of Serbia managed to progress on the competitiveness rank thanks to low inflation rates, stable financial system, improving the transport infrastructure, new business starting times and others. In addition, foreign investments positively affected competitiveness. The new Global Competitiveness Reports was developed with a new methodology. However, it is important to count in the important factors of competitiveness of the domestic economy. In Table 4 the most important problems of the domestic economy (regarding competitiveness) in relation to the competitiveness indicators according to the Report on Global Competitiveness 2018.

Table 3. Competitiveness abilities of Western Balkans countries according basic competitiveness indicators in 2018 [8]

Country	Rank	I 1	I 2	I 3	I 4	I 5
Bosnia and Herzegovina	91	111	89	86	73	52
Montenegro	71	63	86	58	102	55
Croatia	68	74	36	33	106	51
Macedonia	84	85	86	70	70	71
Slovenia	35	35	35	43	1	34
Serbia	65	70	48	60	64	67
Country	**Rank**	**I 6**	**I 7**	**I 8**	**I 9**	**I 10**
Bosnia and Herzegovina	91	87	106	112	83	99
Montenegro	71	52	45	25	51	132
Croatia	68	65	71	96	62	78
Macedonia	84	81	107	78	80	109
Slovenia	35	29	27	43	60	82
Serbia	65	56	66	52	79	75

Label clarification: I1 - institutions, I2 – infrastructure, I3 - ICT. I4-macroeconomic stability, I5-healthcare, I6-skills, I7-product markets, I8-labor market

Table 4. The most important problems of the domestic economy in relation to competitiveness indicators in 2018 [8]

#	Analyzed indicator in context of depth	World rank
1.	Sophistication of customers	127
2.	Ability to rely on professional management	122
3.	Relationship towards entrepreneurship	119
4.	Protection of private property	115
5.	State regulation efficiency	113
6.	Legal system efficiency	108
7.	Reporting system adequacy	108
8.	Independent Judiciary	107
9.	Market dominance level	106
10.	Protection of Intellectual Property	100
11.	Cooperation between employers and employees	100

According to Table 4, in the domain of global competitiveness, Serbia has the worst rankings in professionalism of management, protection of private property, sophistication of customers, efficiency of state administration, attitude towards entrepreneurship etc. Factors such as private property protection, market dominance, professional management, intellectual property protection, employer and employee relations are essential for a modern and functioning market economy. Why is this important? Well, newly industrialized countries, especially China and India, focused on the fostering of entrepreneurship and entrepreneurial behavior. Additionally, a strong focus was put on the importance of managerial knowledge improvement, especially in the domain of applying modern business experiences and practices.

Every country that enhanced entrepreneurship and entrepreneurial behavior to high levels, even breakthroughs have had incentives for entrepreneurship development and overall nourished an entrepreneurial climate in society. In the last thirty years, some of these countries are China and South Korea. Before them Japan, Taiwan and Singapore enhanced their entrepreneurial climate. However, overall there are no “more entrepreneurial” countries and “less entrepreneurial” countries, only entrepreneurial economies and non-entrepreneurial economies. The majority of the countries who are ranked in the top ten, are mainly entrepreneurial-oriented national economies. Countries with non-entrepreneurial economies face numerous challenges and problems which were built over decades. Some of these problems are inadequate relationships towards customers, entrepreneurship, management and private property.

Table 5. Top ranking factors that affect business in the Republic of Serbia in relation to competitiveness indicators in 2018 [8]

#	**Analyzed indicator in context of depth**	**World rank**
1.	Electrification rate	1 (several countries)
2.	Annual inflation rate	1 (several countries)
3.	Insolvency control network	14
4.	Severance pay costs	17
5.	Railway network development	19
6.	Capital banks regulation	20
7.	Time needed to start a new business	25
8.	Import in relation to GDP	31
9.	Education	39
10.	Road network connection	43

According to some studies [10], products and services from Serbia are non-competitive due to the low level of coverage of imports and exports which are technologically intensive. The majority of products exported from Serbia have little to no technological component, quality nor innovation. This further led to small export of technological and innovational products and services, which resulted in low income from technology export. Certainly, Serbia lags behind when it comes to technologically advanced products and services, compared to developed countries, which led Serbia to be dependent on foreign countries. However, it is encouraging that Serbia has factors which, affect business and entrepreneurship, the most highly ranked. Therefore, adequate long-term results can be expected.

GUIDELINES FOR IMPROVING THE COMPETITIVENESS OF DOMESTIC ENTERPRISES IN ACCORDANCE WITH INDUSTRY 4.0 DEMANDS

The global market and the establishment of new competitive relations requires a new approach in organization management which further implies a continuous improvement of not products and services, but every business process as well. Only the best take the “victory” in the competitive “battle” on the global market. To be the best on the market means to be the first, to be innovative, to be creative, to be ready to take risks. These are the characteristic of entrepreneurial behavior. Changes in technology can help enterprises, but at the same time they can bring risk to the business. Applying new technologies, enterprises can improve productivity and business efficiency. Further, some enterprises can use new technologies to create new markets. On the other side, enterprise that can’t adjust to new technologies in a short time, the consequences can be catastrophic, ranging from losing competitive ability to total disappearance from the market. The development of Industry 4.0 creates conditions for economic growth. According to Mitrović [11], 38 countries in the world have national programs regarding Industry 4.0, and from these 38 countries, 18 are from the EU. For a successful development of Industry 4.0, it is necessary to apply a new generation of manufacturing machines, software, and all this connected via cloud computing. According to some studies [12], Serbia is in the process of Industry 4.0 application and during this process it faces numerous challenges. Some of the challenges are limited market, limited resources for development and industry devastation which lasted for several decades and finally, negative economic growth. On the other hand, Serbia can acquire and use experiences from other developed economies, which initiate the further development of the Industry 4.0 model. Some of the possible guidelines for a more adequate application of Industry 4.0 are:

- Increasing the modernization process and the development of a new digital infrastructure, which is oriented towards high value products;
- Creating macroeconomic politics, and development politics which have to be in the function of manufacturing enterprises;
- Establishing an education system which focuses on digitalization and creative technologies, which have to be in the function of modernization;
- Stimulating entrepreneurship and entrepreneurial behavior as well as clustering small and medium-sized enterprises.

In order to successfully develop the domestic economy, it is necessary to commit to high technology, and technological equipment. Domestic enterprises have to orient their business towards technological advancement and the unification of technology and innovation, as these are important requirements of Industry 4.0. In addition, it is necessary to develop products and services with higher level of technological content which would further be export-oriented. Further, the application of information-communication technologies (ICT) is goof for the business. However, enterprises should be more focused on industry products and which are based on the manufacturing industry.
Products should be the priority, while services come later. The implementation of ICT can influence the improvement of productivity and overall business. Now, the organization of the future must be flexible, and focused on innovation of products and services. A company, in order to be successful it has to simultaneously and continuously expand, improve and innovate. In addition, the enlargement and improvement of business knowledge, and intellectual capital overall is an imperative for increasing productivity, and competitiveness. This implies, that domestic enterprises, have to focus on the processes of innovation, and not just the innovation of products but the entire business. Domestic enterprises have to innovate the management system and the whole organizational structure. In order to successfully orient on the market, enterprises have to actively approach the entrepreneurial concept, regardless of the size and activities of the enterprise. This is important, as domestic enterprises can achieve better competitive ability if they nourish an entrepreneurial climate. Therefore, enterprises have to adequately plan, predict and act on changes on the market. According to some studies [13], marketing as a whole is more often than not misunderstood in emerging economies. The problem is the personalization of marketing by the CEO or managers. Thus, it is necessary to eliminate the faster and more adequate application of marketing methods and techniques. Kotler et al. [14] noted that good and effective marketing is not a coincidence, but rather a result of focused and careful planning and organization with the use of modern instruments and techniques. Undoubtedly, marketing is a powerful generator of growth.

CONCLUSION

In the era of global markets and the newly developed competitive relationships, it is necessary to develop a new approach to business organization management, both in the organizational and conceptual terms. Enterprises can't ignore the changes which are happening in the business environment, and they have to not only monitor changes but act on them as well. In addition, enterprises have to modify their approach to technology management, quality management and management overall. The whole business philosophy has to evolve and improve in accordance with the changes in the environment. Peter Dracker [15] noted that results in a knowledge society are not given by an individual. An individual is a center of costs, and not a center that produces and gives results. The organization, the enterprise is the one that creates them.

As mentioned before, domestic enterprise lack competitiveness because of low productivity, low intensity of new technology application, non-existent or inadequate implementation and application of quality management concepts. In order to develop efficiency and competitiveness, domestic enterprises have to implement and apply modern management techniques and methods. Only this way, these enterprises can have a chance on the global market. The mentioned actions include the wide application of methods and techniques which are based on knowledge, and their goal is to improve quality and productivity. Also, it is necessary to improve the technological and technical basis of domestic enterprises. This involves the acquiring and purchase of newer generation manufacturing equipment. For future research it is recommended to address the influential factors that form the competitive ability of domestic enterprises.

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REFERENCE

[1] Arnold F., Menadžment učite od najboljih, Laguna, Beograd, 2015., str. 187.
[2] A predicition for globalization in 2018, WEF 2018., www.weforum.org.
[3] Novačić A., Kineski san - Si Đinping, Filip Višnjić, Beograd, 2018., str. 136.
[4] Ostojić T., BIZIT 2018: Industrija 4.0 – digitalna revolucija psolovanja, PC Press, oktobar 2018, www.pcpress.rs
[5] Kotler P., Kartajaya H., Setiawan I., Marketing 4.0, John Wiley and Sons Inc, Hoboken, new Jersey, 2017.
[6] Germany is the worlds most inovative economy, WEF ostober 2018., www.weforum.org
[7] Opening plenary with Li Keqiang, WEF, September 2018., www.weforum.org
[8] The Global Competitiveness Report 2018, World Economic Forum, October 2018,, www.weforum.org
[9] 4th Industrial revolution, WEF, october 2018., www.weforum.org
[10] Stanković Lj., Popović A., Market size as a determinant of national competitiveness of Republic of Serbia (In Serbian: Veličina tržišta kao determinanta nacionalne konkurentnosti Republike Srbije), Marketing, Vol 47 No 3 2016, SEMA, Beograd, str. 191-204.
[11] Industrija 4.0 budućnost Srbije, Mašinski fakultet Beograd, https://vesti.mas.bg.ac.rs
[12] Ka eksponenicjalnom industrijskom rastu – Industrija 4.0, Kopaonik biznis forum, Panel 2, mart 2019., www.kopaonikbusinessforum.rs
[13] Đorđević D., Ćoćkalo D., Bogetić S., The analysis of marketing concept implementation in domestc enterprises, JEMC Vol 6 No 2 2016., TF Mihajlo Pupin, Zrenjanin. pp. 120-128
[14] Kotler P., Keller K.L., Martinović M., Marketing management (In Croatian: Upravljanje marketingom), Mate, Zagreb, 2014.
[15] Drucker P., My view on management (In Serbian: Moj pogled na menadžment), Adižes, Novi Sad, 2006.

CHARACTERISTICS OF BUSINESS INCUBATORS

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Abstract: The paper presents general characteristics of entrepreneurial infrastructure - business incubators. One of the modern ways of support to small newly established enterprises and entrepreneurs, which are in a development life phase, is the system of technological infrastructure: entrepreneurial incubators, technology centres, science parks and business zones. Those are different organizations which help entrepreneurs to develop their business ideas and to overcome more easily the initial problems in business, for which, in a wider context, the term business incubators is used, and also the clusters related to entrepreneurs who are in an advanced phase of entrepreneurship. An incubator is extremely suitable for newly founded small enterprises, which do not have their own business premises, sufficient funds and experience, on one hand, but, on the other hand, they have entrepreneurial ideas, goals and determination to do business. The opportunity to give local and regional support to newly founded and small enterprises by means of business incubators in Bosnia and Herzegovina is significant because it delivers the key elements for the development of incubators, such as unused spaces in all municipalities, that can be easily transformed into a workspace and adapt to the needs of new entrepreneurs.
Key words: SMEs, Entrepreneurial infrastructure, Business Incubators, Entrepreneurship

INTRODUCTION

The support to the development of small and medium-sized enterprises in the Republic of Srpska had gained in importance in 2002, with the adoption of the Program of Small Business Development, and after that the Law on Stimulating the Development of Small and Medium-sized Companies was adopted. The adopting of the Law has created the basis for legislative, institutional and financial help to this area.

On the basis of the Law, during 2004, there were formed: Department for SMEs and Production Craftsmanship at the Ministry of Economy, Energy and Development of the Republic of Srpska and the Republic Agency for the Development of Small and Medium-sized Enterprises. At the same time, on a local level, local agencies for the development of SMEs were being established. The support to the development of SMEs at a local level is also given by municipal development departments which, together with the above mentioned institutions, make support network for the development of SMEs.

Infrastructure is important for entrepreneurial activities [6] and may have different forms and functions. As first, the development of trade and industrial growth require physical infrastructure, road and railway traffic and transportation etc.

In all developed Western countries and in many developing countries, entrepreneurship and small enterprises as a whole are supported by the state, state institutions and nongovernmental organizations in many ways [7]. Such an orientation of a market-developed countries has deep roots, regarding the fact that the capitalism has tried many development models as opposed to one-dimensional models of economic flows control which have been practiced more-less for decades in the countries of socialist and similar socio-economic systems.

Similarly to the leading countries of the West, many small countries which started with the implementation of market-capitalistic principles in the development of economy three to five decades ago, have reached an enviable level of development today[7] exactly due to the development of small enterprises.

The determinations of Bosnia and Herzegovina [2] related to the SMEs development sector rely on the recommendations of the European Charter and the Act on Small Business. The Law on Ministries and Other Control Bodies of Bosnia and Herzegovina has also defined the institutional framework in the field of issues in the sector of SMEs whose difficulties reflect, above all, in: approaches in defining policies, development strategies and goals in the sector of SMEs, competences, way of work a harmonized monitoring of the results in this area, mutual cooperation and profitability and excessive administration.

At the level of the Republic of Srpska, within the Ministry of Economy, Energy and Development, there is a department for small and medium-sized enterprises, the head of which is an assistant minister with the responsibilities in the work fields: development of entrepreneurship and craftsmanship, making of medium-term and long-term development plans and making of the development strategies of SMEs and entrepreneurial activity.
Pursuant to the (Law on Enterprises of the RS 2006), an enterprise is a legal person which performs the activity to gain profit, and an entrepreneur is a physical person who performs the activity to get profit and the activity of free profession, while an individual agriculturist is not an entrepreneur. The Law does not know the notion of small and medium-sized enterprise, and because of that the same provisions apply to them as to the other enterprises.
The new (Law on Business Companies 2008) is a modern regulation, greatly harmonizes with the directives of the European Union company law and as such should contribute to the creation of a legal framework complementary the internal market of the EU.
The Law on Business Companies of the Republic of Srpska is based on the best solutions of modern national law of the surrounding countries, and also of some countries from Europe and the USA (Illinois), the Statute of the European Company from 2001, OECD Principles of Corporate Governance from 1998 etc. Entrepreneurship, in the sense of the (Law on Development of SMEs of the RS, 2013), is an innovative process of creation and development of business ventures or activities and of creation of business success at market. Entrepreneurial infrastructure presents spatial-technical forms for toe support of entrepreneurship development, with a special emphasis on establishing and development of SMEs.
In recent time [5], there is a greater emphasis in the commercialization of university research, especially through the creation of spin-off enterprises. They emphasize inhomogeneity of the concept of university spin-off enterprises and point out their heterogeneous properties.
The suggestions of [5] for the classification of university spin-off enterprises are: independent spin-off enterprises, connected spin-off enterprises, with joint investment and as organizational units of universities. Three key approaches are used for differentiating the types of university spin-off enterprises: researchers as entrepreneurs of spin-off enterprises, by the nature of knowledge transfer and the participation of external partners in a new company. These different criteria make the phenomena contained by the concept of university spin-off enterprises.

CHARACTERISTICS OF BUSINESS INCUBATORS

In the practice of small business development, the incubator model deserves special attention. It seems to be a practical approach in the countries of traditional support for the development of small business, and it seems that its perspectives also exist in the transition countries. Business incubators present, as stated by [1], a contemporary tool for entrepreneurship development in Europe and the USA, and they appear as a response to the recession era and the failure of industrial systems.
Most business incubators [1] use the existing abandoned infrastructure and brown-field investments for their development. Actually, wherever the surpluses in capacity (empty halls, warehouses, agricultural objects etc.) occur, due to privatization or other reasons, it is possible to use them to develop incubator types of small business. It is, basically, a flexible method for new business development and support for economic development on a confined, local space. Incubators enable many small enterprises to start their work under the same roof with a favorable lease of a functionally prepared space, joint use of infrastructure, services, and specialized types of equipment. Also, they offer equal opportunities for using certain financial, technical and marketing programs. Incubators, located under one roof, enable multiple combinations of business cooperation among the owners of small enterprises, and, on the basis of that, an efficient use of their available resources in a narrow space.
A business incubator (The Law on Development of SMEs 2013) is a form of entrepreneurial infrastructure whose basic activity is to offer services by putting at the disposal, with or without charge, a business premise, consulting, administrative, technical and other services to newly founded businesses, not older than 5 years. Among the participants in the creation of incubators [4] may be: social communities; sponsors (associates); donors (contributors); firms as members or subtenants of incubators; and a service organization to perform common tasks for incubator participants. The social

community (state, municipality) assists in creating the basic infrastructural conditions, especially regarding the provision of a location and respective capacity for incubators, but also in the creation of a local economic basis for the development of entrepreneurship under the roof of incubators. They also create some wider opportunities for gathering modest private capital to their partnership association for the purpose of establishing enterprises.

Starting from this, a very significant question arises: what types of enterprises can or should be potential members or subtenants of incubators? That, above all, depends on a determination of what an incubator should contain, for example, only production activity, crafts-service activity, trading activity or, maybe, the competitive freedom among some of them. What should be especially be taken into account is of how and where to find the locations and buildings for such ventures [4]. With that aim, abandoned smaller factories or particular production facilities should be discussed, as well as abandoned or unused schools, warehouses, storehouses, business premises, communal houses, buildings which were once used by the military etc. The locations of such buildings can be acceptable if they are near established business centers, in the suburbs of big cities, in small cities, bigger industrial and village settlements, tourist locations etc. As appropriate locations and buildings which can be used and revitalized, the ones that are damaged or destroyed to a certain degree can be used as well, if not too large are the financial resources necessary for their revitalization.

In the end, there is no unified concept [7] for, model of or means to develop incubators. There are broad possibilities to establish the contents of work, to design innovative solutions for or opportunities related to urban, suburban or rural position of incubators and the like, and, due to that, the opportunities for specific and untypical types of the business complex. In smaller places, incubators can even be the centers of integrated development of business and employment, and, because of that, every particular case can have individual specifics.

The development of incubators as the instruments of economic policy [2] is especially supported by developed countries, while this cannot be said for countries in transition. The contribution of incubators is reflected by the fact that, when their work well, they significantly decrease the number of enterprise collapses, and they enables enterprises to create new job positions and diversification of production, so that they significantly contribute to the development of the small-business milieu and to local and regional development.

The conveniences and advantages of enterprises that operate in incubators are: use of knowledge and experience of expert and management team of the incubator, as well as the access to knowledge by means of linking into networks on a wider territory; mutual connection of entrepreneurs and opportunities for experience exchange; possibility of additional training and enabling through various programs organized by the incubator; possibility of easier access to financial and investment types of assistance; technical services of incubators; and positive climate and working environment that contribute to inventiveness and innovation of entrepreneurs[2]. Incubator managers and management [4] are among the most important factors for the future success of an incubator because success depends on their ability to manage to connect on the basis of shared interests with the parties seeking work and the success of the incubator (local government, business associations, enterprises), and, through that, contribute to the position and status of the incubator, realizing a quick development of their members, i.e. the enterprises.

Business incubators usually consist of a great number of small business units (usually 10–50 enterprises) [7]. There are usually enterprises with these traits: located in one place, mostly within one building; physically separated by room dividers (it is desirable that there is a possibility of moving the dividers if the enterprises have need to take more space); the building in which the enterprises are located should have, at least, common rooms for the incubator manager, business-consulting services, joint meetings, a refreshment room where the participants can spend time together informally. Also, the facility must be equipped with adequate infrastructure: electricity, water, loading and unloading platforms, a sufficient number of telephone lines, parking space etc. The spaces are offered to entrepreneurs under flexible conditions, with low rents, and simple and favorable lease agreements. The incubator is equipped with integral services for offering business-support services to entrepreneurs on the spot, at low prices or for free. The mentioned services are specially related to training programs through which entrepreneurs can improve their knowledge and skills in specific business areas. There are also the services of business consultants, in the form of advice, business connecting and also the connecting of entrepreneurs with organizations that can provide the capital for the start-up and development of a business.

For the essential nature of the operation and significance of an incubator, the most appropriate definition[2] states that an incubator is an enterprise that operates for various purposes, in various ways, and it helps through various different forms the founding of new enterprises and their development into profitable independent enterprises.

One of the approaches for classification of incubators incorporates the criteria and aims of their founders (i.e. owners), with possible cases [2]:

- incubator is founded as an enterprise that leases the business premises and makes profit, which is the criterion of the ownership approach,
- incubator is founded as an enterprise which, besides inexpensive business premises, supplies professional advice and helps the development of entrepreneurship, thus manifesting the social goal of supporting the development of small and medium-sized enterprises. This type of incubator must also be financially supported, usually during the first 5 years of its existence.

The actual practice [2] shows a larger number of entrepreneurial incubators, such as:

- Traditional or classical business incubators that offer their clients an arranged workspace and expert business advice on the spot.
- Administered organized premises are “naked” business incubators that offer to small enterprises, their tenants, only organized workspaces at affordable prices, not giving business advice. It is assumed that the enterprises have already survived the initial period and that they have already developed. This type of incubator enables renting, but pursuant to market prices, both of bigger premises and of consulting and technical services. Such an approach characterizes the US conception of an entrepreneurial incubator.
- Incubators without walls are organizations that do not offer business premises, but only the organized business-support services.
- Incubators of the new economy are highly specialized in the fields of quick-growing sectors, such as high technology and the Internet. The advantage to the founders is the expected benefit from the quick growth of the value of enterprises in which the owners have their share.

Between the traditional business incubators and the business incubators of the new economy, a great number of different organizations can be placed, dealing more or less with providing support for the development of innovations and entrepreneurship, such as: business and innovation centres (BIC), technology centres, knowledge centres, technology-transfer centres, technology parks, science-technology parks etc.

A traditional or classical business incubator provides the business premises under favourable conditions (with accompanying office, secretary and similar technical services) and also provides business services (training and business advice), which comprises the framework of the concept of so-called traditional or classical business incubators. This type of incubator, usually, usually functions to enhance regional and local economic development (through the development of entrepreneurship and creation of new enterprises) and in the creation of new jobs.

The most important characteristic of the concept and success of this type of incubator is the fact that they offer quality services and business advice individually to every small enterprise. Without this, such business premises would be administered organized workspaces—only similar to incubators. Their emphasis on socioeconomic functions conditions their character, being non-profit almost as a rule, and it means that national and local authorities and the public sector must have a significant role in their founding and operations. Classical business incubators sometimes more emphasise social components, because it is not rare that they are used as the supporting instrument for the development of entrepreneurship of certain social groups, such as women, returnee immigrants, refugees or national minorities.

The Business Innovation Centre (BIC) is the dominant model of business incubator in the European Union. BICs differ from the US incubator model [7] primarily because of the fact that they give greater significance to consulting and developing entrepreneurs’ professional skills, being less targeted at providing premises at lower rents. They are, actually, an improved model of the US business incubator. Thanks to BICs in certain areas, from different sources, by means of various projects and advice to entrepreneurs, local growth and development of services necessary for a success of small and medium-sized enterprises is realised and supported. The concept of business incubators in Europe started to be built in the 1980 s on the basis of the US model, with the aim of alleviating the consequences of breakdown of the large business systems and overcoming the problem of unemployment. It can be said that it demonstrated its justifiability. In the territory of Europe [2], the most famous institution for help and promotion of BICs operates successfully—namely, the EBN (European Business and Innovation Centre Network) which gathers more than 180 BICs. In the realization of its mission, the EBN supports local sources and the development of abilities, securing the unified activity of target groups in the territories similar to regions so that BICs, in their operations, work pursuant to certain standards of the EU. The incubator personnel, both permanently employed and temporarily engaged (Talent Pool), basically provide their clients with twelve main services shown in the following overview[2]: selection of entrepreneurial ideas; selection of entrepreneurial projects; evaluation of entrepreneurial ideas; evaluation of entrepreneurial projects; training and preparation of entrepreneurs; technical services; marketing consulting; preparation of business plans; rental of space; acquisition of space; rental of services; and entrepreneurial advice.

Technological centres offer a highly suitable form of entrepreneurial infrastructure, in which technologically demanding programs are realized on the basis of consulting and a mediatory role. The centres have incubator-like characteristics because they enable the numerous services and cooperative relationships for enterprises. In a technology centre, there are opportunities for: association of entrepreneurs on the basis of interest in various projects and groups; business of a larger number of enterprises in one place with business infrastructure provided; connections to other consulting institutions and networks; access to the bases of patents; and assistance to entrepreneurs on the formalities for obtaining credit or risk capital. Technological centres usually have their own laboratories and special measurement, testing and control equipment. When they reach a certain mass and level of their own equipment, they can easily transform into a technology park.

A knowledge centre is an organization established with the aim of enhancing research in a certain area. The knowledge centres are usually established by public research organizations, faculty institutes and business organizations. They are usually organized as organizational units. A technology-transfer centre is a research-development unit organised as a business association. A technology park unifies, in its structure, the work of technology centres and affirmed medium-sized and big enterprises. There is an emphasis on technology transfer and the cooperation of scientific and research institutions with enterprises.

Technology parks enable the renting of larger areas at market prices for prototype production, and it does not impose time limits on enterprises regarding the use of the space. A technology park (The Law on Development of SMEs 2013) is a form of entrepreneurial infrastructure that, within a defined space and with adequate equipment, performs the connection of scientific and research institutions with business subjects for the purpose of technology transfer, application of innovations and development of the economic area in which it is placed. In the countries in transition[2], due to underdevelopment and the small number of incubators, technology parks work partially as incubators, because the state supervises the space and services, so that the length of stay in a park are limited and only a few enterprises can be accommodated. Technology parks have a significant role in the development of the region because, pursuant to the EU criteria, they are placed in an area where about 300,000 people live, having one or two universities and a few supranational associations [2]. Technology parks are, through joint investments, founded by a country, regions, cities, major enterprises, faculties, banks etc., investing non-refundable assets in the form of land, buildings and money. The members of the management board of a technology park are the most prominent businessmen, representatives of local institutions and representatives of founders and are the basis of further connecting interested parties and securing assistance for the incubator. A technology- park manager is a key person for success, since he/she must be an expert in many business fields and capable of leading a team.

A science park is an institution in which scientifically-oriented people, e.g. researchers, professors, financial experts, consulters and businessmen, are concentrated. At the same time, it is the place that connects science and economy. The basis of the activity of science parks is the application of achievements and innovations in the field of engineering and technology on a commercial basis, and support for the founding and development of enterprises based on knowledge. The most common location of a science park is close to a university, and the founders can vary from a country, municipal and local institutions to banks and chambers of commerce. As stated by [8], universities are the motors of an economy based on knowledge and also the places where knowledge is produced and exploited. They further address the improvement of the concept of entrepreneurial infrastructure as the analytical framework for understanding the organization dynamics of a modern university and insurance of entrepreneurial evolution within higher education. Some research [9] gives useful insights into the planning and performance of technology-transfer activities.

Research shows that the degree of industrial R&D, the quality of faculty and venture capital are significant indicators of the technology-transfer effect. They put the accent on universities as motors of economic development and on increasing their engagement in technology transfer in the field of entrepreneurship. Some research [3] has paid special attention to the characteristics of academic "spin-off policies", where technology transfer and entrepreneurial infrastructure were weak outside high-tech clusters, indicating a significant influence of academic institutions on the potential growth of spin-off policies.

CONCLUSION

Every local community or a set of local communities which are connected geographically, to attract a larger number of enterprises to their territory, the territory of the Region, takes various activities to improve the conditions of work of SMEs. Local community plays a very significant role, while the task of the country, or the government, is to activate the inner resources, as additional development impulses. A prudent activity of local communities with the aim of developing own infrastructure and entrepreneurial potential and attracting of investments can be a concept of regional development. Local community must develop an attractive environment for capital and enterprises. The establishment of business incubators accelerates and simplifies the placement of spatial resources in the function of economic development, investments, growth and employment. Everywhere in the world, business zones present a significant instrument for the stimulation and development of entrepreneurship and general economic growth of a certain area. They are established on the basis of a clearly expressed interest between the businessman and bodies of local and regional government, with the support of higher levels of government and research-educational organizations, universities and institutes.

REFERENCES

[1] Bošnjak S., Business incubators as generators of entrepreneurship development. Practical Management. J Theory Appl Manag 2(2):51–56, 2011.
[2] Cvijić M., Istraživanje uslova i mogućnosti za razvoj preduzetništva u procesu tranzicije. doktorska disertacija. Novi Sad, 2007.
[3] Degroof JJ, Roberts BE., Overcoming weak entrepreneurial infrastructures for academic spin-off ventures, 2004.
[4] Dostić M., Managing small businesses, Sarajevo 2001.
[5] Garmendia B.M., Castellanos R.A., Types of spin-offs in a university context: a classification proposal. Cuadernos de Gestión Vol. 12 - N.º 1. pp. 39-57 ISSN: 1131 – 6837, 2012.
[6] Heger D., at al., The Effect of Broadband Infrastructure on Entrepreneurial Activities: The Case of Germany. Centre for European Economic Research (ZEW). 2011.
[7] Medaković V., Research of conditions for development of small and micro enterprises and development of entrepreneurial infrastructure model. Doctoral thesis. Faculty of Mechanical Engineering. East Sarajevo, 2012,
[8] Nelles J, Vorley T., Constructing an entrepreneurial architecture: an emergent framework for studying the contemporary university beyond the entrepreneurial turn, 2010.
[9] Powersa BJ, McDougall PP., University start-up formation and technology licensing with firms that go public: a resource-based view of academic entrepreneurship, 2005.

POSSIBILITIES OF APPLICATION OF INDUSTRY 4.0 AND CURRENT SITUATION OF FUNCTIONING OF PRODUCTION SYSTEMS IN LARGE ENTERPRISES

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Abstract: From theoretical point of view, authors of this paper analyzed the importance of the application of modern industrial production lines in serial production in the case of large enterprises. Through the work, several aspects that affect the quality, such as productivity, efficiency, effectiveness and other parameters that directly or indirectly affect the quality of finished products are considered.
Key words: Industrial lines, production, large enterprises, quality, productivity, efficiency, effectiveness

INTRODUCTION

Modern enterprise in new conditions, conditions of globalization, turbulence, the global market, numerous rapid and increasingly frequent changes, has been forced to adapt and change, in order to achieve competitiveness and survive in modern business. Companies that want to be successful and to advance in the marketplace must be innovative, flexible, and ready to adopt and apply new knowledge, strategies and technologies. The strategy of constant innovation and the dynamics of change is the response to demands posed by market struggle.
Over the past twenty years, many companies have realized that the demands of the global market, including increasingly demanding and more sensitive customers, set new standards for production flexibility. Additionally, nowadays in very difficult times of the recession and financial crisis, enterprises of all sizes and shapes, from industrial giants, through middle and small, to micro enterprises, face numerous challenges of their own survival. Gradually, mass production, which was inherent in a large number of companies, opened up space for the introduction of a new system whose focus is exclusively on the buyers. In one word, the need to shift from the economies of scale strategy to the strategy of the width of an enterprise's activity is imposed.
According to the [1], system that revolves around the customer is created with the idea that through the process optimization, it enables a cheap product, on time and with the best possible quality. Such a system is just a lean production. By introducing a lean production system, a continuous process of continuous systematic identification and removal of redundant phenomena in the company's operations is established by eliminating everything that represents no value from the buyer's perspective. Thus, in the conditions of crisis, the costs are significantly reduced which enables the achievement of small, but long-term financial benefits, which is the key to achieving a long-term and sustainable competitive advantage. On the other hand, if we neglect the current crisis for a moment in a modern business environment where the life cycle of products drastically reduces, lean production, also known as the world class production, enables companies to respond in an adequate manner, quickly and successfully to various and numerous requirements and users, both in terms of low cost / cost, as well as in terms of quality, time and innovation.

INDUSTRY 4.0 AND THE POSSIBILITY OF ITS THEORETICAL AND PRACTICAL APPLICATIONS

The goal of this philosophy is to enable a company to achieve satisfactory, if not leading, market position in the conditions of growing competition, falling customers' loyalty, constant technological innovations, drastic shortening of the life of products. It is known for its direction to reduce 7 types of losses (7 wastes), and its intention is to increase value in relation to the customer or each of the next in the value chain. For many, this is just a set of tools that help us identify and continually eliminate losses, and consequently improve product quality, reduce production time and reduce costs. There is also an alternative approach to lean production that is changing, Toyota, where it intends to establish a "flow" and a continuous flow of work through the organization of work, which is not based on the elimination of losses. The difference in both approaches is not in the goals, but in the way how to reach them. The advantage of this second approach is that it requires a complete (systemic) approach, while in the first approach we focus only on one narrow part of the problem in the production process [2]. There have been only a few aims to actually calculate readiness factor. Mostly it has been based on the level in the industrial revolutions, but that can really be adequate to decide is the certain company ready or not for the new concept. Figure 1 shows four industrial revolutions.

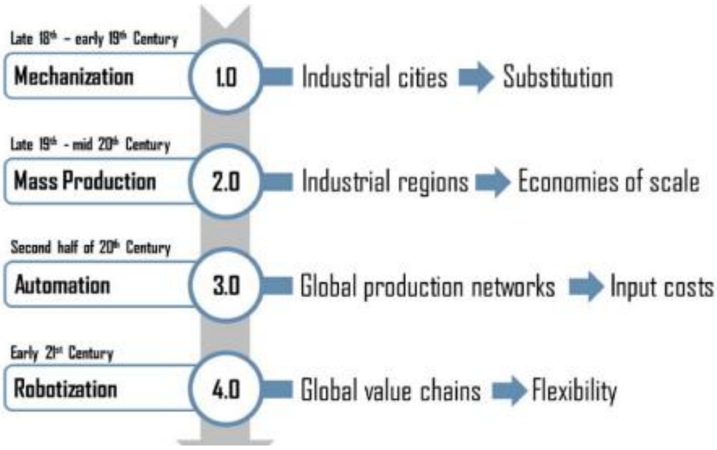

Figure 1. Four industrial revolutions [3]

Through surveys that have been carried out [4], optimization of production and business processes has become the target point for all of the enterprises to strive. Traditional analytical tools used to increase process efficiency and reduce costs have been mostly focused on physical processes that participate in all production stages, while alternative methods of increasing efficiency consider the process as a whole and optimize the integration of each stage of production. The integration of all processes in an enterprise, in itself, has the primary goal of providing such a system that will provide the right information at the right time and in the right place. Today, lean actually represents every effort to achieve greater effects with less investment, exploring value from the customer's perspective, and on the basis of the obtained knowledge, processes are redesigned to increase the value. The socio-technical effects of global competition compel companies to develop and implement new product development strategies, in order to provide the customer with a high-quality product in the short term, with less cost and faster response to customer demand [5].
Observing the differences, traditional or mass production is considered as an outdated paradigm, precisely because there is no direct link between production and demand. On the other hand, lean represents a new paradigm, since the production of different models in small series directly meets the needs of customers, and allows the company to adapt to market changes more easily and quickly. According to [6], the smaller the series, the overall business process is easier and better run. Lean production takes place continuously, from a single-phase flow, emphasizing the optimization and integration of machines, materials, people and objects, which can be defined as a whole. The emergence of a lean production system is not related to the attempt to fully exploit traditional ways of production, but rather to answer the company's ability to survive in a highly demanding, rapidly changing and completely unstable modern market.

Table 1: Basic management principles [7]

	Traditional production	Lean production
Production planning	Forecasting (push)	Buyer order (pull)
Production	Supplies	Buyer order
Time	Long	Short
Size of series	Big	Small (continuous the flow)
Control	Based on samples (inspection)	All effects (on itself source, by workers)
Layout	Functional	In line with the movement product
Training workers	Low	High
Inventory turnover	Low (<7 crafts)	High (> 10 crafts)
Flexibility	Low	High
Purchase value sold goods	High (with tendency growth)	Low (with tendency decay)

If we look at the previous table and take into account all the comparisons between the traditional production systems and the lean system, it can be concluded that the introduction of the Lean concept increases the degree of automation, which in the traditional system is at a very low level, the functions of the system are turning to customers. Observing the presented differences, traditional, or mass-production is considered an outdated paradigm, precisely because there is no direct link between the pace of production and the pace of demand. On the other hand, lean introduces a new paradigm, since the production of different models in small series directly meets the needs of customers and allows the company to adapt more easily and quickly to market changes. Lean production takes place continuously, from single-phase flow, emphasizing the optimization and integration of machines, materials, people and objects [6].

MODERN PRODUCTION SYSTEMS AND THEIR FUNCTIONING IN THE REAL ENVIRONMENT ON THE EXAMPLE OF LARGE ENTERPRISES

Modern companies in the world that deal with large-scale and mass production mainly use line-production systems. The foremost question with such systems is whether the proper quality that is required on the market will be achieved and if it does not achieve what is needed to be improved in order to meet the relevant standards. The world market dictates the conditions that need to be met so the product and the relevant system together with the product can to penetrate the market. New Age demands both time and quality, the ratio of short time and high quality. According to this way of functioning of the market, most of the large companies that contain production are using linear-serial production. From the aspect of linear-serial production, the theoretical claims about the quality for a little time are incomplete, and in this paper the research on the real case of linear series production was carried out. The serial, linear organization of the production process includes drives with specialized plants and devices in which a certain technological process exists in the form of a production process In this organization, production scheduling is conditioned by the existing technology, and the equipment in the process is arranged in the line order given in technological processes for the production of products. The linear-serial form of organization of production is characteristic of the activities such as food industry, dairy, pharmaceutical, textile, leather, automotive, and metallurgy [8].
According to the research carried out at the Novares Serbia factory, which belongs to the companies that produce plastic parts for car bodybuilders in large series, the following results on the quality, productivity and efficiency of line-production have been achieved.
Figure 2 shows the percentage of examined workers in order to create an image of the eloquence of the response.

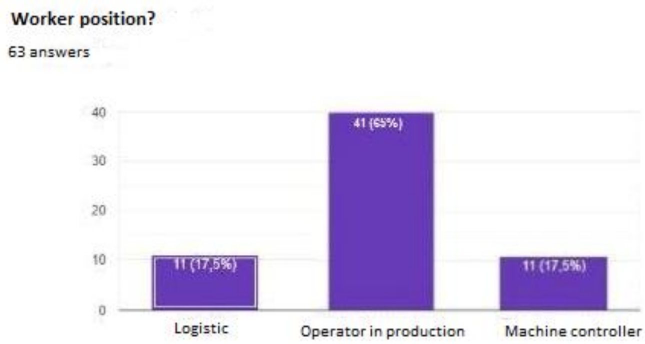

Figure 2. Percentage of examined workers

Figure 3 gives a graphic representation of the productivity of workers on the production line.

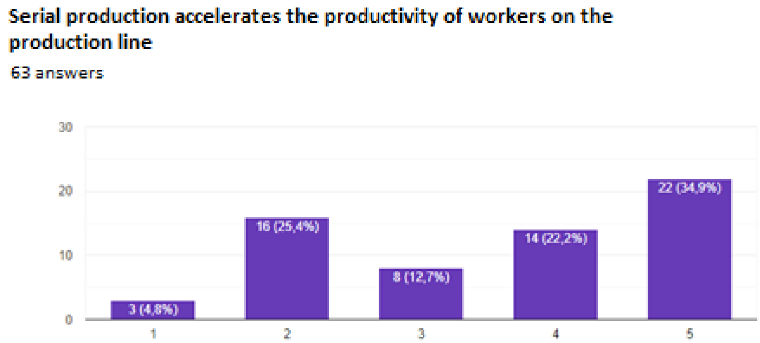

Figure 3. Display of worker productivity on the production line

It can be seen from the graph in Figure 3 that the worker productivity on the production line is mostly produced by serial production, since 63 respondents 23 answered with a score of 5 (34.9%), while 14 responded with 4 (22.2 %), which sums up the majority of opinions on the side of the positive impact of serial production.
In Figure 4 the answer to the question about the relationship of efficiency and effectiveness in this type of production lines is presented.

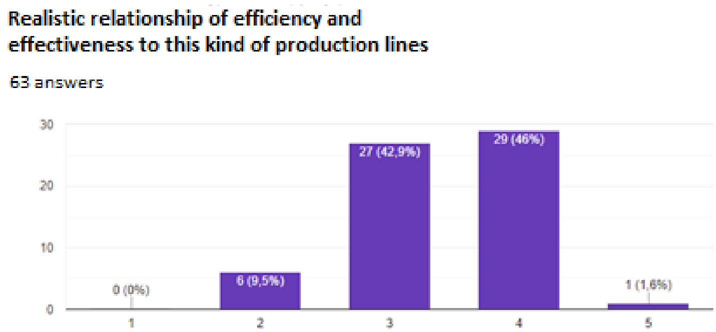

Figure 4. Efficiency and efficiency ratio on line serial production lines

According to Figure 4 and the graphic representation, it can be concluded that the ratio of efficiency and effectiveness to a satisfactory level using this type of production, as 29 respondents gave a high grade of 4 (46%), while a good majority of the majority gave a mean score of 3 (42, 9%).
The graphic representations in the previous figures can be used to answer the fact that linear production by production increases the efficiency of production, where it can be freely stated that according to the given answers this hypothesis can be confirmed, and it is concluded that there is enough space for the ratio of efficiency and effectiveness in this type linear serial production can increase.

Figure 5 gives a graphic representation of the effect of a routine action that requires linear serial production to the very quality of the product that comes out of such production.

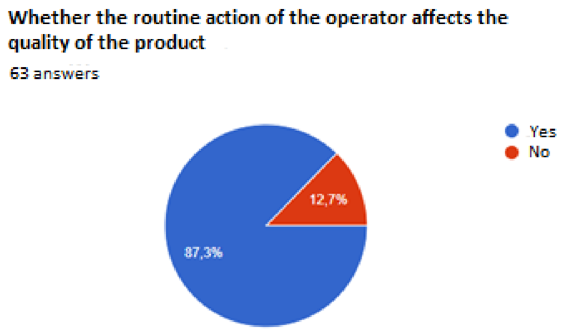

Figure 5. Pie display of the impact of routine on quality

CONCLUSION

Basic knowledge of modern production management, basic theoretical knowledge about Lean concept of production and its influence on production parameters are set out through the work. The Lean concept is a wide system totally implemented in production systems. It takes time, resources, personnel to establish a stable system that is capable of implementing the Lean concept and ultimately applying it to production systems. Until such a type of production is applied in detail, production losses will continue to occur, as in most large production companies we have the presence of line-production, which, as a final result, besides the standardization, has large losses, which are reflected in the decline in quality due to the achievement of the appropriate time frames in which it is necessary to dispose of the product on the market. The stack of combined production systems cannot combine productivity and effectiveness, in order to improve this relationship as already mentioned, it is necessary to first analyze all aspects of the nature of production, and then thoroughly approach the introduction of new methods of production management, modern concepts that strive for the Japanese zero-error philosophy.

With a large number of existing, already established production systems, a very small percentage of the overall time spent and dedication in the business process of waste to activities that really add value to the end consumer (Figure 6). The basic advantage, that is, the basic novelty of the business system, in relation to all other business systems, is the insistence on eliminating all defects and all empty movements, without exception, in the entire business process. It is considered that the tolerance of any kind of disadvantage distorts the overall idea of a successful market operation, because one deficiency leads to the other and as a tower of cards, in a very short time, the market position of the company will be shaken, if not permanently disturbed. This, so called domino effect, in line with the lean concept of business, can be noticed by observing four categories of waste:

- primary category, excessive, unnecessary amount of production resources (labor, equipment, facilities), leads to the creation;
- secondary categories (in the opinion of many authors of the worst categories of waste), hyper production, which, then, leads to the emergence;
- tertiary categories, excessive stocks (additional workplaces obscure the problem of hyper production and increase the losses included in the opportunity costs), leads to the creation;
- quaternary categories, unnecessary capital investment.

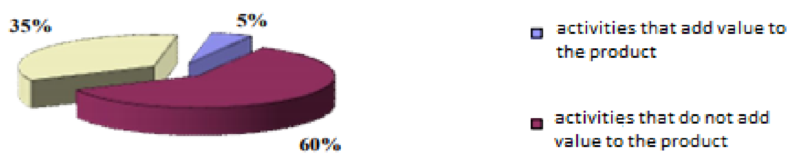

Figure 6. Framework structure of traditional activities of production system [7]

REFERENCES

[1] Stanisavljev, S., Razvoj Stohastičkog Modela Optimizacije Vremena Trajanja Ciklusa Proizvodnje u Malim i Srednjim Preduzećima, Fakultet Tehničkih Nauka, Novi Sad, 2018.
[2] Piškor, M., Kondić, V., Lean Production kao Jedan od Načina Povećanja Konkurentnosti Hrvatskih Poduzeća na Globalnom Tržištu, pp.37-41., Tehnički glasnik, 2010.
[3] Trstenjak, M., Cosic, P., Industry 4.0 readiness factor calculation- problem structuring. International Conference Management of Technology- Step to Sustainable Production, Croatian Association for PLM, Dubrovnik, 2017.
[4] Kendall, K., Mangin, C., Ortiz, E., Discrete Event Simulation and Cost Analysis for Manufacturing Optimisation of an Automotive LCM Component, Composites Part A: Applied Science and Manufacturing, pp.711-720., 1998.
[5] Wasim, A., Shehab, E., Abdalla, H., Al-Ashaab, A., Sulowski, R., Alam, R., An Innovative Cost Modelling System to Support Lean Product and Process Development, The International Journal of Advanced Manufacturing Technology, pp. 165-181, 2013.
[6] El-Homsi, A., Slutsky, J., Corporate Sigma: Optimizing the Health of Your Company with Systems Thinking, Taylor & Francis Group, New York, 2010.
[7] Tanasić, L., Lean Proizvodnja - Inovacija Za 21. Vijek. Zbornik Radova Ekonomskog Fakulteta u Istočnom Sarajevu, pp. 307-322, 2012.
[8] Radojčić, M., Uvod u menadžment, Tehnički fakultet, Čačak, 2010.

THE ROLE OF LEAN PRODUCTION IN ORGANIZATIONS

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Abstract: Strong competition and constant changes in demanding markets require companies to constantly change and improve the organization's operations. This concept requires constant change and continuous improvement. Lean concept has long been a competitive advantage. The concept of lean production aims to reduce the number of product errors and reduce the size of the warehouse, without reducing productivity. This paper presents the criteria for successful implementation and use of the concept, lean production in different areas of the organization. This paper presents a process approach to production management, and provides basic implementation of Lean in manufacturing organizations.
Key words: Lean production, organization, implementation

INTRODUCTION

Today, in the corporate business world, the term lean is used to refer to a modern, successful business philosophy, ie. producing world-class characteristic of the modern era of business. The benefits of implementing Lean can be broken down into three broad categories: operational, administrative, and strategic improvements [12].
Lean management represents a set of production management procedures designed for the customer to improve quality and reduce costs and production time [13]. Lean concept has long been presented as a competitive advantage. The concept of Lean manufacturing aims to reduce the number of defects of the product and reducing the size of the warehouse, without reducing productivity. This concept represents the criteria for successful implementation of lean manufacturing in different areas of the organization. To be successful, Lean implementation for competitive advantage requires organization's to apply Lean principles in all organizational functions, including accounting, sales and marketing, and human resources [7]. Lean production is a concept that tends towards reduction of defect products; waste reduction; higher value for customers; higher satisfaction of customers; robust production; cost reduction; quality improvement; and higher productivity [11]. Toyota Motor Company's high productivity and quality performance is routinely attributed to practices associated with Lean production [10].

LEAN PRODUCTION

The concept Lean production

Lean production is characterized by precisely defined during productions that significantly reduce unexpected situations and events that typically occur in conventional production. The point of Lean production is not only in the competitive implementation of Lean methods and tools, but in a comprehensive change in employee awareness. Employees work in an environment that enhances their confidence and enables them to work stress-free.
In fact, the Lean philosophy is the Toyota Production System - TPS, which was created in the early 50s of the last century and continued to develop until today. It was not until the early 90s of the last century, American experts have realized the superiority of Japanese cars in terms of build quality. To Lean had full effect it is necessary to adapt the entire company philosophy of continuous improvement of production processes and eliminating unnecessary costs. It is necessary that everyone from top management to the workers in the plant know the essence of Lean and is committed to its

implementation. Then he speaks of Lean enterprise, and not just on the production of the elements of Lean [8].
The name Lean is used because at the end of the implementation of this approach to the entire process [5]:

- Uses less material,
- Requires less investment,
- Uses less equipment,
- It takes up less space and
- Requires less manpower.
-

The differences between companies using the Lean concept and traditional companies can best be seen in the table below.

Table 1. The difference between a traditional and a Lean organization [8]

Traditional organization	**Lean production**
Complex	Simple
Budget-driven	Driven by demand
Excessive supplies	Need-driven inventories
Accelerating value-adding activities	Reduction of activities that do not add value
Mass production	Production in small batches
Long time from order to delivery	Minimum time from order to delivery
Quality based on inspection	Quality built into the design
Function services	Process Service

Lean has become a widely recognized philosophy that aims to reduce waste and non-value activities to improve performance in cost-efficiency, conformance quality, productivity, and reduced inventory levels and throughput times [3]. Lean production, evolved from the Toyota Production System (TPS) over a period of several decades, is considered to improve firm performance through elimination of waste. Lean production can be described at different levels of abstraction: it can be defined as a philosophy, as a set of principles and as bundles of practices [10].
Lean aims to reduce human effort, stocks, and delivery time and production space to meet the demands of the market while delivering high-quality products at the lowest price. The gains from implementing Lean can be seen in the productivity results reach [4]. Lean concept implementation has considerable significance for effective and efficient production whose aim is less resources usage and lower production costs. Using both practical and project-based perspectives, a key strategy is the elimination of waste [6].
The critical success factors of Lean production include leadership; finances; organizational culture; and employee skills [1]. The organization should have a strong and competent leader who has the power to improve knowledge and skills of employees. Organizations that have failed to develop a certain level of leadership may be confronted with small process flexibility, risks of possible failure, irregular and inefficient allocation of resources. As one of the most important factors of Lean production, finance is the basis of stable business development [11].
The role of organizational culture is to create support for business processes, as an imperative for further creation of a sustainable and proactive company. Organizational culture has a role to create a strong and powerful management approach, in a dynamic and diverse business environment, with an overarching view of goals and accepting change. Knowledge and skills of employees represent an important role in business development and implementation of Lean production. Employees without

adequate knowledge and skills have a more difficult time to accept new technologies, innovation, and overall development [2]. Lean management implementation can provide product differentiation and help the enterprise to operate with less risk in the selected market [13].

Principles and implementation of Lean production concept

The Basics of the Lean Production Concept consists of five concepts, which, together with Toyota's seven-waste production system, provide a framework for managing Lean-based products.

1. Understand what the customer wants to buy and provide full service and satisfied customer. This principle emphasizes the importance of producing a product which will be valued by the customer and for which the customer is willing to pay. This principle also explains the importance of removing the waste from the processes. Waste is considered as any activity in production system which stops or extends the process of transforming material/information into money.
2. Define the flow of material and all activities from ordering to delivering a finished good to the customer. After defining what and how to produce, it is necessary to analyze all flows (from supplier to the customer) in order to identify and eliminate waste from the process.
3. Enable flow of the product. It means the flow which will provide delivery of the product without delays, waiting or any other disturbances.
4. Adjust the production to the level of demand. When it is not possible to completely define material flows (Because of the number of customers, technology, etc.) It is necessary to stop the production properly in order to readjust the customer's order. In that way, it is possible to accomplish all customer's demands and needs in every stage of production process.
5. Strive for perfection in every aspect of business and in relationship with customers and suppliers. This principle emphasizes the importance of team work in the company. Teams have to be formed at all levels of the company with the goal to solve problems on a daily basis [14].

The benefits of implementing Lean can be broken down into three broad categories: operational, administrative, and strategic Improvements. Some of Lean’s benefits, operational improvements:

- Lead Time (Cycle Time) reduced by 90%
- Productivity increased by 50%
- Work-In-Process Inventory reduced by 80%
- Quality improved by 80%
- Space Utilization reduced by 75% [12].

How could the whole Lean manufacturing concept could be implemented there are a number of methods and techniques must be implemented within the organization. The basic principle is a continuous flow and the system of extraction must be fully satisfied, while the rest are acquired through nurturing Lean productive philosophy in the organization, all focused on the continuous improvement of product quality. Lean is a bottom up approach where management plays a supportive and facilitating role in engaging shop-floor workers to form cross-functional self-directed work teams and apply Lean tools [9].

CONCLUSION

Lean production concept focuses on reducing production, warehouse and higher productivity [9]. Lean Production is an integrated set of activities designed to achieve high-volume production using minimal inventories. Lean thinking is applicable to all business processes within the process industries. The challenge, if people decide they want to be lean, is whether they know enough about their ways of working, what customers of the business processes truly value, and how their businesses operate and need to operate [12].

By the implementation of Lean manufacturing, domestic companies would greatly increase the efficiency and productivity which would certainly contribute to their improved competitiveness in the international market. Also, by the implementation of Lean production, the company would be more profitable and would secure the placement of products and services in the market of great competition. Lean manufacturing is very closely related to Total Quality Management and derives from the Toyota production model. It involves a reconceptualization of the entire production process as a closely interconnected system from which buffers are removed. Complete implementation of the lean manufacturing system involves considerable organizational change [12].

REFERENCES

[1] Ab Wahid, R., & Corner, J., (2009). Critical success factors and problems in ISO 9000 maintenance. *International Journal of Quality & Reliability Management, 26*(9), 881-893.

[2] Achanga, P., Shehab, E., Roy, R., & Nelder, G., (2006). Critical success factors for lean implementation within SMEs. *Journal of Manufacturing Technology Management, 17*(4), 460-471.

[3] Deflorin, P., & Scherrer-Rathje, M. (2012). Challenges in the transformation to lean production from different manufacturing-process choices: a path-dependent perspective. *International Journal of Production Research, 50*(14), 3956-3973.

[4] Drohomeretski, E., Gouvea da Costa, S. E., Pinheiro de Lima, E., & Garbuio, P. A. D. R. (2014). Lean, Six Sigma and Lean Six Sigma: an analysis based on operations strategy. *International Journal of Production Research, 52*(3), 804-824.

[5] Mačižić, I., & Đapan, M. (2016). *Lean koncept u upravljanju proizvodnjom*, Fakultet inženjerskih nauka, Kragujevac.

[6] Pettersen, J. (2009). Defining lean production: some conceptual and practical issues. *The TQM Journal, 21*(2), 127-142.

[7] Pakdil, F., & Leonard, K. M. (2014). Criteria for a lean organisation: development of a lean assessment tool. *International Journal of Production Research, 52*(15), 4587-4607.

[8] Rajković, V. (2012). *Lean Six Sigma concept* Festival kvaliteta 2012. 39. Nacionalna konferencija o kvalitetu.

[9] Petrović, N., Ivin, D., Sajfert, D., & Mjedenjak, M. (2018). Implementation of Six Sigma and Lean production concepts in organizations: a review of concepts, *7th International Symposium on Industrual Engineering (SIE),* Belgrade.

[10] Shah, R., Chandrasekaran, A., & Linderman, K. (2008). In pursuit of implementation patterns: the context of Lean and Six Sigma. *International Journal of Production Research, 46*(23), 6679-6699.

[11] Shah, R., & Ward, P. T. (2007). Defining and developing measures of lean production. *Journal of operations management, 25*(4), 785-805.

[12] Stanisavljev, S., Kavalić, M., Radosav, D., Markoski, B., & Zec, S., (2017). *Lean concept and production management enterprises in Serbia,* VII International Symposium Engineering Management and Competitiveness, 95-100, Zrenjanin, Serbia

[13] Vorkapić, M., Radovanović, F., Ćoćkalo, D., & Đorđević, D. (2017). Applicability of the lean concept to the management of small-scale manufacturing enterprises in Serbia. *Tehnički vjesnik, 24*(6), 1929-1934.

[14] Štefanić, N., Gjeldim, N., & Mikac, T. (2010). *Lean concept application in production business*, Tehnički vjesnik, 17, 3, 353-356.

ANALYSIS OF THE EXPERIENCE OF THE SERVICE PROVIDERS AND USERS IN THE SUPPLY CHAINS

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Abstract: The digitalization of the process of the supply chain (hereinafter S.C.), with the application of the new information technologies, from creating an idea about a product or a service, engineering, production organizing, finances, the development of the visibility process on the net 'end-to-end', the process control to the providing of the complete logistic services in the S.C., present a considerable support to the concept Industry 4.0, which is a present trend in data exchange in intralogistic processes and S.C. In this paper, the state and the problems in the S.C. business, the experiences of the foreign and domestic users and service providers have been a subject of research, as well as the directions of the further development of the S.C. from the managing aspect. The research results have been used in which a number of economic societies (companies) were tested on various bases and they state various problems, from the lack of equipment, visibility, lack of resources, insufficient application of the new information technologies etc. The importance of experiences gained through the S.C. will define the further development directions of the S.C. business entities.
Key words: S.C, experience, information technologies.

INTRODUCTION

Managing the supply chain is a very complex process because it consists of: entire nets of different users (buyers, suppliers, users, producers, transporters...), finances, IT, object management, portfolio management, product design, sales, quality insurance etc. The terms *Supply Chain (SC)*, *Logistics Supply Chain* (LSC) and *Supply Chain Management (SCM)*, are connected with the industrial production and consumption. As for the SCM definition, no definition has been recognized as complete which, among other things, can be related to a greater number of scientific disciplines which have adopted this theme for studying from different aspects of research. Besides the volume of the tasks and the activities which can be included by the term SCM, one spatial and organizational restriction of the term makes sense, especially from the aspect of the problem emerging by the processes which differ from one another, both inside the companies and among them. SCM includes the whole chain of creating the values, from the source of the material to the deliverer, trade (wholesale and retail) to the end user, i.e. the buyer.

Table 1. The possible effects of SCM application [1]

Profit gained	Rate of improvement
Accuracy increase when planning	25 % - 80 %
Supplies reduction	25 % - 60 %
Reducing of the realisation time	30 % - 50 %
Reduction of the SC costs	25 % - 50 %
Delivery accuracy increase	16 % - 28 %
Productivity increase	10 % - 60 %
The capacity utilization increase	10 % - 20 %

In (8), the differences between logistics and L.S., Value Chain, Marketing Channel and SCM are clearly defined and the directions of further development are given. The complexity of S.C. itself requires a detailed study of their processes (sub-processes), their characteristics realization phases, the state of information technologies and equipment, etc. The identification of the problematic spots inside the chain presents the first phase in the chain business improvement. The entire philosophy of managing S.C. lies in greater flexibility, cost reduction in the process of creating new values, quality service improvement, reducing the time of the S.C. realisation, in greater reliability and risk reduction in the delivery realisation. In the S.C. application, because there is no unique concept, the effects cannot always be easily quantified. In table 1, the examples of effects realised by the application of SCM concept are given and they were presented in a study performed in Germany. The results of the listed research point out that the SCM concept application in the ralisation of the logistic planning accomplish considerable effects.

THE RESEARCH OF THE BUSINESS OPERATIONS DEFICIENCES IN SUPPLY CHAINS

Great changes in the company business generate new demands, the fulfillment of which represent an important hypothesis for maintaining and increasing the competitive market capacities. The generator of these changes are the new political strategies of big countries (BRIKS) on a worldwide scale and the powerful development of the new technical acheivements, above all in the information and communication technologies area. These changes represent very high recquirements in S.C. for the business subjects , i.e. small and medium companies which perform the product delivery. Changes in the work process, techology and organisation are demanded, as well as the new communication ways, postponed payment deadlines etc. Factories tend to improve the S.C. efficiency, gain greater costs' control, increase the visibility in all the processes along the S.C., increase the compatibility of the business processes from the beginning to the end and provide the appropriate information at the right time for the more efficient managing.

Figure 1. The greatest interferences in achieving the S.C. goals [4]

According to [4], the research was conducted via Internet by the Peerless Research Group, via the subscribers of the *Supply Chain Management Review (SCMR) and Logistics Management (LM)* magazine, for the needs of a big world company Kewill, 210 top experts were interviewed in the matters of evaluation and purchase of the S.C., performance platforms, the applications and logistic outsourcing services for their company and its users. When asked what they would improve in the organization of their S.C.s, according to the importance, 67% of them chose the S.C. efficiency improvement, 63% would introduce a greater cost control, 61% would perform a better supplies' optimization and the reduction of supplies, 58% would work on the optimization of the transport-logistic activities (ways of transport, routes, masses), 56% of them would pay more attention to customers' contentment, 47% would dedicate to supplying processes management and to relations with the suppliers, 46% point to the necessity of waste reduction, 44% are for the higher quality of risk management and planning, 32% of them are for a better cooperation with the users and a better data exchange, 32% point out that a more complete tracking and managing of the deliveries is necessary and 28% are for the TQM before the delivery. In the following research, the interferences in achieving the goals of the S.C. are being identified, as well as the lack of full-scale visibility of S.C. in real time, the synchronization of processes, the inability of obtaining the up-to-date and accurate data, the ill-timed responses from the suppliers, as well as the lacks of the integration and correct managing of business processes, which made it impossible to fulfill the set goals in S.C., figure 1. All others detail are given in paper [4].

EXPERIENCES OF THE SERVICE PROVIDERS AND USERS IN SUPPLY CHAINS

Research about experiences in S.C. was performed by the Peerless Research Group, via the Internet and the subscribers of the Logistics Management (LM) magazine, for the needs of the American company Ryder which helps companies in North America, Britain and Asia in transforming their S.C.s. 366 top managers were interviewed from the aspect of their experience in managing the risks, new products development, net optimization, supply reduction, adjusting the products to the end-users, business costs reduction etc. According to their experience, such solutions are required which would better predict the buyers' demands, the tracking of their demands for production, supplies and distribution, the increase of operative efficiency, elimination of mistakes concerning the supplies and the waste, a faster turn of supplies, perfect planning and the synchronization of capacities. According to [3], even 51% companies would like to reduce the delivery deadlines, 50% to reduce the costs of keeping the supplies, 43% to demand a better optimization of supplies, 42% to improve the total efficiency of S.C. Also 35% would like to own a more flexible S.C., 35% a better and complete focus on the end customers (buyers), 29% would like to increase the profit growth under the influence of S.C., 23% want shorter producticon ycles, 12% a greater possibility for product adjustment and 12% shorter procedures of closing the deals.

Supplies present an important problem because only 7% of companies have a complete control of their supplies, 27% a very good, 39% good, 24% exposed on stock and 3% don't control the supplies. More than a third, 33% (7%+27%) of the subjects claim that their S.C.is very efficient from the aspect of supplies' control, 39% consider themselves as average and 27% (24%+3%) think they are less efficient in their S.C.

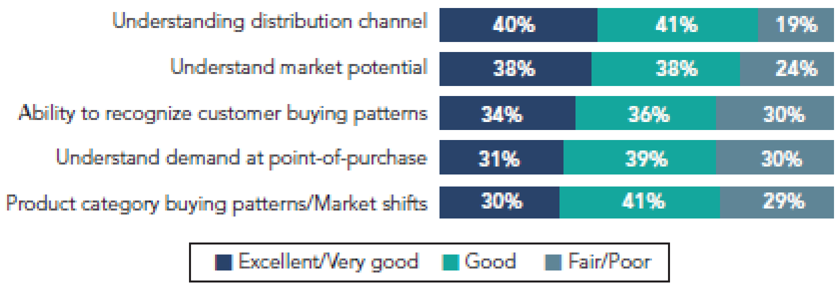

Figure 2. The ability of S.C. to meet the users' demands [3]

The experiences of producers and movers differ in their assessment of their S.C. capabilities when estimating the needs of their end users. More than a third of the subjects estimated their S.C. as excellent or very good. They also claimed that S.C.s have both good and bad characteristics to recognize the habits of the buyers, that the demand on the location of end users can be estimated and that the buying trends according to the product category can be predicted, figure 2. The question of the management was rated as the most important one because it is necessary to provide more timely warnings about the changes in managing which can later affect the business (60%). Besides, an integration in business with the total S.C. is needed, their better planning and logistic performance (47%), the cooperation inside the companies and with partners in trade (44%) and the ability to predict the influence of marketing promotions or irregular activities (42%). Only 18% of the subjects claim that they have excellent experiences in managing the requests of the end users.

Describing what they refer to as the ideal S.C., service providers, with the improved supply management, point out the importance of the distribution realization process, the promotion of the procedures, a better integration of all the systems and platforms, a higher level of automatization and the increased visibility from the producers to the end-users. The adjustment of products to the buyers' demands was marked as a very important function and an especially significant one. More than a half of the subjects, 54%, got the requests for the change of the products' characteristics, both concerning the packaging and the quality of the products and the emballage, before they are sent to distributors or the end-users, and almost always 6%, often 19% and sometimes 29%. Out of the remaining 46%, 33% of them didn’t often get such requests and 13% never received the requests for the product change.

EXPERIENCES OF DOMESTIC SERVICE PROVIDERS AND USERS IN THE SUPPLY CHAINS

In the Republic of Serbia (RS), supply chains have been a subject of attention of the economy, various researchers, universities, different institutes, associations and other institutions for a long period of time, in the sense of their analysis, optimization, improvement etc. The aspects of observation are different, from the business economy, marketing, transport, storage to the perfecting and the organisation of S.C.

In the last few years, the domestic economy also started to deal actively with S.C. from almost all aspects and activities. In 2016, The Serbian Association of Supply Chain Professionals (SUPLS) was founded in Novi Sad, with a great number of members (Carlsberg, Knjaz Miloš, Delhaize, E2E, Milšped, Nektar, British American Tobacco, Hemofarm, Tarkett, IBM, Ball Packaging, Viktoria Oil, Norma Group, Roaming Networks, Veletabak, CHEP....). This association has as its basic goals: connecting all the expert members for the purpose of exchange and improvement of knowledge and skills, of strengthening the integrity and importance of the profession of S.C. in the development of the economy and business organisations in RS. It also collects and processes scientific and professional literature in the S.C. area, organizes expert meetings, counselling, seminars, workshops and other forms of education, publishes articles, analyses and other writings in the area of management and S.C., electronically or in the form of paper builtins (newsletter and white paper), via web sites and magazines, [10]. The Association has cooperated with Ministries, Inspectorates and other institutions and organizations having an influence on S.C.

That's how the association organized II Regional Forum in December 2018, where, among other things, a survey was organized among the members of the Association and other participants, from the aspect of management S.C. The interviewers' questions were categorical and mostly directed to needs and the development of human resources, need for skills, working in S.C., etc. When asked: “How do you evaluate the general economic ambiance in Serbia in the S.C. domain”, 2.7% of them declared that it was very favourable with a clear perspective for the immediate future, 25.2% that there were certain positive marks and the reason for being optimistic in the years to come, 54% that, although there were some positive signals, there was a great uncertainty and 18% that it would take a lot more time and hard work to have reasons for being optimistic. When asked “How do you grade the level of understanding of the integral approach to the value chain management and S.C. in Serbia”, 0.9% of them declared that the level of understanding was very high at all levels of the state, companies, educational institutions and individuals, 34% that in some parts of the society the state is better than in the others, 50.9% said they were not pleased with the current level of understanding, 14% said that the level of understanding was very low. When asked, ”What is the job offer like in the area of S.C. management in the labour market in Serbia”, the responses were: very good various jobs were available 3.3%, it’s getting better the existing companies understand the importance of S.C. better, and new companies bring new opportunities 60%, “the cards” are dealt and that’s mostly it 15%, not good enough to motivate young people to direct their career towards S.C. 21.7%. When asked, “What is the offer of the expert staff in the market, trained for quality management of the S.C. like”, the results are: very good 2.4%, satisfactory 28.5%, scarce 60.2% and absolutely insufficient 8.9%. When asked, “Are you ready to change your job and abandon your career in S.C. to create possibilities for promotion”, the results are as follows: I am happy with the perspectives which are provided 11.6%, if an opportunity presented itself, I would be ready to think it over 64.5%, I’m actively thinking about that 14.9%, I would be ready for an immediate change because it believe that in S.C., the possibilities are restricted 9.1%.

When asked, “Are you ready to go abroad for the sake of a better professional career”, the results are: no, my choice is to build my career in Serbia 37.7%; I believe it’s possible that a potential opportunity meets my professional aspirations 31.1%; I’ve already considered the possible options 23%, and I will surely do it 8.2%. When asked, “How do you evaluate the current offer for higher education in Serbia when it comes to educational backgrounds in S.C.”, the results are as follows: the current offer is excellent and an accordance with the real market requirements and the newest trends 3.3%, the chasm

between what the companies need and what the schools offer is rapidly decreasing (proactive staff, innovative programmes, new technologies, a better integration with economy..) 18.7%, the lack of synchronization between the education and the economy is obvious 64.2% and these two worlds are completely separated 13.8%. There were other issues, too. On the basis of the questionnaire results, it can be concluded that the questions asked were clear and unambiguous. All the subjects included in the survey were in the trade and they possessed a certain level of knowledge and skills in S.C. Through the analysis of the responses, it was shown that more than 50% of the subjects found the uncertainties about the S.C. bigger, in spite of the development, that they were not happy with the level of understanding of S.C. , the new possibilities arose in the development of S.C., there was a lack of staff, they would change their job if there was a better opportunity, there was no synchronization between the education and practice in S.C., etc.
In that sense, new researches have recently been performed (August 1-September 1, 2019), by the same association in 16 companies (worldwide companies which have businesses in the Republic of Serbia) with a basic goal to examine the state and the need for the application of the new information technologies in the S.C. business. The results of the research are these, given in Table 2. When asked ”Do you use information technologies in business and in which segments”, all 16 subjects answered affirmatively, that they've been using information technologies in all segments of their business (in sales, production, logistics, acquisition, finances...), linked to the complete business. To the first question, all respondents answered in the affirmative, that they use information technologies in different business processes from sales and procurement, in production, logistics, finance…, stating that their information systems are linked into a single information management system of the company. For question two, about using technology, (multiple answers question), all of them 31% said they used RFID, 69% used 2D Bar code, 56% answers and in the category Linear bar code, and the OCR 38%. For one question that has not to answer. A very significant question was, regarding the use of the same technologies in the supply chains, 56% said yes and 44% no. This issue has shown that the same technologies are used in a number of SCs.

Table 2. Reasearch results

Questions	Answers
Do you use informations technologies and in which processes	Yes: 16 No. 0
Do You in the distribution of your products used some of following technology (you have more solution for selection)	RFID: five , 2D Bar cod 11 Linear Bar cod: nine, OCR: six
Have your partners use the same technology in their business	Yes: nine No: seven
In which business processes use some of these technologies	Distribution, transportation and communication during the same, improvement of planning, procurement planning, automation of internal processes
Which area of your business do you want to improve	distribution, all processes, transportation and communication during the same, improvement of planning, procurement planning, automation of internal processes.
Do you want to monitoring the condition of goods throughout the SC	Yes: 14 No: 2
Do you want to manage the fleet in real time	Yes: 10 No: 6
Do you want to manage other processes in SC and by which	Procurement and distribution
Do you think IIoT, Blockchain and AI can enhance your business processes and which	Yes: 14 No: 2
Do you think there are obstacles to applying new scientific approaches to SC optimization and what are these obstacles	Different answers

When asked, “Do you want to monitoring goods in the entire S.C.”, 88% of them answered “yes”, and 12% answered “no”. About real-time fleet management, 63% said they wanted to, 27% did not. When asked, “Do you want to manage other processes in LS and which ones”, the majority cites the

following processes: procurement and distribution, with tendencies to improve management in most processes that fall within LS. When asked, “Do you think that IIoT, Blockchain and Artificial intelligence (AI) can improve your business processes and which ones”, the majority or 88% says yes, while two or 12% of them the answers are negative. For last question, about application of the new scientific approaches in the optrimization of the S.C. and which are those obstacles”, these very significant answers were received. The majority believes that the infrastructure is insufficiently developed, that the competencies are not synchronized, as well as the resources, priorities, means, that there is a resistance to change, a lack of knowledge and experience. Some subjects stated that it wouldn’t be good but that they believed this would soon be overcome, that the transformation was complex, that the cited technologies were still in its infancy (especially Blockchain and AI) and that we should postpone their application.
They also claim that the level of technical background is insufficient, that the internal capacities aren’t educated enough and that it presents one of the key obstacles for their introduction into the business systems of today. They also state that there is a problem of the non-existence of the quality case studies, that there is no critical mass which will become the main trigger of changes in this segment. They think that the innovations of this type are usually followed by uncertainty, so it is necessary to wait for them to come to life in everyday usage so their integration into the complex processes of the S.C. could be considered. When it comes to the totals. C., a big obstacle is the fact that these kinds of technologies must be accepted not only by individual subjects, but by the other participants in S.C., to be able to give their maximum. Without that, they can become unsustainable in long term and open more possible problems than it was the case with the technologies they dominantly rely on. The research results point out that:

- companies use certain information technologies (software) mainly through book keeping and finance, procurement/sales, production, but not new managing technologies,
- companies want to improve their business by applying new methods of distribution management, stating the possible problems in the application,
- businesses generally mostly use RFID and Bar Code, with certain subvariants to monitor status rather than process management,
- companies do not use certain programmes for the managing and optimization of the distribution of its products, but they see the problems of their application,
- businesses see significant problems in implementing new technologies,
- there aren’t any problems in the introduction of the new technologies in the company itself, but the problems lies with the end users and the distributors of their goods and in connecting them, because more of them using different technologies,
- problem is implementation of new technologies requires the integration of all participants in the SC of the enterprise itself, mainly due to the diversity of information technologies.

This survey has shown, that companies do not use the modern information management technologies, supported by IIoT, AI, blockchain and Cloud, but it has been shown, at the same time, that there is an interest for their application.

TENDENCIES IN THE DEVELOPMENT OF THE SUPPLY CHAINS

The development of the future economies of different engineerings and, therefore, their S.C., should be based the increase of the industrial demand for the new quality of S.C. The organizations which manage to synchronize pre and post sales service activities (including the knowledge about the products, sales facilities adjusted to buyers, maintenance and guarantees of the products and services, listening to the VOC (Voice Of the Customer), VOB (Voice Of the Business), VOP (Voice Of the Process), will have an advantage over their competitors who are only focused on the product and its pure sale. Besides, the future development will demand a constant reduction of the extreme influences in the S.C., especially when it comes to identification, analysis and risk control [6]. This, among other things, implies the precise declaring of the possible negative consequences for the user, on the product label itself, and which can appear when using such a product. This especially applies to cold food. It is necessary to shape the S.C. so that they can be adjusted to broad masses of population of lower affiliation which make the majority of a society in the sense of satisfying their needs, primarily from the aspect of acceptable prices. Several authors had prognoses about the S.C., so that [9] points to six key directions of the future development, them being: visualization of data will reduce the delivery time in S.C., managers in S.C. will be focused on correct deliveries, sustainable experience will be focused on S.C. realization, services in the S.C. will be dominant on the market, there will be certified processes in S.C., the role of social media in S.C. management will increase.

In [5], further development of SC is indicated through several technologies: additive manufacturing (3D printing), simulation application, AI/ML (Machine Learning), emergence of new materials and application of high performance computers (Cloud computing). Based on the acquired knowledge, domestic and foreign literature, it is considered that in the following period, the tendencies for further development of LS will go in the following directions:

- S.C. will become more important than S.C. with the integration of activities before and after the sales service of the product,
- companies will have to track and analyze completely the external influence on its S.C. and the influence of their S.C. on the environment and other segments of the society. In the papers [2], [7], the authors define the key S.C. indicators and the ways of their tracking systematically,
- the micro segmentation strategy of the market and their S.C. will be the key to the success,
- the S.C. must be designed to serve the base (the foundation) of the pyramid which contains a great number of people who have very low yearly income, and products and supply chains which will cover this segment of the market will have to be created since there will be a great potential there,
- the knowledge in the information technologies will be applied more with complex analyses, planning, acquisition, which will lead to the globalization of the information technologies in S.C.,
- MLS (Management LS) should have a standard certificate process similar to the one existing in other activities (Certified public accountants, driving instructors, teachers etc.),
- the production processes should be synchronized with the nature of S.C. and the companies will have as many different S.C.s as the product has expiration dates,
- many information technologies supported by MLS will be “at a grasp”. The example is SaaS (Software as a Service)which will get a lot of attention. The users will pay for this service and they won’t have to cope with considerable maintenance costs of the upgrading of their infrastructure which can even go to 25 % – 30% from owning their own information center,
- the management (the managers) will use social media more in the process of feedback for tracking new products and services, data studying and they will have the access to the information of of different S.C. contents (designing, planning, acquisition, servicing, production etc.),
- AI will certainly be included into the basic activities of the SC, with the algorithmical approach which “learns” and keeps the acquired knowledge and experience. Because of that, the AI of the S.C. has to be included into the more efficient automatization of regular activities in S.C.

Not all the tendencies in the development are equally important for all the companies and branches of the economy, but the companies should decide what their priorities are in the development of new technologies. It is predicted that micro segmentation of the market will be the key to the success. Right behind this one, the fastest development will appear in the globalization of the information experts and the artificial intelligence. Although, the result confirms that, regardless of the fact that a ‘great number of information’ is a useful tool, the possibility of data transfer through S.C. and the possibility of its performance remain a great challenge.

CONCLUSION

So far, the experiences of the most S.C. users have pointed out to the inability of gaining the current and accurate data, to the untimely response from the suppliers, the lacks of integration and correct managing of the business processes. Essentially, it is about the lack of visibility along the entire S.C., whereby there is a demand for the shorter delivery time, lower supply costs, a more flexible S.C. etc. On the basis of the research, it can be concluded that, a globalization of the information technologies in S.C. is necessary for being able to communicate on wider geographical areas, certification of different subjects in all the activities of SCM should be required from the transporters, forwarders, financial experts to the professional S.C. managers. From the aspect of normalizing the delivery time, the offered contents of the activities and certificate issuing. It also implies an on-going professional education and testing of knowledge (should be measured by a certain number of hours per year), to increase the speed of reaction in the market which will condition a certainnumber and nature of the S.C. The time for offering the product and/or services by a catalogue is in the past, which is ‘a receipt for the disaster’. One should think electronically. A detailed knowledge of the micro segmentation of the market (individual or as groups of buyers)and of S.C. to be able to realize successfully their goals from the global business strategy. In other words, to adopt B2C (Business to Consumer) way of thinking even though the activities are more oriented towards B2B (Business to Business). The application of a new technology which will support S.C. and be ‘at hand’ is necessary, **s**ome information technologies have already been used in S.C., and some models will be used in different applications with very low costs (Office & Messaging software, DBMS software, Management software, CRM, MIS, ERP, HRM etc.), which especially refers to SaaS (Software as a Service), which is becoming more and more important. The management (managers) will use social media more in the process of feedback to gain knowledges about the quality of their products and services , which will enclose a circle from the idea to its realization. New information technologies and especially the AI/ML must be included into the management of the basic activities of the S.C. The S.C. issues are entering the process of digitalization and will present a serious domain for research.

LITERATURE

[1] Becker, T, Geimer, H. (1999). Prozessgestaltung und Lei stungsmessung-wesentliche Bausteine für eine Weltklasse Supply Chain, HDM , Heft 207.
[2] Chandak A. (2019). “ “The Impact of Supply Chain Strategy and Supply Chain Flexibility on the Performance of Small and Medium Enterprises (SME’S) In Indian Automobile Sector”. American Based research Journal, Vol. 7, Issues 9, ISSN 2304-7151
[3] Demand Management: Customize Products through the Use of Product Completion Centers (2013). Ryder Supply Chain Solutions. Miami. USA.
[4] Improving Supply Chain Efficiency Through Convergence, Collaboration, and Visibility (2014). Kewill, Inc. Chelmsford. USA.
[5] Maletić, J., Radičević, V. (2018). “Neki aspekti automatizacije lanca snabdevanja”. FBIM transactions, No. 6(1), p.p. 46-58. doi:10.12709/fbim.06.06.01.05. Meste NVO. Beograd.
[6] Maslarić M. (2014).“Razvoj modela upravljanja logističkim rizicima u lancima snabdevanja”. Doktorska disertacija. Unverzitet u Novom Sadu. Fakultet tehničkih nauka, Novi Sad.
[7] Mogaka C., Odari S. “Role of Supply chain operations reference metrics on performance of small and medium enterpriecs in Kenia: A case of Issiya feeds limited”. International Journal of Social Science and Information technology. ISSN 2413-0294. Vol IV, Issues II. 2018.
[8] Parkhi S. et all (2015). “A study of Evolution and Future of Supply Chain Management”. AIMS International, Vol.9, Number 2, p.p.95-106.
[9] Robinson A. (2018). “The 6 Top Supply Chain Trends to Make Supply Chain Managers the Hero of Their Company”. Cerasis. Dalas. USA.
[10] Statut, Srpsko udruženje profesionala u lancu snabdevanja. N.Sad. 2016.

SESSION 6. HEALTH AND ENVIRONMENTAL PROTECTION

ENVIRONMENTAL PROTECTION THROUGH COMPOSTING PROCESSES

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Abstract: Composting of organic waste as a secondary material resource is an exoteric process in which the organic substrate is subjected to anaerobic and aerobic biodegradation under the action of the natural community of microorganisms as well as specialized microorganisms - EM technology, in conditions of increased temperature and humidity. The latest achievements in composting organic waste are based on the application of effective microorganisms - EM technology that accelerates the composting process, preventing the appearance of unpleasant odors, suppressing pathogenic bacteria while simultaneously increasing the utilization value of the compost obtained.
Key words: composting, specialized microorganisms, environmental protection

INTRODUCTION

Compost is a product produced by the composting of plant and animal remains in somewhat controlled, usually aerobic conditions. Almost all herbal remnants (grasses, leaves, branches, fruits and vegetables, etc.) can be composted, and some residues of animal origin (fertilizers, meat residues, etc.). As a compost product, useful material is obtained, similar to humus, which does not have an unpleasant smell and which can be used as a soil conditioning agent or as a fertilizer.
A large amount of biodegradable waste is collected in the process of maintaining green areas in the city. Waste is collected in public urban and suburban areas in the city of Čačak, and these jobs are performed by the employees of “JKP Gradsko zelenilo” from Čačak. Mechanical harvesting of leaves is carried out by a towing vacuum cleaner with a volume of 10 cubic meters. The type of biodegradable material varies throughout the year, such as leaf, mowed grass, weeds, pruned sheep, pruned sheets and sawdust. The first selection and separation of biodegradable waste is carried out by field workers at the source of raw materials production. After the manual loading, the raw material is delivered to the compost area where it is recorded and weighted, since the company does not have a wheel scale. The raw material that does not need to be crushed is deposited in passive piles, and it takes at least a year to complete the composting process. The raw material to be picked (shrubs and branches) is crushed using the appropriate crusher, and that raw material can be used for heating or composting. It is necessary to engage the SKIP machine for mixing, overturning and watering the pile. With this process, composting time is about 7 months. If there is less woody material, the process is completed in 4 months. Upon completion of the process of composting the raw material from the total quantity in cubic meters, 40 to 50% of the compost is obtained which should be drying, screening, deposit and packaging of the finished product.
Why compost biodegradable waste?
In natural environments extinct organic matter is converted into humus under the influence of ecological factors. The resulting humus becomes food and habitat for the growth and development of new plants. This process of organic mass circulation takes place continuously. In urban horticultural environments due to the effects of decorative plants, plant residues (pruned herbs, mowed grass) have to be removed from these surfaces. By composting these plant residues, we allow these vegetable residues to return to the same green areas, but in the form of humus. In this way, in the urban conditions, we are trying to ensure the process of circulating organic matter.
The composting process is:

- Allowing green waste
- Mulching green waste
- Mixing and homogenization
- Forming compost piles
- Watering compost piles (humidity should reach about 30% to 40%)

- Constant twisting of compost piles (EM procedure runs in two phases ANAEROBNA (lactic fermentation about 28 days without mixing) and AEROBNA with mixing and air extraction at least twice at 21 days intervals)
- Temperature control
- Control PH values
- Composting of compost
- Chemical analysis of compost
- Packing and delivery

Reasons for composting

Compost in the soil has a favorable effect on improving the water, air and heat regime of the soil. It can be used to improve the quality of degraded soils and as a substrate in the production of various plant species.
It should be kept in mind that large quantities of solid municipal waste are deposited in landfills and affect human health, but also to the quality of the environment. Gases emitted at this occasion are CO_2, CH_4 that contribute to the greenhouse effect.
Also, in agricultural production, large amounts of organic residues are generated. Agricultural organic residues include agricultural biomass residues of one-year plants, straw, corn, shrubs, stems of other plants, shells, fruit-based remnants, as well as unused residual foods from domestic animals. These substances can serve as a good raw material for obtaining quality compost.
There are many reasons why composting of waste is necessary, and they are:

1. Financial-composting saves money:
   - Most of the waste is disposed of at dumps, which is a set of disposal methods. By composting waste, the amount of waste that is sent to the landfill is significantly reduced and thus significantly saving money in the long run.
   - Rich soil additives are produced from waste.
2. Environmental protection- protect the local environment, and thus natural resources:
   - Landfills cause environmental damage. "Buried" waste at the landfill, without the presence of air, produces methane, a significant greenhouse gas, which negatively affects climate change.
   - You will no longer use compost from shops.
3. Healthy plants:
   - The soil structure has been improved, drainage and aeration have been accelerated.
   - In this way, nutrients are returned to the soil, such as nitrogen, phosphorus and trace minerals, which are released slowly over a period of 1-2 years.
   - When straw and fertilizer straw is used, compost preserves water and prevents the formation of weeds.

Locating the composter

When defining a composting site, the following should be considered:

- The ideal place for the composter is to place in a sunny position on the earthen base, to allow free drainage of liquids and the input of compost microorganisms that will speed up the composting process. This segment has been achieved using EM funds.
- It is not good to place the compost near the large trees.
- It should be readily available, in order to be able to manipulate.

Natural organisms are the most important for successful composting, and they only need air, water and organic matter that they mix and release nutrients. In such conditions we have:

- Bacteria and mushrooms recover materials and release heat during decomposition.
- Worms recycle organic material. In the EM composting agent there are microorganisms that are cellulose dehumidifiers, produce sugars, later digestion by digesting the organic matter, and prepare to decompose when aeration is done. At the same time, micro-organisms from EM that azoto-fixers improve C / N ratio and thereby bring it to an optimum level.

Insects allow air intake and mix substance.

COMPOSTING METHODOLOGY WITH EM NATURALNIE AKTYWNY

Composting should take place according to the following procedures:

1. Start with a thin layer of animal fertilizer or kitchen waste, to cause worm migration from the soil to start the process. Instead of animal fertilizer or kitchen waste, the product EM Naturalnie Aktywny can be used. The compost obtained by the use of this product is without the presence of pathogenic microorganisms (disease causing agents) as temperatures of over 70 degrees Celsius develop which do not favor the development of pathogenic organisms. Positive microorganisms from EM Naturalnie Aktywny will dominate the pathogen in the compost and thus further disinfect compost.
2. Place the layers of green or brown (grass, leaves, etc.) of the material in the compost (compost). It is useful to add a layer of raw materials, such as twigs, cut flowers and the like. This part is unnecessary for the first phase, in the second it is mixed up anyway.
3. It is always necessary to cover other waste with brown waste. It's always good to leave some brown material reserve, like drops of leaves, to cover.
4. Cover Compost and add water only if necessary. Check that the bundle has enough humidity if it is covered by some thick airy cloth (tarpaulin).
5. Large quantities that are added at once will break down faster than small quantities that are added on multiple occasions. When the bundle reaches a height of 1 m to 1.5 m covered with foil and provide the conditions for ANAEROBE lactic fermentation, after this phase, rotate the pile every two weeks, which is quick-warm composting, or simply pierce several holes in the center of the crowd which is slow-cold composting.
6. Compost is finished when it becomes dark brown or black and smells sweet and on the ground.

Brown matter are dry adsorbents and carbon-rich fibers, organic materials. Brown substances provide the necessary amounts of carbon for the organisms, adsorb moisture and help increase the amount of air in the crowd. Leaves, straw, shavings, wood shavings, napkins, paper towels, eggs.
When the composting pile begins, the material should be added in layers to ensure proper mixing. Organic waste such as leaves, mowed grass and plant parts are first placed at the bottom in a layer of 20 to 25 cm. The rougher materials will be explained more quickly if they are placed in the lowest layer. This layer should be filled with water until it is well moistened. Above this layer, nitrogen-rich material should be placed. It can be 3-5 cm mango or ammonium nitrate, i.e. ammonium sulphate in a 1/3 cup ratio on each 150 cm^2 surface. In the absence of these nitrogenous fertilizers, fertilizer 10: 10: 10 can be used. It is not necessary to use those containing pesticides of any kind. When placing the layers reach the top, the bundle should be covered with a layer of soil or mature compost. The main reason for adding this finishing layer is the inoculation of a bunch of microbes that break down organic material. It is best to add some old compost to the microbial activators of the composting process when composting the compost. Adding the soil of the bundle helps prevent the washing of mineral nutrients, for example, potassium, which is released during the decomposition process. Repeating the alternative addition of layers of organic matter, fertilizer and soil or mature compost should accompany the wettability of each layer until the completion of the pile. If the piles are added only to leaves, there is no need to make layers. If the leaves are dry, it should be moistened. Since there is not enough nitrogen for rapid decomposition in opal foliage, fertilizer with a high nitrogen content (up to 30%) should be added to accelerate decomposition. Approximately 1/2 cup (10%) of nitrogen fertilizer should be added to every 10kg of leaves manually compressed. The C / N ratio determines how long the decomposition process will last. The initial C / N ratio of about 20 or 30: 1 is necessary for quick composting. If the initial ratio is above 50, the process is considered slow.
The application of the microbiological fertilizer EM "Naturalnie aktywni" in the composting process of available agricultural residues will have the effect of accelerating the decomposition of organic matter and improving the physical structure of the compost obtained. Compost obtained from the mix of available agricultural residues using the microbial fertilizer EM "Naturalnie aktywni" will have an effect on improving soil fertility, soil regeneration, efficient humus formation, increasing soil nitrogen

fixation, increasing the ability of soil to retain water in the dry season and increasing plant resistance to disease and pests. Application of compost obtained from available agricultural residues with microbiological fertilizer EM "Naturalnie aktywni" is a prerequisite for the introduction of the parameter "mineral nitrogen content" in the soil fertility control system. As a final result of the application of compost obtained by the technology of effective micro-organisms, it will allow increasing and stabilizing the yield and quality of these crops in agricultural plantations.

Maintenance of compost piles

Since there is no stench in the first stage of lactic fermentation, no ammonia, sulphides and other decomposition products are produced. Therefore, this procedure is INNOVATIVE. The pile should be damp, as this is one of the prerequisites for faster decomposition. Unpleasant odors are created due to the addition of large amounts of moist material or excessive humidity. If the compost material is properly mixed and properly sprinkled with the composting agent, the compost batch will not produce unpleasant smells. Using EM Naturalnie Aktywny we achieve composting without unpleasant smells. The compost pile center, due to microbial activity, reaches a temperature of 70^0 C. If the pile is not warmed enough, it means that there is not enough nitrogen or oxygen, or it is too damp or dry. The pile should be overturned when the central part (when touched) is not so hot. By pushing the crowd, it is exposed to a larger airflow, and in addition, the unloaded part of the material is moved to the central part where the process is heated. It is considered that the composting process is completed when the overturning does not generate heat in the crowd. It is recommended to add fresh composting material when overturning the pile. If there is a lot of waste material, then it is better to make a new pile than to mix with old compost material. According to experience, compost can be obtained within 2 to 4 months if the compost batch is properly treated. This means that the waste particles are ground to 3 to 5 cm thick and that the ambient temperature is high enough. Piles that are made late in autumn will not be composted until next spring because cold weather can nots provide the required temperature of decomposition inside the crowd. Bundles that are not properly accounted for or composed of large materials will require a longer time to be converted into compost (about a year). When the composting process is completed, the compost obtained will be smaller by 1/2 to 1/3 in relation to the original mass at the beginning of the process. The resulting compost has the scent of the earth.

The role of micro-organisms in composting

The most active organisms in the composting process are bacteria, fungi and actinomycetes. These organisms are present in food waste, land, leaves, grass waste. Composting is based on the succession of microbial populations, where the conditions created by one group of microorganisms stimulate the activity of the population of the organism that is inherited.
Different types of microorganisms are active in different stages of composting. Mesophilic microorganisms destroy organic matter and increase the temperature of the compost compound, creating conditions for their own growth and development, but at the same time creating conditions for the development of thermophilic populations. Bacteria are largely the most numerous in the composting bunch and are disintegrating easily accessible compounds (proteins, carbohydrates). Also, nitrogen-fixing bacteria that bind atmospheric nitrogen are present and incorporated into the cellular mass. Mushrooms play an important role in composting, at the stage of composting, as they tolerate conditions with low moisture better than bacteria. Also, some mushrooms have enzymatic systems that participate in the decomposition of lignin and chitin.
Composting is a long-lasting process, but in recent years there has been progress in compost technology by introducing microbial inoculants and thus speeding up and directing the composting process. In addition, the use of selected microbial inoculants makes it possible to obtain a compost of a defined and uniform quality.
Composting is not: meat, fish, tusks, fats, oils, whole eggs, animal waste - pets, etc.

AVAILABLE QUANTITIES FOR COMPOSTING "JKP Gradsko zelenilo Čačak"

In the territory managed by “JKP Gradsko zelenilo Čačak“ while maintaining urban green space as well as roads, they collect wood and agricultural biomass that can be used for compost production. According to the available data from the relevant services of "JKP Gradsko zelenilo Čačak", the available amounts of wood and agricultural biomass are given in Table 1.

Table 1. Quantities available for composting

Type of raw material	**Quantities during the year**
Collected grass mass	Close by 800 m^3 – humidity around 80%
Collected branches	Close by 300 m^3 – humidity around 50%
Waste wood collected (stumps, etc.)	Close by 300 m^3 – humidity around 50%
Other sources of wood and vegetable biomass	Close by 500 m^3 – humidity around 20%
IN TOTAL	Close by 1900 m^3

Based on the conducted research "PUC Gradsko zenelilo" Čačak, it collects wood and plant biomass in the amount of about 1900 m^2 that can be composted.
For the rational use of wood and plant biomass collected by "JKP Gradsko zelenilo" Čačak, the following works were done: COMPOSITION COMPONENT 45mx15mx4m.

CONCLUSION CONSIDERATIONS

Compost can also be used for:

1. Bioremediation and Pollution Prevention
   The new composting technology, known as compost bioremediation, is now used to restore contaminated soil, to control the odor, degradation of fragile organic compounds. In Čačak it is necessary to cover the old dump of Prelići with a layer of humus.
2. Control of diseases of plants and animals
   Composting is used to increase yields for farmers engaged in organic production. Research has shown that compost is used to stop the spread of plant diseases and to combat pests. Compost can help farmers save money, reduce pesticide use, protect natural resources.
3. Erosion control and landscaping
   Compost is used to improve plant growth. Compost enriches soil and reduces erosion and outflow of nutrients from the soil, ensures soil compaction and helps control the disease and pests that endanger plants.
4. Afforestation, restoration of the swamp and revitalization of the habitat
   Compost can be used for afforestation, restoration of wetlands and revitalization of habitats.

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REFERENCES

[1] Srećko Ćurčić: ELABORAT ZA PROJEKAT: "Racionalno održivo korišćenje otpadne biomase u JKP Gradsko zelenilo Čačak", Fakultet tehničkih nauka u Čačku, decembar, 2018.
[2] Radenković G., Radenković R.: Ništa nije nemoguće – Postrojenje za selektiranje, uklanjanje i preradu komunalnog otpada – Postrojenje budućnosti, A-21/02/1, od 28.02.2002. Savezna Republira Jugoslavija. Savezni zavod za statistiku2000: Statistički godišnjak 2000, Beograd, 2000.
[3] Podaci od JKP Gradsko zelenilo Čačak, 2017.
[4] Ivana Ilic-Krstic, Jasmina Radosavljevic, Amelija Đorđević: KOMPOSTIRANJE KAO VID TRETMANA BIORAZGRADIVOG OTPADA, Conference: XVII Naučni skup Čovek i radna sredina - "Upravljanje komunlanim sistemom i zaštita životne sredine, December 2017.
[5] Boldrin, A., JK. Andersen, J. Moller, T.H. Christensen I E. Favoino. 2009. Composting and compost utilization: accounting of greenhouse gases and global warming contributions. Waste Management I Research. 27:800-812.
[6] Boldrin, A., Andersen, J.K., Møller, J., Christensen, T.H., Favoino, E., 2009. Composting and compost utilization: accounting of greenhouse gases and global warming contributions. Waste Manag. Res. 27, 800-812.
[7] Ćurčić, S., Đurić, M., Milunović, S., Mandić, L., 2008. Composting like a modern kind of solid waste treatment in function of environmental safety, Proceeding of 35 National Conference of Quality, Quality Festival 2008 13-15 may 2008, Kragujevac, Serbia. pp. 10-15 [In serbian].

AIRBORNE WEAR PARTICLES FROM AUTOMOTIVE BRAKES AND TYRES FOR PERIOD 2001-2017 IN REPUBLIC SERBIA

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Abstract: The increase of the people mobility has led to vehicles number increasing, which have direct influence on harmful products increasing, which appear during the vehicle exploitation. The wear of tires, brakes, clutches, as well as the wear of the road, is considered as very harmful for the people health and besides that it have the negative influence on the environment. In the areas, where the traffic frequency is very high, and besides that, if those are densely populated areas, the different health problems appear in people. Because, it is necessary to redirect traffic by different detours, in order to avoid the people health problems in densely populated areas. In this paper, it will be shown the total emission of the particles, by sectors for the Republic of Serbia, for the period from 2001 to 2017, as well how much influence has the traffic on particles formation. Besides that it has been given an analysis of vehicles participating in particle emission, in function of the formation source.
Key words: vehicles number, vehicles exploitation, people health, traffic, emission

INTRODUCTION

Particulate Matter (hereinafter PM), is a complex mixture of extremely small particles and liquid droplets. Particle pollution is made up from a number of components, including acids (such as nitrates and sulphates), organic chemicals, metals, and soil or dust particles [1].
The size of particles directly connects with their potential for causing health problems. EPA (United States Environmental Protection Agency) is concerned about particles that are 10 μm in diameter or smaller because those are particles that generally pass through the throat and nose and enters in the lungs. Once inhaled, these particles can affect on the heart and lungs and can cause serious health problems. EPA groups particle pollution in two categories:

- Inhalable coarse particles, such as those found near roadways and dusty industries, range in size from 2.5 μm to 10 μm in diameter.
- Fine particles, such as those found in smoke and haze, are 2.5 μm in diameter and smaller. These particles can be directly emitted from sources such as forest fires, or they can form when gases emitted from power plants, industries and automobiles react in the air.

The emissions in the Republic of Serbia are the most influenced by the age structure of vehicles, then by the vehicle category, which is directly related to the power unit. Therefore, the emission of suspended particles and ammonia was increased in comparison to 2001, while other harmful substances have decreased considerably [2]. If an internal combustion engine is excluded from particle emission analysis, the highest influence have tires and brakes [3].
How further in the paper will be analysed the amount of particles that are generated from brakes and tires, it is very important to observe, which parameters affect on their wear. Wear of brakes depends from [4]:

- Vehicle weight (heavier vehicles with larger brake pads have higher brake wear)
- Traffic conditions (stop-and-go traffic increases brake use and wear)

Influencing parameters that affect on the wear of tires, can be separated into four groups, Table 1.
During the braking process, the brake pads, acts on the braking disc. Braking pads slides on the disc, and during this we have transformation of kinetic energy into the heat. Besides that, it comes to wear on braking pads, where the size of wear particles is in microns, Fig. 1.

Table 1. Influence parameters that affect on wear of tires [5]

Tyre characteristics	**Road surface characteristics**
• Size (radius/width/depth), • Tread depth, • Construction, • Tyre pressure and temperature, • Contact patch area, • Chemical composition, • Accumulated mileage and • Set-up (e.g. Tracking, toe-in and camber)	• Material (bitumen/concrete), • Texture pattern and wavelength, • Porosity, • Condition, • Wetness and • Surface dressing
Vehicle characteristics	**Vehicle operation**
• Weight, • Distribution of load, • Location of driving wheels, • Engine power, • Electronic braking systems, • Suspension type and state of maintenance	• Speed, • Linear acceleration, • Radial acceleration, • Frequency and extend of braking and cornering

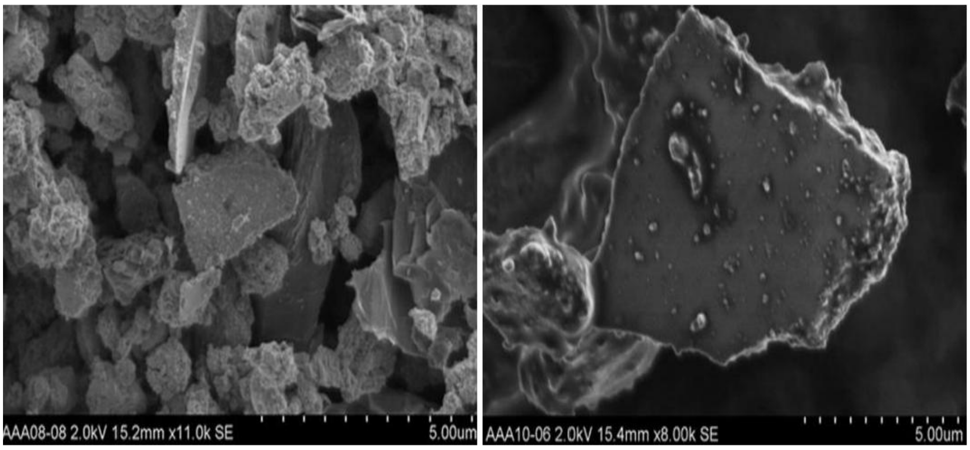

Figure 1. SEM images of brake wear particles generated at a road simulation study [6]

Particles from tires occur during the acting of shearing forces that appear between the tire and the road, or can appear in conditions of high temperatures that occur between the tire and road [7, 8]. The size of particles that appear during the wear of the tires, depends from the type of the tire. Dahl et al. have analysed the transmission of the electron microscope and they have discovered five major particle types [9].

Influence of particles on human health

The size of particles is directly linked to their potential for causing health problems. Small particles less than 10 μm in diameter are the greatest problem, because they can get deep into the lungs, and some may even get into the bloodstream (Fig. 2).
Exposure to such particles can affect on both, on the lungs and heart. Numerous scientific studies have found a connection between particles pollution exposure and a variety of problems, including [10, 11]:

- Premature death in people with heart or lung disease;
- Nonfatal heart attacks;
- Irregular heartbeat;
- Aggravated asthma;
- Decreased lung function, and

- Increased respiratory symptoms, such as irritation of the airways, coughing or difficulty breathing.

People with heart or lung diseases, children, and older adults, most likely can be affected by particle pollution exposure.

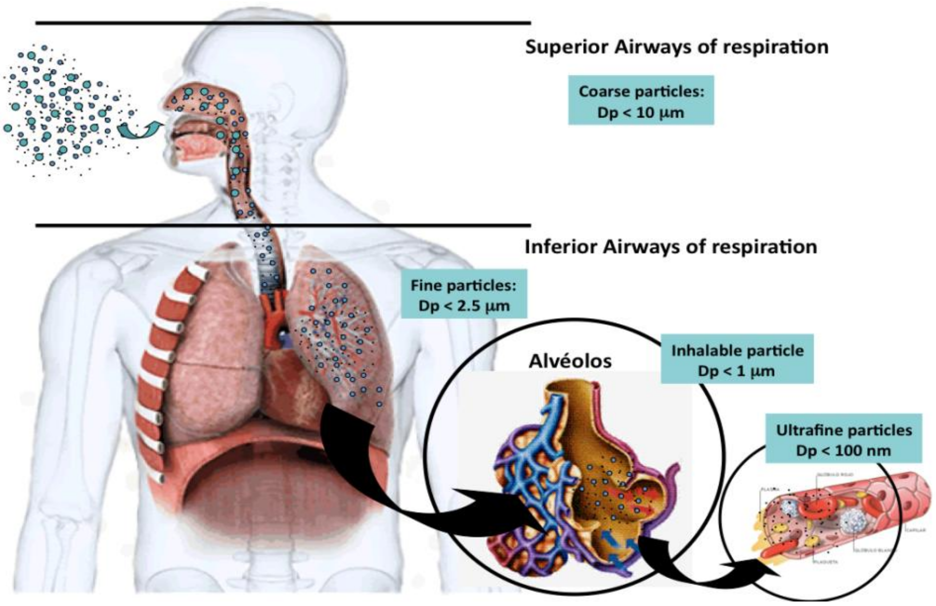

Figure 2. The areas where particulate material is deposited in the body [12]

The goal of this study is to present quantity of ultrafine particles number distributions in the Republic of Serbia and also give the attention on the importance of these particles on assessing health risks.

MATERIAL AND METHODS

The data that have been used for the statistical analysis of particles emission from traffic in the Republic of Serbia, are taken from the website Centre on Emission Inventories and Projections, CEIP. Besides that, it is given the number of registered vehicles in the Republic of Serbia, which is public in Statistical Office of the Republic of Serbia. The working machines are not considered in the paper, so they are not included in the analysis.
Data collecting and processing about emissions of pollutants in the air in the Republic of Serbia is carried out on the basis of [13]:

- Rulebook on the methodology for the development of national and local registers of sources of environmental pollution as well as methodology for types, methods and time limits for data collecting ("Official Gazette of RS", No. 91/10, 10/13 and 98/16);
- Regulation on limit values of air pollutant emissions from combustion installations ("Official Gazette of RS", No. 6/16);
- Regulation on limit values of air pollutant emissions from stationary sources of pollution, except from combustion installations ("Official Gazette of RS", No. 111/15);
- Regulation on measurements of air pollutant emissions from stationary sources of pollution ("Official Gazette of RS", No. 5/16) and
- Regulation on the methodology for the development of air pollutant emissions and projections inventory ("Official Gazette of RS", No. 3/16).

RESULTS AND DISCUSSION

The share of the vehicle in entire emission of the suspended particles within the anthropogenic sources

At vehicles exist three sources of particles formation, which occur during the:

1. Fuel combustion process;
2. Braking process, as well as the wear of tires during the braking and during the driving and
3. Vehicle movement, more accurate wear of the road.

The share of the vehicle in the entire emission is on the third place by size of emission of the $PM_{2.5}$, which amounts 17.3%, while the highest share has other stationary combustion sources and their share is 30.35%, while some smaller share have the industry 25.68% (Fig. 3). If only vehicle is analysed, the $PM_{2.5}$ that occur from the wear of brakes and tires, it amounts 18.76%, the wear of road amounts 10.5%, while the rest of percentage share is from combustion.

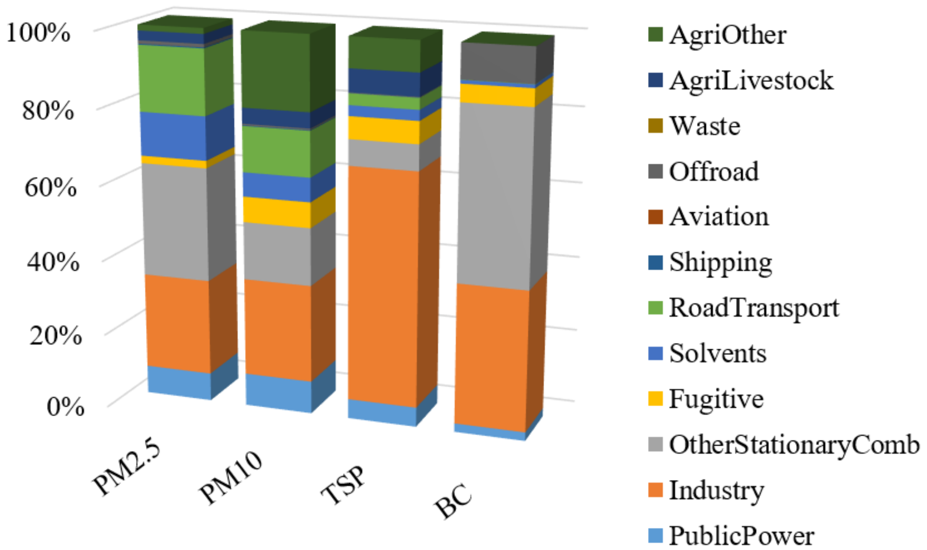

Figure 3. The share of individual sectors in total emission for 2017. [14]

The percentage share of the vehicle in the emission of the PM_{10} amounts 12.11%, while the share of the industry in the emission is 26.03%, the agricultural activity 19.78%, the stationary sources 15.39%. By observing only the vehicle, the wear of brakes and tires emits 25.18% of the PM_{10}, and the wear of road that occur during the exploitation of vehicles amounts 13.92%, and the rest of the percentage of the PM_{10} occurs during the combustion process.
The highest share in the emission of the TSP (total suspended particles) have the industry, which share amounts 62.08%, while the share of the vehicle in the entire emission amounts 3%. The aviation doesn't have shares in the emission of the TSP. The emission of the TSP is only the result of the wear of brakes, tires and road. The percentage value that occurs during the wear of brakes and tires amounts 54.4%, and the rest is from the wear of the road. The share of vehicles in the emission of the BC (black carbon) is 0.07%. The highest share in the emission of the BC has the other stationary sources of combustion (45.87%), after that industry (37.19%), while vehicles with entire emission are involved with 0.07%. However the waste and agriculture don't have shares in the emission of the BC. Formation of BC occurs only due to wear of brakes and tires.

The influence of registered vehicles on the entire emission of suspended particles

The emission of suspended particles that are from road traffic, the last three years have constant growth, Fig. 4. One of the reasons is because exist the number of registered vehicles have been increased in the Republic of Serbia [15], and besides that, it has increased the mobility of peoples.

For the analysis period from 2001 to 2017, the number of registered vehicles has been growing from year to year. At the end, if it is observed the number of registered vehicles in 2017 with respect to the 2001, it has been growth of 61.7%. The percentage grown for the $PM_{2.5}$ is 18.7%, while for the PM_{10} is 36%, Fig. 5It is characteristic for $PM_{2.5}$ and PM_{10} that by increasing of $PM_{2.5}$, the PM10 rise also.
However, the growth for the TSP have been increased from 146.3% (Fig. 6), which is very high value.
While the value for BC have been increased to 50%, Fig. 7.

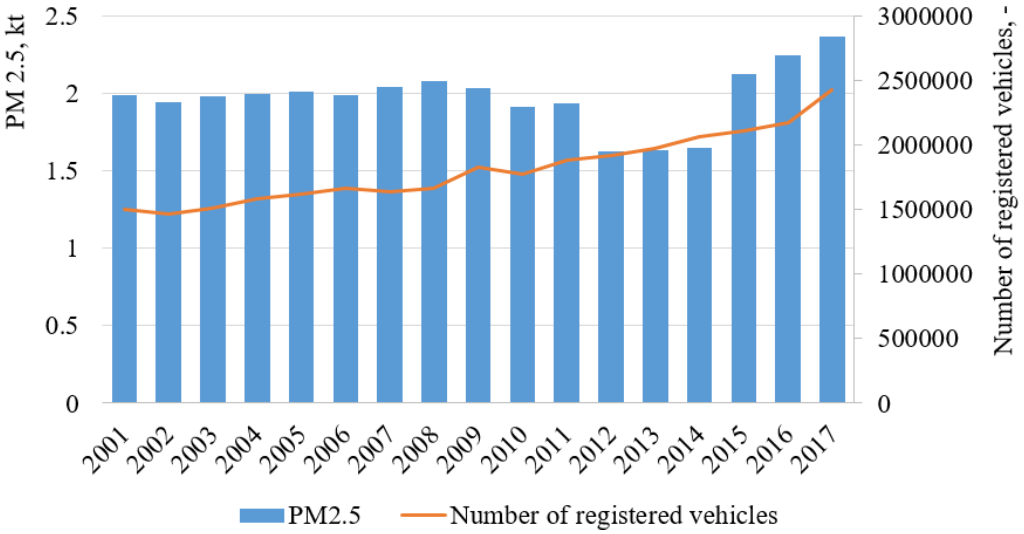

Figure 4. $PM_{2.5}$ emission in function of number of registered vehicles in the period 2001-2017 [14, 15]

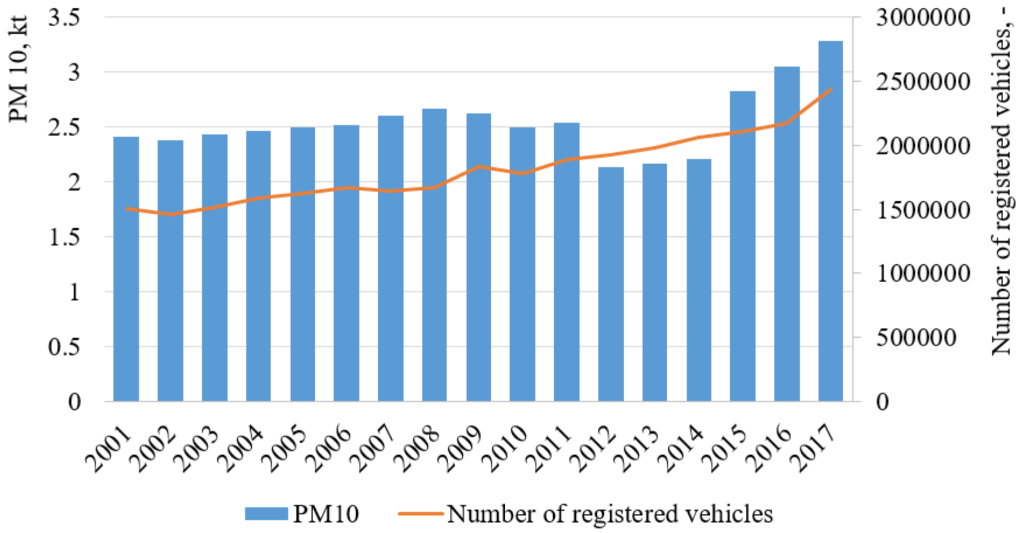

Figure 5. PM_{10} emission in function of number of registered vehicles in the period 2001-2017 [14, 15]

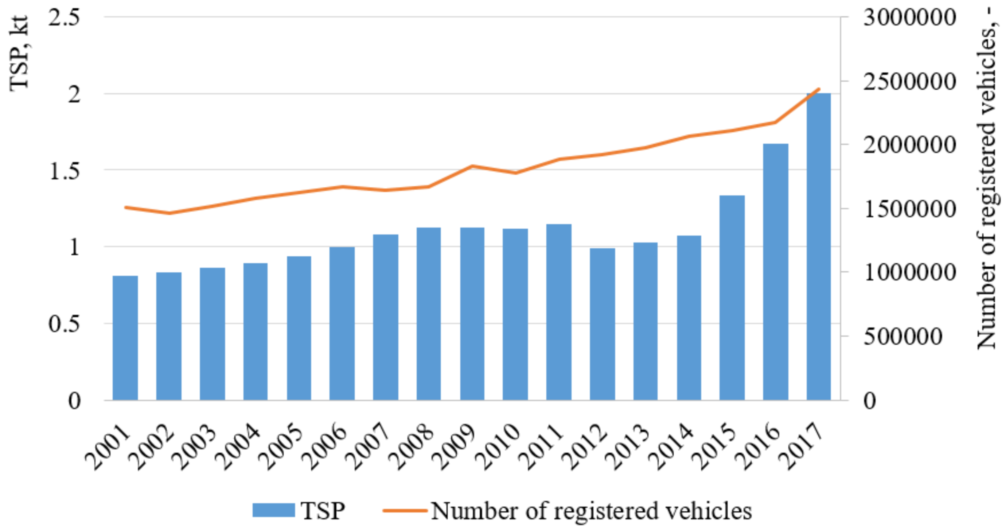

Figure 6. TSP emission in function of number of registered vehicles in the period 2001-2017 [14, 15]

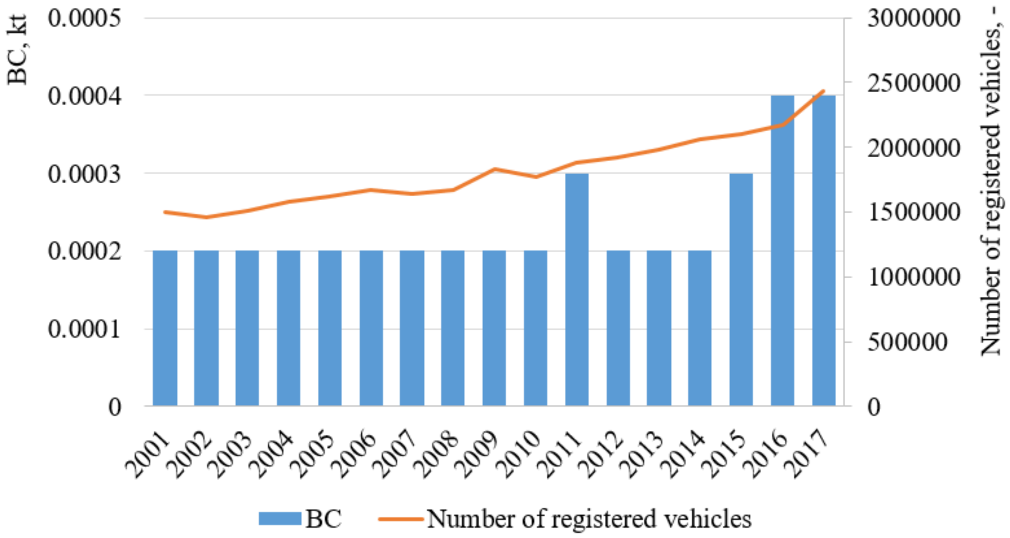

Figure 7. BC emission in function of number of registered vehicles in the period 2001-2017 [14, 15]

CONCLUSION

During the analysis of the wear of tires, it is concluded that the highest influence have the way of driving, vehicle weight, characteristic of tires. Also very influencing can be the type of the tires that are used. For example, if the winter tires are used during the summer, the wear will be greater. While on the wear ratio of brakes, the most influencing parameter is the driving regime, for example stop and go, which is characteristic for city driving. After that, influence has the terrain on which is driven. If is driven on long downhill's, the wear of brakes will be greater, in order to maintain the constant speed. For the analysis period from 2001 to 2017, the number of vehicles has increased from year to year, which have direct influence on the growth of wear of tires and brakes. Particles from tires and brakes occur in many different driving regimes, for example, during the constant speed, slowing down, and stopping the vehicle. The percentage growth of the particles for the $PM_{2.5}$ is 18.7%, for PM_{10} is 36%, for TSP is 146.3%, and in BC is 50%.

ACKNOWLEDGMENTS

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REFERENCES

[1] Internet source: Environmental Protection Agency website: https://www3.epa.gov/region1/eco/uep/particulatematter.html
[2] Stojanovic, N., Glisovic, J., Grujic, I., Pesic, R., Davinic, A.: Ecological aspects of using motor vehicles, МЕЖДУНАРОДНА КОНФЕРЕНЦИЯ „ЕКО ВАРНА“ 2018, pp. 21-31, Варна, 14-16 June, 2018.
[3] Glišović, J., Pešić, R., Vasiljević, S., Stojanović, N., Grujić, I.: Road vehicle as a source of non-exhaust particulate matter, 14th International Conference on Accomplishments in Mechanical and Industrial Engineering, pp. 585-590, Banja Luka, Repubika Srpska, 24-25 May, 2019.
[4] Internet source: Environmental Protection Agency website: https://www.epa.gov/sites/production/files/2015-09/documents/sbai_pres.pdf
[5] Boulter, P.G.: A review of emission factors and models for road vehicle non-exhaust particulate matter. TRL Report PPR065. TRL Limited. Wokingham, 2006.
[6] Kukutschová, J., Moravec, P., Tomášek, V., Matějka, V., Smolík, j., Schwarz, J., Seidlerová, J., Šafářová, K., Filip, P.: On airborne nano/micro-sized wear particles released from low-metallic automotive brakes, Environmental Pollution, Vol. 159, No. 4, pp. 998-1006, 2011.
[7] Kreider, M.L., Panko, J.M., McAtee, B.L., Sweet, L.I., Finley, B.L.: Physical and chemical characterization of tire-related particles: Comparison of particles generated using different methodologies, Science of the Total Environment, Vol. 408, No. 3, pp. 652–659, 2010.
[8] Mathissen, M., Scheer, V., Vogt, R., Benter, T.: Investigation on the potential generation of ultrafine particles from the tire–road interface, Atmospheric Environment, Vol. 45, No. 34, pp. 6172-6179, 2011.
[9] Dahl, A., Gharibi, A., Swietlicki, E., Gudmundsson, A., Bohgard, M., Ljungman, A., Blomqvist, G., Gustafsson, M.: Traffic-generated emissions of ultrafine particles from pavement–tire interface, Atmospheric Environment, Vol. 40, No. 7, pp. 1314–1323, 2006.
[10] Internet source: Environmental Protection Agency website: https://www.epa.gov/pm-pollution/health-and-environmental-effects-particulate-matter-pm
[11] Internet source: Environmental Protection Agency website: http://www.sepa.gov.rs/download/izv/Vazduh2018_final.pdf
[12] Upadhyay, S., Ganguly, K., Stoeger, T.: Inhaled ambient particulate matter and lung health burden, European Medical Journal, Vol. 2, pp. 88-95, 2014.
[13] Internet source: IntechOpen Limited website: https://www.intechopen.com/books/biofuels-economy-environment-and-sustainability/vehicle-emissions-what-will-change-with-use-of-biofuel-#SEC10
[14] Internet source: Centre on Emission Inventories and Projections website: http://www.ceip.at/ms/ceip_home1/ceip_home/review_results/review_results_2019/
[15] Internet source: Statistical Office of the Republic of Serbia website: http://www.stat.gov.rs/sr-Latn/publikacije/?d=2&r=

ENVIRONMENTAL NOISE POLLUTION IN THE UNIESCO CITY OF OHRID

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Abstract: In this paper a research is made by analyzing the noise level variations in the area of city Ohrid. City of Ohrid is one of the 28 sites that are part of UNESCO's World Heritage of Cultural and Natural treasures and it is also the largest city on Lake Ohrid, making it a vast tourist attraction. One of the main complaints by the tourists during the tourist season is the level of noise that is produced by several sources. For better understanding and analyzing the noise pollution in the environment, two kinds of research are made. Firs research is made by public survey and the second one is made by measurement of the level of noise produced in specific locations that are most frequent with visitors.
A set of measures are made for reducing the noise pollution, making better environment and improving locals and tourist accommodation.
Key words: environment, noise pollution, Ohrid

INTRODUCTION

The Municipality of Ohrid is located in the southwestern part of the Republic of North Macedonia. Ohrid is also the name of the city where the municipal seat is found. Ohrid is a small resort city on the hilly shores of Ohrid Lake in the southwest of the Republic of Macedonia (Fig.1). In the city's compact old town, medieval churches, monasteries and open-air ruins stand alongside traditional houses with red-tiled roofs. The massive walls of the centuries-old Samoil's Fortress, at the top of the hill, dominate the city skyline (Fig.2).

Figure 1. Location of Ohrid in south-west region of Republic of North Macedonia

Ohrid region which includes Ohrid Lake and the mountain Galichica, allow Republic of North Macedonia to be among the few countries with rich diversity of habitats for wildlife. In 1958, due to the characteristic location, extremely rich flora and fauna and exceptional natural beauty and landscape values, Galichica Mountain was declared as a National park "Galichica" with 25,000ha protected area. On the other hand, in 1979 the Ohrid Lake was declared under UNESCO protection. With its unique flora and fauna, the lake is one of the largest biological reserves in Europe. The Ohrid Lake is one of deepest and the oldest in Europe, preserving a unique aquatic ecosystem with more than 200 endemic species. The lake fish fauna include 17 native species, of which 10 are endemic (two of which belongs to Salmonide family). Ten from the fish species have a commercial value. But also a lot of snails (85%), worms, and sponges are endemic species. Littoral zone is characterized by considerable communities of the plant and animal species. The red belts at this part of the lake have a big ecological importance as biotopes for a lot of other organisms, places for fish reproduction, and bird nesting place. Related to bird nesting over 60,000 birds have been observed in the Lake.

Figure 2. Map of Ohrid city

Environmental noise is a severe problem in urban cities similar as Ohrid. Noise pollution and its consequent influence over the environment and life quality of human beings may be considered a ''hot topic'' in scientific research. Many noise surveys treating the problem of noise pollution in many cities throughout the world have been conducted **(Curitiba**, Brazil [1], Sa˜o Paulo [1], Rio de Janeiro [2], Belo Horizonte [3] and Porto Alegre [4,5]. Sounds are part of our everyday life and they are often unwanted or harmful in outdoors environment created by human activities. Environmental noise affects primarily the quality of life, disruption of the normal rhythm of work and rest. It causes both physical and psychological problems among population by disturbing the basic activities of man such as sleeping, rest, study, communication, and it reflects especially on hearing impediment. Noise is constantly growing and it is especially difficult to control in densely populated agglomerations and residential areas near airports, railways and highways [4-8].

MATERIAL AND METHODS

Research methodology

Some researches [6] use methods that develop SILENCE Work package H.2 for monitoring roadside noise and identifying noisy vehicles, and [8] take the measurements that are carried out according the ISO 1996-2 standards, other are made [7] by analyzing the sound level data collected from different points and vulnerable institutions, which were selected according to the importance and vulnerability.
For the purpose of defining the future policy for environmental noise as one of the main environmental problems in the Republic of North Macedonia, noise management is regulated in the provisions of the Law on Protection against Environmental Noise [11]. This Law has transposed the basic Directive on environmental noise - 2002/49/EC (12), by which the main recommendations of the European Union

have been fulfilled and full management of environmental noise has been enabled. The Law provisions specify:

- Methods of assessment by noise indicators;
- Methods of assessment for harmful effects;
- Adoption and implementation of planning documents, as well as
- Undertaking of measures for protection against environmental noise.

Based on the Law on Protection against Environmental Noise, the Ministry of Environment and Physical Planning, in cooperation with the competent ministries has so far adopted several bylaws in order to enable full implementation of the Law on Protection against Environmental Noise. These bylaws regulate detail inspection supervision, environmental indicators and their application, noise monitoring, adoption and implementation of planning documents and conditions and technical measures for protection against environmental noise caused by specific sources.

The Law stipulates the main carriers of the obligation for environmental noise management, these being [27-30]:

- Bodies of the state administration;
- Municipalities (in our case study, Ohrid Municipality), City of Skopje and municipalities in the City of Skopje;
- Legal and natural persons.

Control and reduction of environmental noise has two main goals, first to protect us from noise that annoys us or disturbs everyday activities and second, to protect us in future from increased noise levels that will further deteriorate the quality of the environment, like in [1-4,6-8].

Measurement and monitoring of noise in the Republic of Macedonia is not a continuous process. One of the basic measures for achievement of high level of noise control and reduction is to establish noise monitoring, which is systematized measurement, monitoring and control of the state of environmental noise. For the above reasons exactly, it is necessary to establish state and environmental local noise monitoring networks, especially for agglomerations, main roads, main railways and airports as specified in the Decree for agglomerations, main roads, main railways and airports for which strategic noise maps should be prepared. Collected, verified and processed data and information on the state of environmental noise make the official database of the state of noise in the environment, serving as basis for noise management and protection against noise.

For the purpose of avoiding, preventing or reducing harmful effects on human health and environment, limit values for noise levels are specified to limit the levels of all sources of noise, including time period, position of the source and types of areas where noise is generated.

According to the extent of protection, limit values for the basic noise indicators Ld and Le range from 50 dB (A) for areas of first extent, to 70 dB (A) for areas of fourth extent, while for the basic indicator Ln they range from 40 dB (A) for areas of first extent, to 60 dB (A) for areas of fourth extent.

According to the type of premises when measured inside the premises, limit values for the basic noise indicators Ld, Le and Ln range from 30 dB(A) to 55 dB(A). Limit values for noise levels in areas outside urbanized locations, depending on the area, for the basic noise indicators Ld, Le and Ln range from 35 dB(A) to 70 dB(A).

RESULTS AND DISCUSSION

On (Fig.3) are presented the hot-spots in the central city area that is protected by the UNESCO as a cultural and natural treasure, where largest noise generators are located such as the crowded restaurants and bars with frequent tourist visitations.

Figure 3. Hot-spots for noise measurement in Ohrid City

Indentified noise sources [6] in the municipality of Ohrid mainly originate from:

- Local noise,
- traffic noise,
- noise from industrial plants and factories and est.

Local noise-originate from the restaurants, cafe bars, night bars, open party events.
The level of noise is highest in the old city core such as the area of the Old City, City Square, Ohrid Bazaar and Ohrid Lake Port and Lake Shore where the intensity of tourist is in a large number. This level of noise is also present on the beaches trough the day.

Traffic noise- [6] Problems that originate from traffic occurs as a result of:

- Increasement of vheicle frequency during the rush hours especialy during tourist season
- Lack of parking places in private and manicipality sector
- Power engines and sirens from vheicles and motor boats
- Airplanes noise from taking off and landing
- Loud music originating from powerful sound sistems in cars and boats
- Lack of bycycle paths and standards for their usage as a transport method
- Lack of public transportation

Noise form industrial plants and factories-originate from everyday activities from the local industrial plants and the ones in the industrial area in Ohrid municipality.

For complete analyses of the noise distribution, several measurements are made in the locations presented on the map. Measurements are made in several time intervals during morning hours (lowest frequency of people movement), afternoon hours (high frequency of people movement) and in the night hours (highest frequency of people movement).

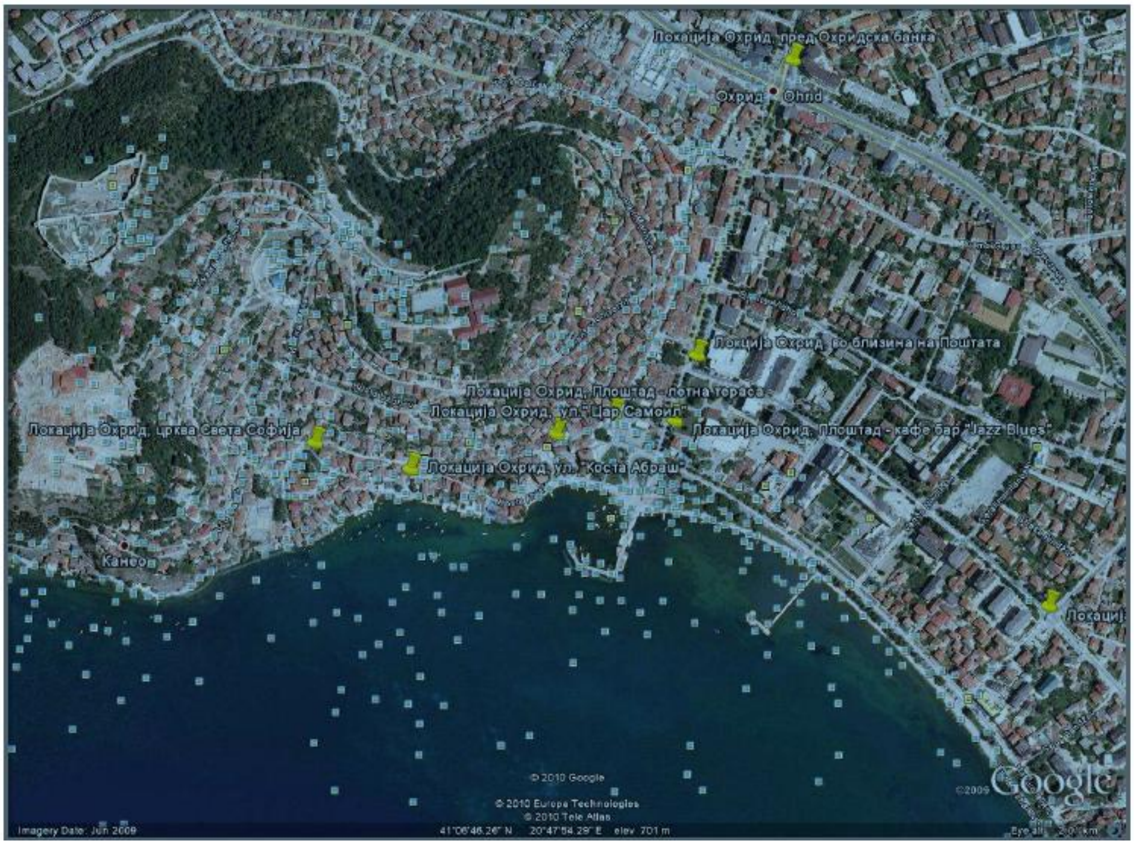

Figure 4. Points for noise measurement in Ohrid City

The first noise measurement was made in the period between 30-th of April and the 1-st of May 2010, a period in which the number of tourists was increased as a result of the holidays. Measurements where made in the defined points (Fig.4) in different periods of the day.

Second noise measurement was made in the period between 22-nd and 24-th of July 2010 on the same defined points (Fig.4). This set of measurements was upgraded with additional points of noise measurements as a result of the alarming noise pollution that was register at the measuring points. This period is also known as starting point of the tourist season.

From the obtained results from all of the measuring points the conclusion is that in all of the time intervals day or night, values are over the maximum limit of noise set by the Law on Protection against Environmental Noise.

The maximal values that are over the limits are measured during the night hours. The extreme values of noise are registered in the measure points set on the street Car Samoil, Kosta Abrash and the city square where values reaches up to Leq=81.9-89.9 dB(A).

These streets are full of cafe bars, night bars equipped with powerful sound speakers producing loud music. In the night hours are registered noise from young people conversations, singing and laughter etc. All of these factors contribute of stepping over the appropriate limit of noise production.

In a comparison of the results with the one obtained from the period of 30-th of April – 1-st of May 2015 the same specified locations have values that are over the noise limits in the night hours that are up to Leq=75 dB(A) on street Car Samoil, Leq=68.1dB(A) at measuring point Leskoec, Leq=66.9dB(A) measuring point bul.Turisticka-Jane Sandanski, Leq=68.1dB(A) measuring point near Ohridska Banka etc.

From the field inspection of the given locations the results are leading toward conclusion that the main reasons for noise pollution are:

- Not abiding the laws and its requirments
- unapropriate working regulations
- lack of behavior from the locals and tourists

- distance and splace planning in the Old City area
- unapropriate sound issolation in the local coffe bars and restourants
- high viacle frequency, lack of parking places
- driving with high speed etc.

CONCLUSION

The Seventh Environmental Action Programme (7EAP) "living well in the boundaries of our Planet", has an objective to provide, by 2020, significantly reduced air pollution in EU and approach to the levels recommended by WHO. It also recommends that this will require implementation of updated policies for noise harmonization with the latest knowledge and measures for reduction of noise and its sources, including improvements in urban planning. In short-term, the European Commission will undertake review of the Directive on environmental noise in the course of 2014, which might result in proposal to amend Directive and strengthen its implementation.
In order to achieve the objective of the7EAP and enable prevention and reduction of noise which causes harmful effects on human health and reduce the number of people exposed to harmful noise levels, the following recommendations should be followed:
1. Adoption of all bylaws deriving from the provisions of the Law on Protection against Environmental Noise;
2. Provision of maximum implementation of the provisions of the existing legislation in the area of environmental noise;
3. The process of preparation of spatial and urban plans and acts for their implementation, in the frames of the content on protection, should include protection measures against noise as well;
4. Planning documents for structures that are subject of building approval should fulfill specific conditions and measures concerning standards for protection against noise in buildings;
5. Preservation of quiet zones in agglomerations as such;
6. Provision of modernization of installations by remediation of existing and introduction of new solutions for noise reduction;
7. It is recommended that the Ministry of Environment and Physical Planning and agglomerations obliged to prepare strategic maps to commence the process of preparation in the course of2014;
8. It is recommended that the Ministry of Environment and Physical Planning forms a working group composed of professional representatives of the relevant institutions to work on determination of national method for noise mapping;
9. It is necessary to establish noise monitoring as systematized noise measurement, monitoring and control of the state of noise in environmental media and areas;
10. It is recommended that the Ministry of Environment and Physical Planning in cooperation with the Ministry of Health, prepares the Annual programme for work of the state noise monitoring network and the Programme for public health in the segment of protection against noise;
11. It is necessary to establish Information system of the state of environmental noise as part of the overall environmental information system in the Republic of North Macedonia to cover data obtained from noise monitoring, strategic maps and action plans for noise and other relevant data obtained by individual noise measurements; and
12. Based on processed data on environmental noise in the three cities in the Republic of North Macedonia, undertake measures for reduction of environmental noise in them.

REFERENCES

[1] Paulo Henrique Trombetta Zannin*, Fabiano Belisarˊrio Diniz, Wiliam Alves Barbosa, Environmental noise pollution in the city of Curitiba, Brazil, Elsevier, Applied Acoustics 63 (2002) 351–358
[2] Bertoli SR, Paiva CEL. Exposic¸a˜o na˜o ocupacional ao ruı´do de passageiros de trens metropolitanos da grande Sa˜o Paulo. XIX Meeting of the Brazilian Society of Acoustics, 15–19 April 2000, Belo
[3] Arruda FR, Coelho JLB, Slama JG. Aapectos do Controle de Ruı´do Urbano na Cidade do Rio de Janeiro. In: XIX Meeting of the Brazilian Society of Acoustics, 15–19 April 2000, Belo Horizonte/
[4] Barros CJO. Ana´ lise Espacial do Controle da Poluic¸a˜o Sonora em Belo Horizonte. XIX Meeting of the Brazilian Society of Acoustics, 15–19 April 2000, Belo Horizonte/Minas Gerais, Brazil, p380–5
[5] Sattler MA. Urban noise survey for the city of Porto Alegre. Acustica 1999;85:356.
[6] Rolf Annecke, Truls Berge, Steve Crawshaw, Lars Ellebjerg, Selina Mårdh, Ernst Pullwitt, Heinz Steven, Andreas Wiberg, Uta Zimmermann, Noise Reduction in Urban Areas from Traffic and Driver Management, EUROPEAN COMMISSION DG RESEARCH, SIXTH FRAMEWORK PROGRAMME PRIORITY 6 SUSTAINABLE DEVELOPMENT, GLOBAL CHANGE & ECOSYSTEMS INTEGRATED PROJECT – CONTRACT N. 516288
[7] M. A. Haq, M. M. Islam, M. S. Ali, M. F. Haque and M. M. R. Akhand, Status of Noise Pollution in Mixed Areas of Dhaka City: a GIS Approach, *J. Environ. Sci. & Natural Resources*, 5(1): 09-17, 2012
[8] *Zekry F. Ghatass*, Assessment and Analysis of Traffic Noise Pollution in Alexandria City, Egypt, World Applied Sciences Journal 6 (3): 433-441, 2009
[9] Reina Ezzeddine, Basma Hallak , Fawzi Khalifeh, Tamer Ladan, Nabeeha Shokor,URBAN NOISE MITIGATION, American University of Beirut, CIVE 402 - Final Project Report, May, 2005
[10] Noise Control for Nightclubs, Restaurants, Bars, and Cafes Product and Services Guidance Sheet http://www.nyc.gov/html/dep/pdf/noise_consultants_list.pdf.

SPECIAL TECHNIQUES FOR PREDICTION POLLUTANTS IN THE ENVIRONMENTAL SAFETY

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Abstract: The paper presents a new method of prediction pollutants (organic and inorganic) in an integrated system of environmental safety. In the following thesis, results of innovative research which included pollutants` NO_2 and SO_2 in complex process systems have been presented. Licensed EPA (Environment Protection Agency) model was used for the dispersion of pollutants into the air ALOHA (Areal Locations of Hazardous Atmospheres). ALOHA is a modeling program that estimates with hazardous chemical releases, including toxic gas clouds, fires and explosions. A threat zone is an area where a hazard has exceeded a user specified Level of Concern (LOC). Input data of the model are: pollutants` flow at the source, diameter of emitter`s opening and meteorological data. Achieved results represent maximum distance that SO_2 and NO_2 pollutants reach. All high emitters of industry have been modelled and the dispersions of pollutants have been presented for the highest emitters.
Key words: monitoring, predictions, environmental security

INTRODUCTION

The paper presents modeling of pollutants SO_2 and NO_2 for industry (example 1(*fertilizer industry*), 2(*petrochemical industry*) and 3(*oil industry*)) to represent maximum reach of pollutants in the atmosphere. Sulfur and nitrogen oxides have been selected because of the acid rain which is extremely harmful to the environment. There are other programs for modeling pollutants, but we used ALOHA, because of its quick and easy results. In the following paper, results of pollutants modelling in the oil and petrochemical industry are presented. These industries represent the highest emitters of two important pollutants: SO2 and NO2, and we evaluated their influence on the environment. No study that deals with the pollution in this manner has ever been made.

METHODS

An US EPA (Unated States Environment Protection Agency) model was used for the dispersion of pollutants into the air, called ALOHA (Areal Locations of Hazardous Atmospheres) [1]. ALOHA is a modeling program that estimates the hazardous chemical releases, incuding toxic gas clouds, fires and explosions. ALOHA is a good programme because it includes both physical and chemical charasteristics of pollutants (density of the gas, molar mass, boiling point) in its calculations. A threat zone is an area where a hazard has exceeded a user spefiied Level of Concern (LOC). Data used for the analyses has been taken from the project documentation and measurements of emissions performed by the certified institutions. Certified institutions are accredited organizations that perform the tests; they fulfill all of the set conditions and they have permission from the ministry, which is in charge of environmental problems, to perform air monitoring and/or the measuring of emissions.

Input data of the model are: pollutant flow at the source, diameter of emitter`s opening, meteorological data, chemical properties, ground roughness, and source location. The Achieved results represent maximum distance that SO_2 and NO_2 pollutants reach. All high emmiters of oil and petrochemical industry have been modelled and dispersion of pollutants are presented for the highest emitters. Input data represent emissions of inorganic pollutants, meteorological data in the worst case scenario. As the foundation we used a geographical map with the positions of emitters (all emitters are over 2m). All the Necessary information for the modeling which represents dimension of emitters are provided by the certified institutions that performed the measurements.
The Oil and petrochemical industry releases pollutants that are supposed to be measured and controlled. The Law on Integrated Prevention and Pollution and Control IPPC defines and requires

the reduction of pollutants to clearly determined levels. The Emitters that release pollutants are presented on Figure 1. ALOHA will plot user-defined levels of concern (LOC).

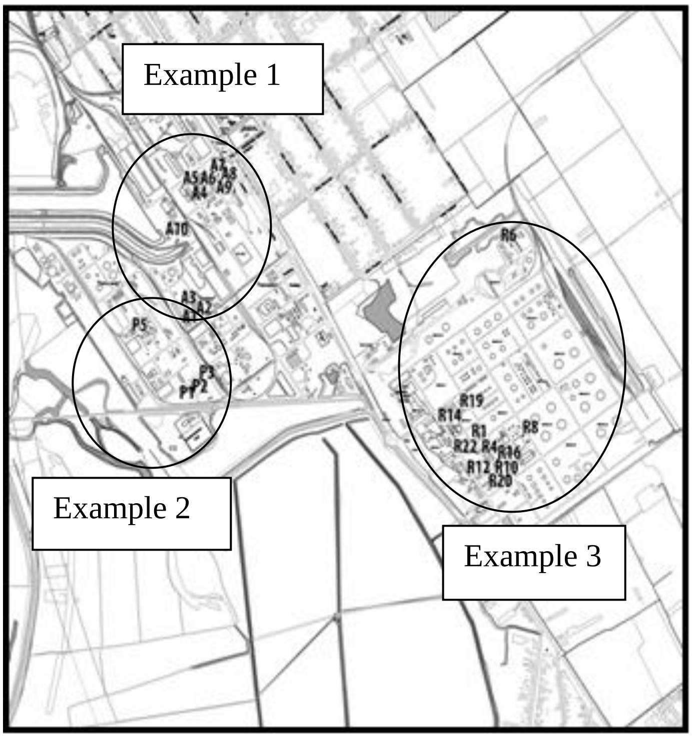

Figure 1. Position of emitters` measuring points in industry (example 1, 2 and 3)[2].
A, P, R are symbols for high emitters in the plants of chemical industry

A model of integral control and the prevention of pollution in oil and petrochemical industry has been developed using ALOHA to determine what emission rates are allowable under the law as compared to what is actually happening. In this case do you consider superposition of all the emitters. You have a map of the locations, you can use ALOHA with MARPLOT to plot the plumes on the map and see where the problem areas are. This model indicated the most critical points where we could reduce pollution using the technical and technological measures[3,4,5]. A developed model of integral control and the prevention of pollution utilizes diffusion equations of emissions during the continual work of the plant as well as equations for the performance of plant when it is not functioning properly.

EXPERIMENTAL

Modelling of inorganic pollutants has been done as an experiment in the oil and petrochemical industry.

Example 1. Modelling of pollutants NO_2 and SO_2 in the oil and petrochemical industry

The model for integral control and the prevention of pollution for the industry (example 1) has been applied on defined emitters A1-A10 (Figure 2). Table 1. represent result of modelling for pollutant NO_2.

Table 1. The Result of modelling for pollutant NO_2 (Example 1)

Measuring spot*	Pollutant ***	Mass flow rate (kg/h)	Height of emission source (m)	Maximum distance** (km)
A4	NO_2	83.4	82	5.7
A6	NO_2	213.21	82	9.3
A8	NO_2	116.8	18	6.8

** A are symbols for high emitters for the industry (example 1) (facility emission source location).*
*** Distance from high emitter to max range*

**** Pollutant SO_2 is not considered because example 1 use gas in the production process*

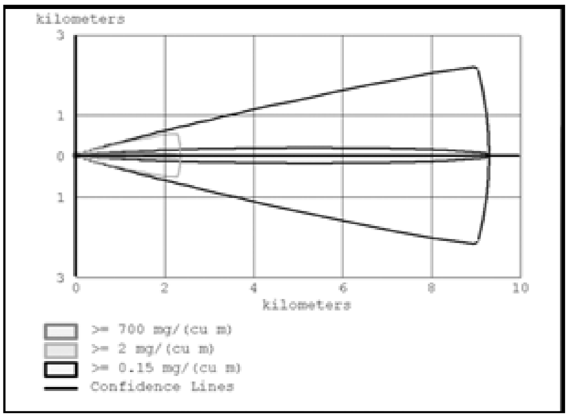

Figure 2. Graphical presentation of NO_2 dispersion at A6 measuring point

Example 2. Modelling of pollutants NO_2 and SO_2 in industry

The model for integral control and the prevention of pollution for the industry (example 2) [3,4,5] has been applied on defined emitters P1-P6 (Figure 3). Table 2. represent result of modelling of pollutants SO_2 and NO_2.

Table 2. Result of modelling for pollutant NO_2 (Example 2)

Measuring Spot**	Pollutant	Mass flow rate (kg/h)	Emission height (m)	Maximum distance (km)
P1	NO_2	82	40	5.6
P2	NO_2	84	40	5.7

*** P is symbols for high emitters for industry (example 2) (facility emission source location).*

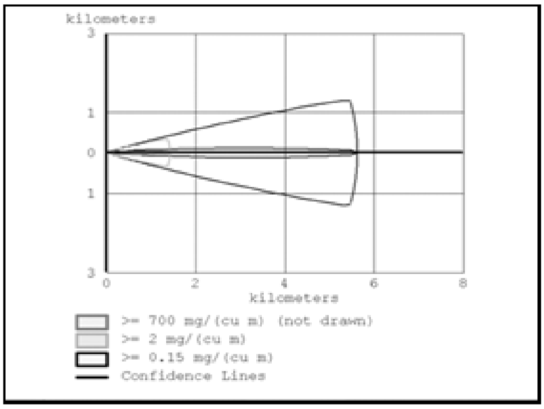

Figure 3. Graphical presentation of NO_2 dispersion at P1 measuring point

Example 3. Modelling of inorganic pollutants NO_2 and SO_2 in industry

The model for integral control and the prevention of pollution for the industry (example 3) has been applied on defined emitters R1-R22 (Figure 4). Table 3 represent result of modelling of pollutants SO_2.

Table 3. Result of modelling for pollutant SO_2 (example 3)

Measuring spot***	Pollutant	Mass flow rate, (kg/h)	Emission height, (m)	Maximum distance, (km)
R1	SO_2	$204.0 \cdot 10^3$	40	10
R19	SO_2	96.67	150	3.9
R22	SO_2	77.5	50	3.5

**** R is symbols for high emitters for industry (example 3) (facility emission source location.*

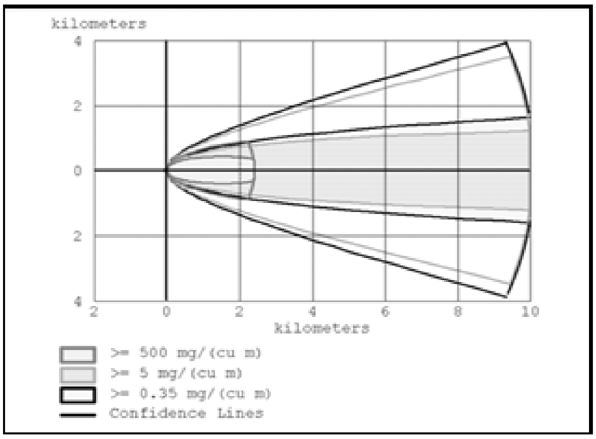

Figure 4. Graphical presentation of SO_2 dispersion at R1 measuring point

RESULTS AND DISCUSSIONS

Modelling results for the industry (example 1) present the maximum reach for boundary values of inorganic pollutants` emissions at:

- A6 measuring point (max reach of NO_2 is 9.3 km),
- A8 measuring point (max reach of NO_2 is 6.8 km),
- A4 measuring point (max reach of NO_2 is 5.7 km) and
- A9 measuring point (max reach of NO_2 is 5.3 km).

The Results are shown in Table 1. The highest percentage has A6 emitter and it is 22%, which can be seen in Figure 5.
Modelling results for industry (example 2) present maximum reach of inorganic pollutant nitrogen dioxide boundary values of inorganic pollutants` emissions at:

- P2 measuring point (max reach 5.7 km),
- P1 measuring point (max reach 5.6 km) and
- P3 measuring point (max reach 4.1 km).

The Results shown in Table 2. The highest percentage has P2 emitter and it is 34%, which can be seen in Figure 6.
Modelling results for industry (example 3) present maximum reach of inorganic pollutants for boundary values of inorganic pollutants` emissions at:

- R1 measuring point (maximum reach is 10 km),
- R8 measuring point (maximum reach is 4.7 km),
- R10 measuring point (maximum reach is 4.3km),
- R15 measuring point (maximum reach is 4.5 km),
- R19 measuring point (maximum reach is 3.9 km),
- R9 measuring point (maximum reach is 3.7 km) and
- R22 measuring point (maximum reach is 3.5 km).

The Results shown in Table 3. The highest percentage has R1 emitter and it is 18%, which can be seen in Figure 7. According to the results, maximum reach values (over 5 km) can be expected at A1 point. Measuring point R1 has the maximum pollutants` reach of over 10 km, and A6 point is in the vicinity. Maximum reach for industry (example 1) with inorganic pollutants` modelling can be expected at the following measuring points: A1, A6, A8, A9. Maximum reach for industry (example 2) with inorganic pollutants` modelling can be expected at the following measuring points: P1 and P2. Maximum reach for industry (example 3) with inorganic pollutants` modelling can be expected at the following measuring points: R1.

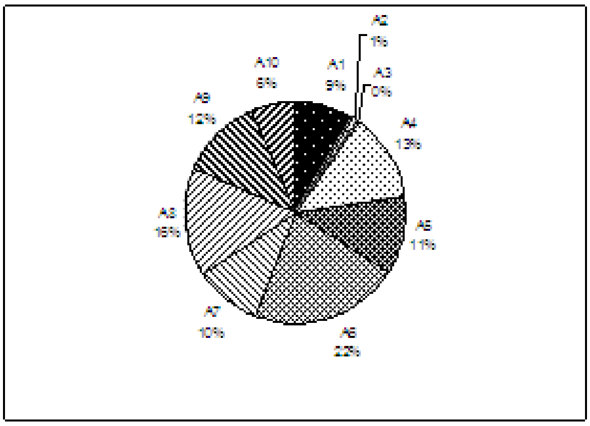

Figure 5. Percentage of inorganic emitters in pollution in industry (example 1)

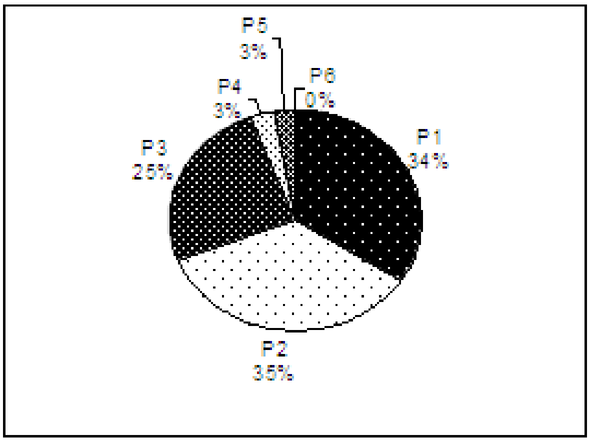

Figure 6. Percentage of inorganic emitters in pollution in industry (example 2)

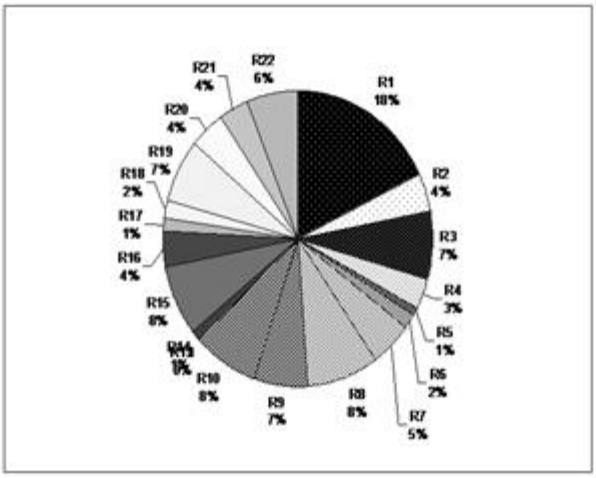

Figure 7. Percentage of inorganic emitters in pollution in industry (example 3)

Figure 8 represents the relation between measuring points and the maximum reach of pollutant. In graph 4. we can see that emitters with the highest reach during the modelling of inorganic pollutants SO_2 and NO_2 are: A1, A6, A8, A9, P1, P2 and R1. The Emitters with the lowest reach during the modelling of inorganic pollutants SO_2 and NO_2 are: A2 ,A3, P4, P5, P6, R5, R6, R14, R17. These results enable the formation of groups on the map (the zones with very bad conditions) and they can help you mark where the greatest problems in the area are[12,13].

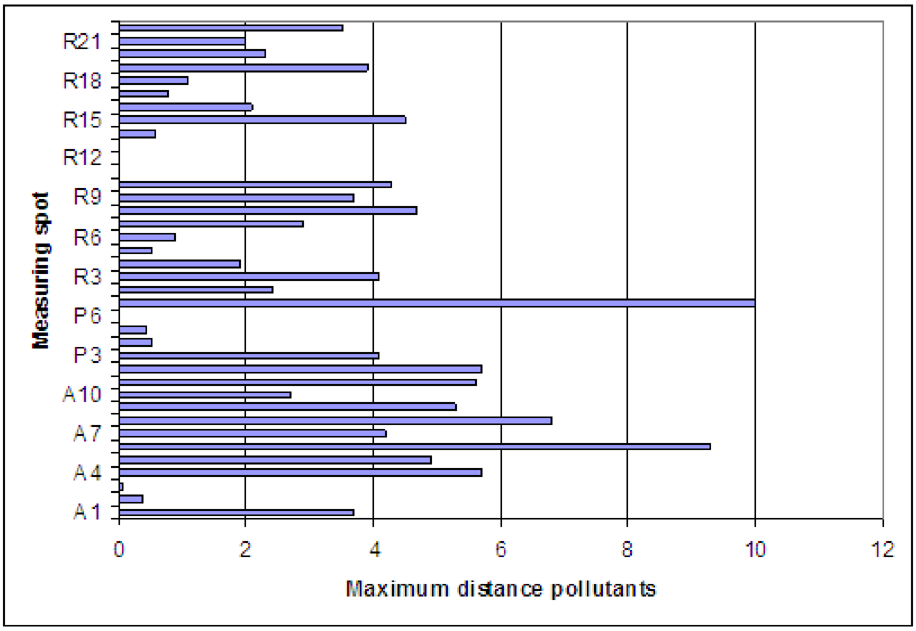

Figure 8. Relation between measuring points and maximum reach of pollutant

CONCLUSION

The Paper presents emitters with the highest reach during the modelling of pollutants SO_2 and NO_2 : A1, A6, A8, A9, P1, P2 and R1. Emitters with the lowest reach during the modelling of inorganic pollutants SO_2 and NO_2 are: A2 ,A3, P4, P5, P6, R5, R6, R14, R17. The least influence on the reduction of pollution is in the industry (example 2), which has the smallest number of emitters and takes a small part in the pollution. The graph shows the highest emission concentration, at what distance from the emission source SO_2 and NO_2 is 10 km. It has been calculated for the emitters in industry (example 3), which leads to a conclusion that the highest reach for inorganic pollutants is in the industry (example 3) as well as the greatest number of emitters that release pollutants.

As Presented here, the new modeling of pollutants in industry (example 2 and 3) could be applied on organic pollutants (benzene, toluene, xylene). The Results of pollutants` modeling in industry (example 2 and 3) show points (emitters) that could significantly influence the air quality as well as points of pollution reduction. The reduction of pollution as well as the control of pollutants` emission is regulated by the law that was defined by the Law on integral prevention and the control of pollution[8,9,10,11].

REFERENCES

[1] http://www.epa.gov/emergencies/
[2] http://ekologija.pancevo.rs/
[3] Stefanov, S., Comparative analysis of the monitoring for the assessment of risk in the complex process system. Master's Thesis. Novi Sad (Serbia): University of Novi Sad, Faculty of Technical Science, 2004.
[4] Stefanov, S.: The estimate of chemical accident hazard in the process of high density polyethylene production. Expert's Study. Novi Sad (Serbia): University of Novi Sad, Faculty of Technical Science, 2003.
[5] Stefanov,S., Vojinovic Miloradov,M., Sokolovic,S., Bogdanovic,V., Integrated pollution prevention and control in oil-petrochemical industry in Pancevo, XII Symposium on Analytical and Environmental Problems, Szeged, Hungary, 2005.
[6] Gastor, Strategic environmental impact assessment (Oil and Petrochemical plant), 2005.
[7] Stefanov S., Vojinovic Miloradov M., Basic Đ., Comparative Analysis Of The Monitoring And RA of the Chemical Accidents in Serbia, PSU-UNS International Conference, on Engineering and Environment – ICEE-2005, Novi Sad, 2005.

[8] Law on integrated environmental pollution prevention and control,"Official Gazette of the Republic of Serbia", No. 135/2004.
[9] Limits values, methods of measuring emissions, establishing criteria for measuring and places of data recors, "Official Gazette of the Republic of Serbia", No 54/92, 30/99, 19/2006.
[10] Law on air protection,"Official Gazette of the Republic of Serbia", No. 36/2009.
[11] Law on environmental protection, , "Official Gazette of the Republic of Serbia", No. 135/2004.
[12] Biocanin, R., Stefanov, S., Urosevic, S., Mekic, S. (2012) Modeling of Pollutants in the Air in Terms of Fire on Dumps, Ecological chemistry and engineering S – Chemia i inzynieria ekologiczna S 19, 609-616.
[13] Takic, Lj., Ketin, S., Marjanovic, R, Preljevic, A., Sacirovic, S. (2018) Comparison of maximum range of pollutants. Frenesius Environmnetal Bulletin,Vol.27, No.2,pp.1157-1163

SPECIAL METHOD FOR INVESTIGATION OF GEOCHEMICAL PARAMETERS IN STUDIES OF ENVIRONMENTAL PROTECTION, HYDROLOGICAL AND MINERALOGICAL STUDIES

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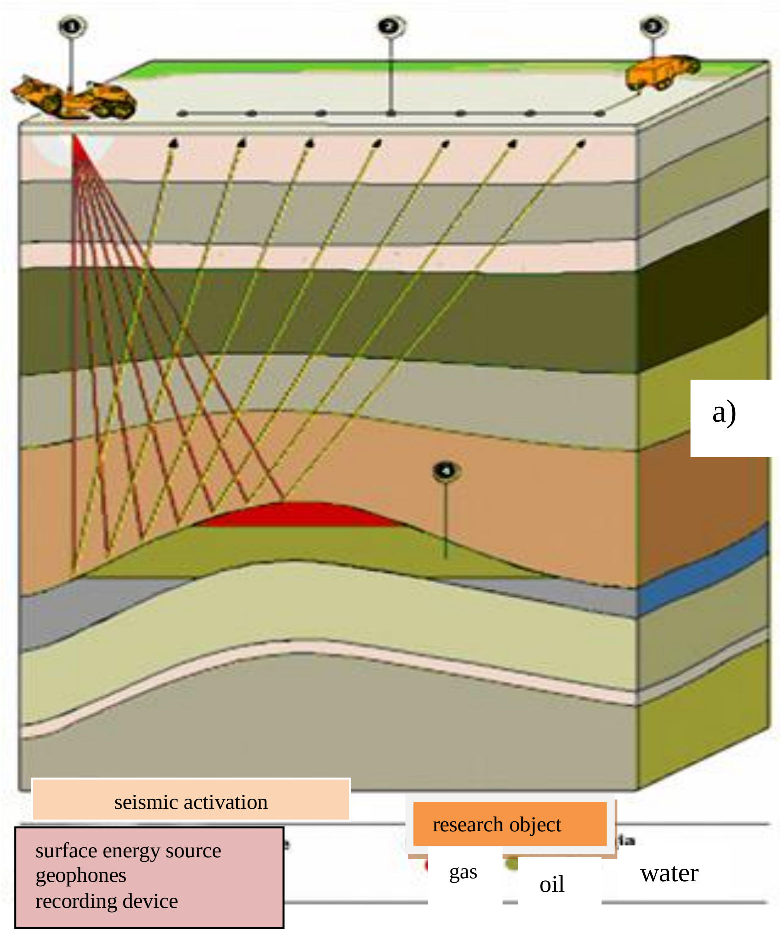
Abstract: For a long time, seismic exploration deposits have been particularly related to areas distant from urban environment, from settlements, traffic arteries and objects of specific purpose. Nowadays, predominantly speaking about Europe, seismic exploration is successfully performed in towns and villages, as well near to important traffic arteries. Modern technical devices, as modern technology of 2D and 3D seismics on land or water, but also necessary measures of caution, are the guarantee that reliable seismic section could be obtained after seismic data processing related to half-space under settlements, airports, roads, railroads and objects of specific purpose.
Keywords: geology, seismics, acquisition, exploration

INTRODUCTION

Seismic tests are often mentioned for its use in oil industry, and that is when seismic section is referred to in scientific circles. Seismic section is just one of the final results of a long and complex procedure of seismic tests, which hides a very demanding technical and technological process starting from seismic acquisition, via seismic processing to seismic interpretation. Seismic acquisition is therefore selected as the basis for all further manipulation of registered seismic records. Further steps in manipulation of seismic signal, which is the core of each seismogeological interpretation, depend on the proper use of seismic acquisition. Seismic tests are being performed in various conditions: in deserts and in many of the world`s capital cities.
In order to carry out the seismic tests under safe conditions that are in accordance with clearly specified ecological demands, it is necessary to apply adequate ecological and technical and technological steps of specialised seismic acquisition while operating in areas with distinct elements of urban areas. This requires a good knowledge of seismic testing methodology and environmental protection as well as keeping up with ever-changing trends in science and technology and having experience with the research in various geological and ecological areas [1-4].

BASIS OF SEISMIC REFLECTIVE RESEARCH

Methodology of seismic reflective research refers to the CMP method and the method of multiple seismic overlaying. 2D, 3D and »n«D seismic research could also be conducted, on land and in water. The most common sources of seismic waves used in seismic researches on land are: explosive in a manshaft or on the surface, vibrations and blasts. Obtaining an adequate sub-surface overlay is of great importance while using the equal level of energy, which represents one of requirements to obtain a high quality image of the research area.
In picture No1 we can see the geometry of seismic research done on land and in the sea. The images are sufficiently illustrative and they show how important the geometry of seismic research is, when defining the research area. The geometry is defined with the position of seismic lines determined by the layout of receivers and transmitters of seismic energy [5-7].



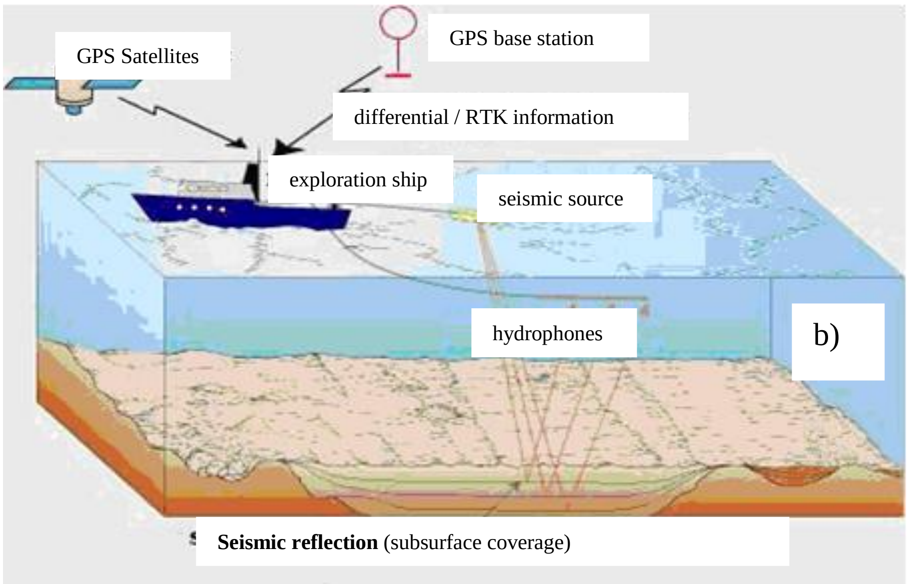


Figure 1. Geometry of seismic research on land (a) and in water (b).

In picture No 2, we can see the scheme and image of seismic reflective research, whose final goal is obtaining the high quality record of seismic waves and clear perception of reflection boundaries that is shown in the seismogram [8-10].

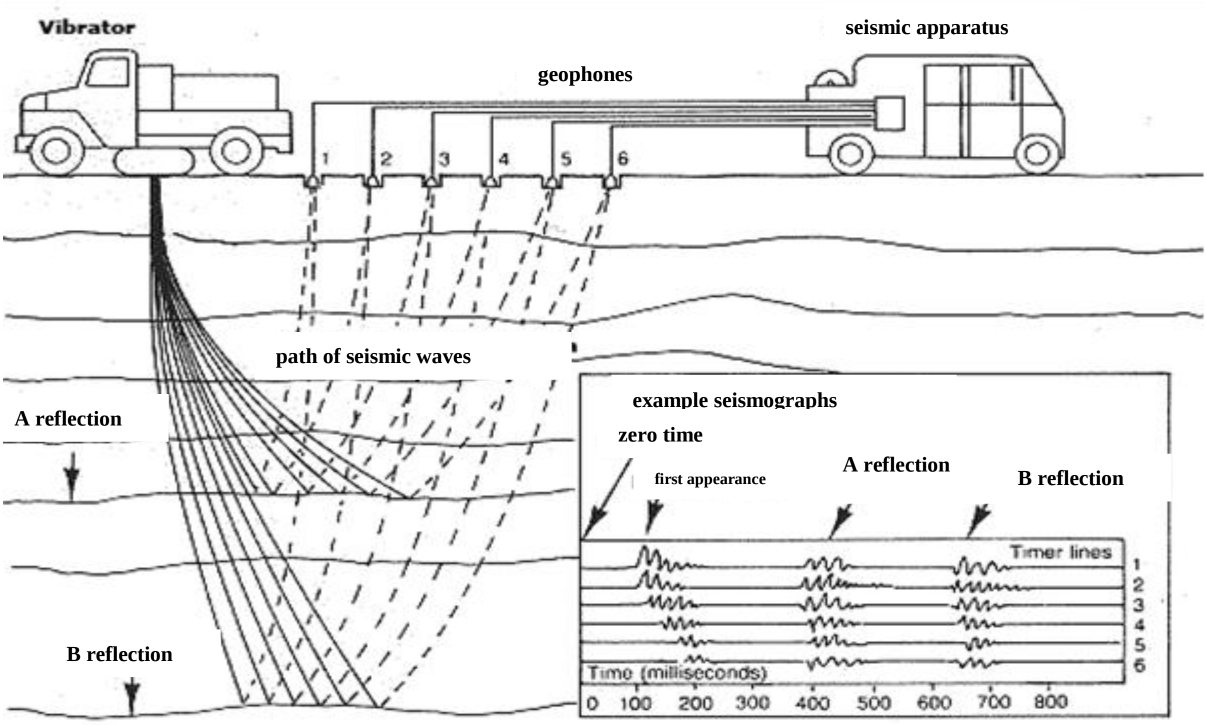


Figure 2. Schematic presentation of 2D seismic reflective research

PROBLEMS WITH THE PERFORMANCE OF SEISMIC ACQUISITION WITH THE AIM OF PROTECTING THE ENVIRONMENT

Seismic reflection tests have been performed in non-urban areas for years, very often in inaccessible areas. The accompanying problems were inaccessibility of measuring points, the safety of workmen and equipment as well as the removal of spatial barriers.
Seismatic tests, done in marine and terrestrial environments, were accompanied by different types of problems, such as different weather conditions, sea waves, navigation, sea currents etc.
As we approached research areas with higher population density, problems with test performance have gained in importance [11-13]. These problems that might arise in urban areas could be classified into the following categories:

- Technical problems, related to the sources of seismic waves and perception line as well as seismic energy receivers,
- Problems related to the quality of seismic signals,
- Problems related to workmen`s and equipment`s safety,
- Problems related to the protection of facilities,
- Ecological problems.

MEANS OF OVERCOMING THE PROBLEM OF SEISMIC RESEARCH PERFORMANCE WITH THE AIM OF PROTECTING THE ENVIRONMENT

Adequate precaution measures are being taken, depending on the type of problem that might arise during the seismic testing in various areas: urban areas, industrial zones with a high level of activity, areas of special importance etc.
Different companies that carry out seismic tests deal with this problem in accordance with the permission they were granted and their technical and technological capacities as well as the budget money they have to set aside for the removal of damages, damage prevention and gathering the information. This money is also necessary to obtain high quality seismic signals under unfavourable conditions.
Technical problems related to the source of seismic waves and their reception are being removed in the research area, while obeying the all the rules and regulations. It is necessary to implement all the regulations in the most economical way. In the case of seismic energy sources, this could be done in the following manner by:

- Using the approved quantity of explosive;
- Drilling deeper shafts (10 metres and higher);
- Having less number of shafts in »source figure of seismic waves«;
- Having less number of vibrations and less vibration energy;
- Preliminary processing in REC, which eliminates the disruptions and raises the level of useful signal;
- Transferring the receivers of seismic waves, i.e. reception line and emitting seismic energy from the source that is at a safe distance;
- Replacing the types of seismic energy (an offensive with a less offensive one),
- Interpolation or extrapolation of data in REC or in the phase of preliminary processing in the research area;
- Interpolation or extrapolation of data in the course of seismic interpretation.

Problems with setting the receivers and reception line seldom appear. However, they are accompanied by other issues. If it is being set in the city with artificial surfaces, high noise levels and spatial barriers, we need to remove all the obstacles either during the data recording or data processing. This problem could be solved by:

- Stopping the traffic flow, if possible, or working when the roads are empty of traffic;
- Stopping the flow of people and animals and eliminating the influence of noise;
- Eliminating all the obstacles while recording; e.g. elimination of electricity influence (50 Hz in Europe or 60 Hz in USA);

- Eliminating the disruptions in REC in the research area in seismic apparatus or during the phase of preliminary processing;
- If the disruptions remain during the processing and interpretation, we need to file them with the research data, which follow all the technological phases of acquisition.

If we cannot solve this problem in an adequate way, we need to apply the seismic line that follows the surface that is suitable for carrying out tests. That is the so called »slalom or zig-zag line«. Apart from this line, we can use other types of seismic lines, such as parallel lines, adjusted to the conditions of terrain selected for observation.

Workmen`s safety problems are being handled by taking certain precaution measures, set by the law. In nearly all the countries, the implementation of these measures is defined by the law. In order to work without disruptions and obtain a high quality seismic record, we need to obey the regulations and use all the available technical and technological advances of seismic apparatuses [14,15].

Facilities` safety problems that might appear are handled by:

1. Respecting the regulations set by the law and the codex of professional conduct in the observation area;
2. Registering the influence of seismic waves sources in the case of vibrations or explosive;
3. Providing the support of engineering geophysics team that registers and evaluates the influence of seismic movements of different origins.

Requests imposed by the contemporary technology as well as the new way of living are often very harsh. Therefore, industrial complexes are often built in areas with natural or man-made monuments that represent a blend of beauty and usefulness.
Geological activities are not destructive and they are close to the ecological principles and the Nature-Man-Civilisation relation.
Artificial earthquakes that seismics utilizes are harmless to the surrounding environment. The moment they cross the safety boundaries, we need to take measures that will enable the safety of all participants in the seismic testing and at the same time provide a high quality seismic record. Having analysed these records we can find valuable fluids, oil and gas now and water in the future.
There are a number of instances of seismic tests in urban areas. In Europe, seismic lines went through the centre of big cities and traffic and industrial networks. Seismic tests were carefully conducted so that cultural heritage of these cities was not damaged.
Many times, teams that performed seismic tests conducted their lines through inhabited areas and in the vicinity of cultural monuments and caused no harm to the surrounding environment.
During the seismic research, we often use seismic reflection method, and for the source of seismic waves we use vibrators, such as the one shown in picture No2.
Depending on the nature of the research task and the conditions dictated by the urban area used for seismic tests, we can use a different number of vibrators per source of seismic waves.
Vibrators` performance is controlled by geophysicists, whose responsibility is to supervise seismic vibrations caused by the motion and operation of vibrators.
With all the modern equipment that registers vibrations in the above mentioned situations and the equipment for measuring the effects of mining, when the source for seismic waves was the explosive located on the surface, we successfully recorded all the negative effects that could be initiated by the artificial source of seismic waves.
Most world companies that perform seismic acquisition tend to inform the inhabitants in the research area that seismic tests will be done. If the company causes any damage, the inhabitants will be indemnified against any loss. However, when we perform observations in urban areas, we tend to minimize the possible damages.
Sometimes it is necessary to remove certain »obstacles« during the research and then return them to their initial position when the research is over. Reconstruction is being done by the reconstruction specialists depending on the type of so called obstacles; it could be a historical monument or horticulture. Therefore, the use of GPS orientation equipment is of paramount importance nowadays.

The law defines ecological requirements that need to be fulfilled when performing tests. During the seismic tests, we conform to all the above mentioned requirements thanks to the highly sophisticated seismic tests that use advanced technology to register seismic signals.
From an ecological point of view, an important part of seismic testing represents an adequate and purposeful use of recording geometry. In picture 3, we can see a 3D scheme of seismic tests performed in the area with high ecological standards.

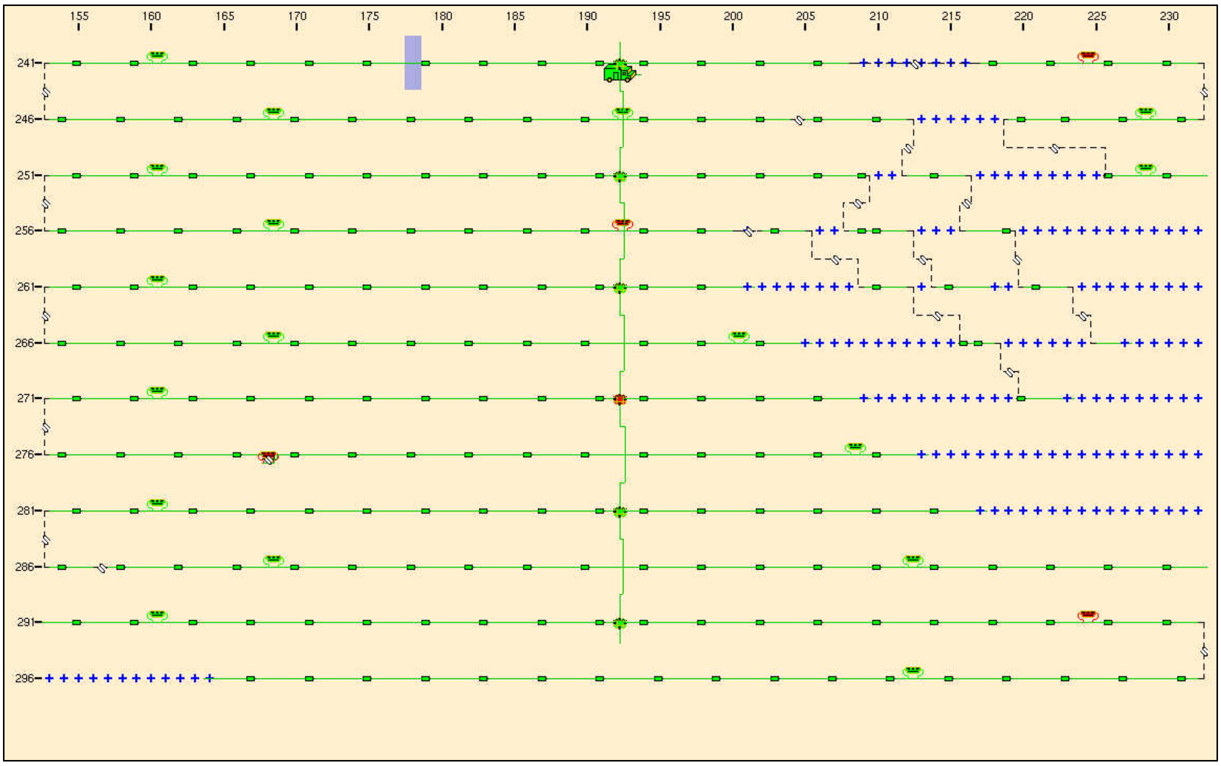


Figure 3. Seismic line under complex conditions in the research area

CONCLUSION

Nowadays, seismic research as well as any type of human activity has to meet the high ecological standards. All the problems that might accompany the performance of seismic tests could be successfully solved if:

- we continually keep up with technical and technological advancements related to seismic research,
- we hire competent and responsible researchers,
- we prepare research thesis in advance while adhering to all the rules and regulations,
- we provide continual and rigorous supervision of data quality as well as ecological conditions

This piece of work is a compilation of several thesis from the domain of seismic acquisition and authors` experience. It has been written in popular style in order to introduce a broad spectrum of people with seismic research and ecological requirements. Our goal is to obtain a high quality seismic record while respecting all the environmental laws and regulations.

REFERENCES

[1] Stanic S., Ružic R., Zoric L. and Vitas-Djokic Z., Possibilities Of Application Comparative Analysis Of Seismic Migration In 2D Seismic Data Reprocessing, 4th Congress of the Balkan Geophysical Society (2005).

[2] Stanic S., Djordjevic K., Pavlovic Z. and Negovan K., Seismic Data Acquisition in Urban and Industrial Zones, 4th Congress of the Balkan Geophysical Society, (2005).

[3] Stosic P., Stanic S., Control of induced earthquakes during seismic oil-geological exploration. International Geological Congress, Congres Geologique International, Resumes 32, Part 2: 1342, 2004.

[4] Husejnagic E., Stanic S., Boškovic Z., Rešavanje problema inženjerske geofizike i hidrogeologije primjenom seizmike, Rudarsko-Geološko-Građevinski fakultet, ISSN 1512-7044, Tuzla, 2010.

[5] Stanic S., Application of seismic migration in hyudrocarbons detection, 4th National Geophysical Conference with International Participation, Sofija, Bulgaria, p.196-198, 2004.

[6] Stanic S., Solving problems of seismic data acquisition in the setthements of Serbia and Montenegro. 4th National Geophysical Conference with International Participation, Sofija, pp. 198-200, 2004

[7] Stanic S., Petroleum - Geological exploration of karst terrains, p.551- 554, 2005.

[8] Stanic S., Komatina S., Seismologic Investigations, Geodynamics of Balkan Peninsula, Monograph, No. 5(80), 2006.

[9] Stanic S., Doprinos rada Nikole Tesle razvoju seizmike, DIT NIS-Naftagas, god. XXIII, Avgust P. 1- 8, 2006.

[10] Stanic S., Ravilic M., Izvođenje seizmičke akvizicije u složenim uslovima, DIT NIS-Naftagas, br. 37, god. XXIV, 2007

[11] Boskovic Z., Husejnagic E., Čebašek V., Stanic. S., Aplication of local cement for cementing oil wells the south eastern region of the Pannonian basin, 21st International Mining Congress of Turkey, Turkey, 2009.

[12] Stanic S., Nikola Tesla seismicist, 5 th. Congress of the Balkan Geophysical society, 2009.

[13] Stanic S., Komatina S., Doprinos seizmičkih ispitivanja rešavanju problema zaštite životne sredine, 5.th. Congress of the Balkan Geophysical society, 2009.

[14] Ravilic M. , Stanic S., Implementation of a program for the control of data quality during seismic reflective research, A compilation of works "Current trends in geophysics advancement", Belgrade, 1996.

[15] Stefanov S., Biocanin R., Miloradov M., Bancov S., Ecological Modelling of Industrial Pollutants - Serbian Case, Journal of Environmental Protection and Ecology, vol. 13 br. 4, pp. 2068- 207E, 2012.

[16] Ketin S., Sacirovic S., Sacirovic S., Plojovic S., Skrijelj R., Biocanin R., Method for Comparison of the Maximum Range of Chemical Pollutants, ISSN 1070-3632, Russian Journal of General Chemistry, Vol. 84, No. 13. pp. 2677-2680, 2014.

COLLECTING ELV RECYCLING CENTERS FOR CIRCULAR ECONOMY REQUIREMENTS

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Abstract: The circular economy is extremely important for achieving sustainable development, to which the international community has agreed and committed itself. In EU countries and other developed countries, the struggle for the reuse of resources is taking a long time since the need to change the concept of a global economy has become a necessity. This paper aims to analyze and briefly describe the functioning and organization of recycling centers in some EU countries that represent examples of good practice in the field of waste recycling, with the aim to illustrate the positive practices of the countries of the European Union that are one of the leaders in this field, the basis for the development of a more efficient and sustainable recycling system in the Republic of Serbia.
Key words: recycling centers, recycling, circular economy, waste management, End of Life Vehicles (ELVs)

INTRODUCTION

The principle of circulation of matter in nature has long been known, and today it has become necessary to introduce the principle of circulation and production in order to minimize the production of waste, and the previously obtained products have a new purpose after rebuilding or a completely new form and purpose after recycling.
In contrast to linear, the tendency is towards a sustainable development in the form of a circular economy that represents a closed system in which it is reused and recycled. The circular economy provides a reduction in the use of raw materials to optimize the use of by-products, waste and recycling of rejected products as the primary source of materials for the production and reduction of pollution at all stages of the cycle (Figure 1). [1]

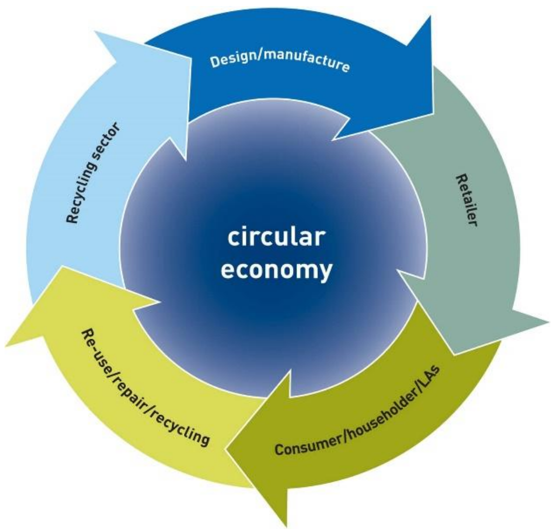

Figure 1. Circular Economy Model [2]

Recycling and treatment of waste represents the first major step in changing the way of thinking of businessmen and the overall cultural orientation of the society. Linear economy received it opposing the concept that, instead of the movement of matter and energy in one direction is represented by the rotation of the energy and materials - a concept known as the circular economy. [3]

CIRCULAR ECONOMY - INSTRUMENT FOR SUSTAINING SUSTAINABLE DEVELOPMENT

The term "sustainable development" entered the general term in the 80s of the 20th century with the aim of indicating the connection between environmental protection and development.
The circular economy represents a new, more sustainable economic approach that should replace the widely represented and worn-out linear model. Traditionally, the current concept of life has been based on the policy of taking, exploitation and rejection, while the circular model advocates return to nature and the reuse of already used products. Drawing attention to energy efficiency and ecological sustainability is the basis of this way of thinking and can be applied to all aspects of life. According to the World Economic Forum, Switzerland is the country with the best attitude towards the natural environment and the significant extent of the use of renewable energy sources. [3]
The circular economy is extremely important for achieving sustainable development, to which the international community has agreed and committed itself. In EU countries and other developed countries, the struggle for re-use of resources is taking a long time since the need to change the concept of a global economy has become a necessity. [4,5]
Recycling is at the base of the changes that are needed in the fight against climate change. It leads to reduction of carbon dioxide emissions, reduces the exploitation of natural resources, is a valuable source of secondary raw materials for the industry, but it also has great economic potential. The EU counts that if the goal of recycling 70% of waste is achieved, about half a million new jobs could be created [6].

The situation in Serbia and potential opportunities for the development of the circular economy

EU Action Plan for the circular economy
Circular economic package gives a clear signal to EU businessmen using all the tools that are available to transform their economies, opening the way for new business opportunities and increasing competitiveness. Broader measures to change the entire life cycle of the product beyond a narrow focus on the completion stage of life and emphasize the clear ambition of the Commission to transform the EU economy and bring adequate results. Innovative and more efficient ways of production and consumption should be increasingly occurring as a result of incentives being put in place. Application of the principle of circular economy has the potential to establish a significant number of new jobs in Europe, while preserving valuable and dwindling natural resources, reducing the impact of resource use on the environment and add value, notably economic, social and social, waste materials. Were determined and sectoral measures, as well as key activities include:

- Funding in the amount of over 650 million euros under the program Horizon 2020 and the 5.5 billion under the Structural Funds;
- Development of quality standards of secondary raw materials to increase the confidence of operators in the single market;
- Measures in the Work Plan of the Eco-design promote increased possibilities of repair of waste products, increasing their endurance and the possibility of a greater level of recycling, increasing the energy efficiency of these products;
- The revised Regulation on fertilizers, in order to facilitate the identification of organic fertilizers and fertilizers based on waste in the single EU market and support the role of biological nutrients;
- The strategy of plastics in a circular economy, which addresses the issues recyclability, biodegradability, presence of hazardous materials in plastic in order to achieve the goals of sustainable development with a significant reduction in the amount of waste ending up in the seas;
- Several other activities in the re-use of water, including the legislative proposal on the minimum requirements for the reuse of wastewater. [7]

Waste recycling

Waste is any material or object which is formed in the course of their production, service or other activities, the objects taken out of operation, as well as waste materials generated in the consumer and which, from the producer, or the consumer are not for further use and must be discarded.

Inadequate waste management is one of the biggest problems in terms of environmental protection of the Republic of Serbia and exclusively the result of inadequate attitude of the society towards waste. It was first reported in the period of rapid industrialization of the country, which followed the real danger of depletion of some strategic resources in a very short period and the progressive increase in the total amount of all types of solid waste. These developments were not accompanied by appropriate environmental policies. [7]

National Waste Management Strategy

National Waste Management Strategy is a basic document which provides conditions for the rational and sustainable waste management at the national level (in Serbia).

In order to overcome these problems in the National Strategy shows the solution involving the formation of a network of five types of infrastructure in Serbia in the function of efficient waste management, which are shown in the table 1.

Table 1. Network of five types of infrastructure in Serbia [7]

Type of Property	Objects
Regional landfill	29
Transfer stations	44
Recycling centers∗	17
Centers for composting	7
Municipal solid waste incinerators	4

∗ Recycling centers - The place of recycling of the waste materials in the production process for the original purpose, organic or recycling purposes other than for energy

The development of recycling of waste is one of the key preconditions for successful coping with the challenges of today's environmental protection. The socio-economic benefits that are reflected in the development of the recycling industry and the creation of new jobs have contributed to the strengthening of the competitiveness of cities and local communities. [7]

Waste recycling in EU countries

Slovenia, as one of the smallest countries in the European Union (about 2 million inhabitants) managed to quickly adopt European standards in the field of waste management and to approach the European level. When we look at other countries in the region, Slovenia is a good example of positive practice when it comes to waste recycling and generally waste management. Ljubljana is one of the first European cities to adopt the "Zero Waste Europe" model (the EU program dealing with the design and management of production processes to reduce the amount and toxicity of waste, while promoting recycling to save resources). [8]

Germany is one of the world's leaders in the field of waste management. The waste management system is regulated by numerous laws, regulations and regulations that are in line with European directives in this field. The efficiency of the waste management system in Germany is not the result of the adoption of laws and their application, but also a high level of public awareness of the importance of environmental protection. The promotion of recycling has led to the fact that the citizens of Germany actively participate in the recycling process not only in habits, but also in need. Waste is considered as raw material and the inhabitants of Germany are aware that inadequate waste disposal is a waste of money. The increase in standards has led to an increase in waste quantities and citizens have been faced with the great problem of its accumulation, and then as an effective solution, recycling, which in this country reaches an extremely high level, is imposing. [8]

The biggest problem of every country is waste. There are many landfills to which no one pays attention, but everyone wants to remove and clean them as soon as possible. In highly developed countries, such as Sweden and Norway, recycling is at an enviable level. More than 50% of waste is recycled in the European Union. France, Germany, Austria and Switzerland are unrivaled leaders in the recycling of packaging waste.
Although only 15% of waste is recycled in Serbia, this industrial branch goes upward. There are over 2000 companies dealing with the collection of secondary raw materials and recycling of waste.

RECYCLING CENTERS

An important part of the recycling system of waste is recycling centers. Recycling center is a functional environment, that is, an object / space equipped with appropriate equipment and machines, and as such is a place intended for separation and temporary storage of recyclable and bulky waste. These facilities play a very important role in the waste collection system, connecting citizens, collectors and operators, and in providing enough quantities of recyclable raw materials for the development of the recycling industry. The operation and functioning of recycling centers proved to be very cost-effective in European countries such as: Austria, Germany and Belgium where recycling rates exceed 50%, followed by Great Britain, Finland, Slovenia at the very top. Among the latter in this area are less developed countries such as Latvia, Lithuania, Slovakia and others. [8]
The Ministry of Environmental Protection plans to open several recycling centers for plastics and other waste in Serbia recently, which would create not only a good waste recycling system, but also through which employment will find more unemployed persons across Serbia.
From the above text it can be concluded that private sector participation, which is largely represented in EU countries, can additionally contribute to better organization, functioning and efficiency of recycling of waste within the framework of recycling centers, i.e. the experience of public-private partnerships has shown good results. The recycling industry in the Republic of Serbia is at the very beginning, the challenges we are facing in the field of waste management are big, but not insurmountable. The next period will show whether we are ready to properly use the proven European experiences.

End of Life Vehicles (ELVs) aspect in Serbia

At the beginning of mass car production and creating a car waste that have completed their life cycle, the idea emerged that certain parts of such cars can be reused (e.g. as spare parts). The car is a complex product and its life cycle should be in accordance with the cycle of circulation of raw materials. It should be recyclable as much as possible, and thus becomes an environmentally friendly product. [9, 10, 11].
Examining the legislation, primarily by considering the current general situation in the field of ELV (End of Life Vehicles) recycling in our country, the following can be concluded: ELV generally cannot act in a manner that ensures the environmental protection; ELV recycling system is not established because there is no globally organized management of such waste.
The overall aim of the Waste Management Plan is to establish an effective system for the management of waste vehicles in Serbia, including Legal, Institutional and Technical aspects. To achieve this goal, it was assessed the current situation regarding ELVs and it were identified deficiencies in the legal framework and implementation in practice. The main objective of EU Directive about ELV is synchronization of different national measures about ELV in order to minimize the ELV impact on the environment thereby contributing to the protection, conservation and improvement of environmental quality and conservation of energy. [12]
ELV dismantling centers are becoming a very topical issue in Serbia since efforts are being made to bring closer the standards in the EU countries. Like all other organizations, ELV dismantling centers face various risks and uncertainties in business. Bearing in mind that the network of ELV dismantling centers in Serbia is developing, it can be clearly seen that their business should be thoroughly studied as well as the interactions of the environment and the environment. Given the need to invest a lot in the development of the network of centers, the assessment of all the risks in their business becomes inevitable, and the definition of recovery capacity metrics becomes imperative. [13]

Vehicle manufacturers across Europe have their own concept of recycling ELV and a developed network of recycling centers. The goal of the manufacturer is to minimize unwanted environmental impacts throughout the vehicle's life cycle. For this reason, even at the design stage of the vehicle, the requirements for recycling are considered - the time required for the dismantling of the ELV, the selection of recyclable materials, the calculation of the time that will be foreseen for exploitation.
Based on the presented state, it can be concluded that the recycling centers are very necessary for Serbia and that their construction and sustainable development will significantly improve the domestic industry. In order to ensure their smooth operation and existence in stable but also crisis situations, it is necessary to provide guidelines on assessing their recovery capacity in case of any performance decline during work. [13]

CONCLUSION

Natural raw materials are limited and their availability and benefits in creating a new value can be extended using a circular economy. The concept of transition implies processes through which we strive to achieve economic growth and development.
The transition in terms of the improvement process represents the need to abandon the existing linear economy and find a better concept. For the abandonment of the concept of linear economy and the transition to the concept of a circular economy, changes in the system of values are necessary: education; defining and publishing new policy changes; changing consumer preferences and habits and developing new forms of behavior; organization of society; innovation in technology and other activities: new product design and business processes; designing, implementing and developing new business and market models; creating an appropriate institutional framework; creating appropriate material infrastructure; development of new methods for managing integrated systems; development of new financial products that support the concept of circular economy; development of a waste management system.
The car industry has greatly progressed in reducing the amount of ELV waste going to landfill and significantly increased the level of recycling and recovery. In this paper, we reviewed the current situation in Serbia and some EU countries. The main recommendations are to develop a shared vision and increase collaboration between stakeholders.
Recycling centers in EU countries are examples of good practice, models that should be used as a starting point in the field of recycling of waste in the Republic of Serbia. Recycling, recycling centers and transfer stations in our country are defined by legal and planning documents based on European experience. But this alone is not enough to achieve the high standards that these Member States have set before us.
The construction of recycling centers will make sense only with the education of the public and the promotion of recycling as a socially responsible behavior.

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REFERENCES

[1] Sassanelli, C., Rosa, P., Rocca, R., Terzi, S., Circular Economy performance assessment methods: a systematic literature review, Journal of Cleaner, Production, 2019., doi: 10.1016/j.jclepro.2019.05.019
[2] https://www.libertas.hr/za-studente/sto-je-cirkularna-ekonomija-i-kako-utjece-na-novi-svjetski-poredak-i-stvaranje-novih-radnih-mjesta/ (accessed on May 2019)
[3] Radivojević, A., Circular economy - implementation and technology application in its function, Ekonomske ideje i praksa, 28, pp. 33-46, 2018.

[4] Eco Efficiency Consulting and Engineering Ltd. in collaboration with WEFalck, Pöyry Finland Oy, Botond Kertész & CRS Ingenería, Development of a guidance document on best practices in the Extractive Waste Management Plans - Circular Economy Action, January 2019. https://ec.europa.eu/environment/waste/mining/pdf/guidance_extractive_waste.pdf (accessed on June 2019)
[5] European commission, Sustainable Products in a Circular Economy - Towards an EU Product Policy Framework contributing to the Circular Economy, Brussels, March 2019., https://ec.europa.eu/environment/circular-economy/ (accessed on June 2019)
[6] Desnica, E., Selection of Maintenance Strategies for Automobile Shredder Residue – Reliability, Economic and Human Resources Aspect, 18th International conference on social sciences, Lisbon, pp. 386-493, 2019.
[7] http://www.sepa.gov.rs/ (accessed on June 2019)
[8] Ružić, M, Lukić, A., Recycling centres in EU countries – experiences from Croatia, Slovenia and Germany, Conference: Druga ekološka konferencija "Smederevo ekološki grad", Smederevo, 2016.
[9] Desnica, E., Popescu, F., Nikolić, M., Vulić, M., Education strategy analysis and development of human resources in the field of elv recycling, VII International Symposium Engineering management and competitiveness – EMC 2017, Zrenjanin, pp. 124-128, 2017.
[10] Despeisse, M., Kishita, Y., Nakano, M., sBarwood, M., Towards a Circular Economy for End-of-Life Vehicles: A Comparative Study UK – Japan, Procedia CIRP, 29, pp. 668–673, 2015., doi:10.1016/j.procir.2015.02.122
[11] Lorz. B., The ELV Directive as an instrument to drive circular economy in the automotive industry, Internacional conference Driving towards circularity, Bratislava, 6/7 November, 2017.
[12] Desnica, E., Vulić, M., Pavlović, A., Nikolić, M., ELV managing through analysis of resource capacities of the Serbia: equipment, human resource and financial support, 13th International scientific conference MMA 2018 Flexible technologies, Novi Sad, pp. 305-308, 2018.
[13] Pavlović, A., The research contributions of an integrated management model of motor vehicles at the end of life cycle to the development of the Republic of Serbia,Doctoral dissertation, University of Novi Sad, Technical faculty “Mihajlo Pupin”, Zrenjanin, Serbia 2016.

CAUSES OF AIR POLLUTION AND HEALTH RISK TO THE URBAN POPULATION OF SERBIA

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Abstract: This paper presents a comparative analysis of air quality in Serbian cities and the incidence of respiratory and other diseases that can be caused by excessive air pollution. Central focus is given to cities with excessive air pollution. The officially registered concentrations of air pollutants were used as benchmarks for calculating the hazard quotient for the general and individual health risk of the exposed population, according to US EPA methodology. The results of the analysis confirmed a cause-and-effect relationship between the level of air pollution and health risk.
Key words: air pollution, hazard quotient, probability of cancer risk, health risk

INTRODUCTION

The effects of air pollutants on human health vary depending on such factors as type of pollution, duration and level of exposure, individual sensitivity of the body, and characteristic toxicity of a pollutant. The most common effects of air pollutants on human health are the following: reduced lung function, asthma attacks, respiratory diseases, cardiovascular diseases, lowered immunity, and carcinogenic diseases.
Since the picture of individual exposure to a pollutant becomes clearer only after considering the physical and health status of the individual, it is impossible to establish a linear connection between pollutant concentration in the atmosphere and the negative impact of pollutant on the individual. The interaction between a pollutant and the human body depends on the physicochemical properties of the pollutant as well as on the physiognomy of the receiving exposed individuals, which includes their anatomic and physiological characteristics. Important characteristics of pollutants that affect the health of exposed individuals include: state of matter (gas, aerosol), concentration in the air, chemical properties, and temporal and spatial distribution in the body. Important anatomic parameters of individuals are related to the size and structure of the receiving system (e.g. the respiratory system), while important physiological characteristics include body weight and respiratory rate. All these factors affect the absorption, metabolism, and excretion of pollutants, so their threshold values are not the same for different individuals within a population (e.g. children, elderly persons, or persons suffering from chronic diseases).

METHODOLOGY

The connection between urban air pollution, air quality, and health risk can be verified by means of causal analysis. Causal analysis is based on the processing of statistical data of measured atmospheric concentrations of standard air pollutants, on the evaluation of air quality, and on the determination of health risk in the exposed population.
Evaluation of the state of air pollution in Serbia is performed according to the Law on Air Protection ("Official Gazette of the Republic of Serbia", No. 36/09 and 10/2013) and according to the Regulation on Monitoring Conditions and Air Quality Requirements ("Official Gazette of the Republic of Serbia", No. 11/2010, 75/2010, and 63/2013).
According to the Law on Air Protection, air quality is defined in terms of pollutant concentrations in the air or suspended particulate matter on the surface over a specific period of time.
Based on the results of pollutant concentration measurements, the following air quality categories are established (Figure 1) [1, 2]:

1) **Category I** – clean or slightly polluted air; limit values are not exceeded for any pollutant;
2) **Category II** – moderately polluted air; limit values exceeded for one or more pollutants but tolerable values not exceeded for any pollutant;

3) **Category III** – highly polluted air; tolerable values exceeded for one or more pollutants. If a pollutant has no prescribed tolerable limit, its limit value is taken as the tolerable value.

National positive legislation that regulates the monitoring, assessment, and management of air quality does not regulate the procedure required to establish the correlation between the effect of short- and/or long-term exposures to air pollutants and their impact on the exposed population. This is a significant shortcoming in terms of prompt notification of the public and implementation of adequate safety measures.

Health risk level in the exposed population can be determined according to the U.S. EPA recommendations.

Measurement of pollutant concentrations in ambient air is followed by the characterization of health risk to the exposed population.

Risk characterization involves a unification of data on the toxicity of a specified chemical agent to which a subgroup of the human population is exposed and data on the characteristics of exposure.

For the purpose of assessing carcinogenic effects due to long-term exposure to pollutants, the potentially higher risk of carcinogenic diseases can be determined as a product of exposure and carcinogenic coefficient, established for every carcinogenic pollutant. The potentially higher risk of an individual in subgroup *y* developing cancer due to exposure to pollutant *x* is:

$$ICR_{i,x,y} = E_{i,x,y} \cdot SF_x \qquad (1)$$

where: $ICR_{i,x,y}$ – probability of individual cancer risk for individual *y* exposed to pollutant *x* in environment *i*, SF_x – carcinogenic coefficient of pollutant *x* [mg/kg/day].

Exposure can be expressed using the following physical equation [3]:

$$E_{i,x,y} = 0{,}001 \cdot C_{i,x} \left(\frac{IR_y}{BW_y}\right)\left(\frac{ED_i \cdot ET_i \cdot EF_i}{AT_x}\right), \qquad (2)$$

where: $E_{i,x,y}$ – exposure, or the average uptake of pollutant *x* as a function of time, for the representative individual *y* in the observed subgroup in environment *i* [mg/kg per day].

Individual health risk R_i can be calculated through the potential dose and the SFI (Inhalation Slope Factor).

$$SFI = \text{unit risk } (\mu g/m^3)^{-1} \cdot BW\ (kg) \cdot IR\ (m^3/day)^{-1} \qquad (3)$$

The U.S. EPA recommendation presupposes that non-carcinogenic effects occur only when the exposure threshold of a chemical agent's reference dose (*RfD*) has been exceeded. For air pollutant exposure, the EPA established a reference concentration (*RfC*), which represents the exposure concentration threshold below which, even with continuous inhalation, there are no detrimental health effects on humans, including the highly-sensitive population.

The increased probability of health risk in individual *y* exposed to non-carcinogenic pollutant *x* in a given subgroup in environment *i* can be obtained by calculating the health risk hazard quotient (*HQ*) [3].

$$HQ_{i,x,y} = \frac{E_{i,x,y}}{RfD} \qquad (4)$$

where: $HQ_{i,x,y}$ – health risk hazard quotient for non-carcinogenic substances (dimensionless quantity).

Health risk *HQ* for non-carcinogenic substances implies the existence of an *RfD* below which there is low probability of any detrimental health effects on the exposed population, even on the highly-sensitive population (e.g. children). If the exposure level exceeds this limit, i.e. if the *E/RfD* ratio exceeds 1, there is a possibility of negative non-carcinogenic effects. The bigger the *E/RfD* ratio, the higher is the possibility of detrimental effects. However, during exposure to a mixture containing up to

10 substances, in case of their addition, health risk assessment is performed for each substance based on their *HQ* value.

RESULTS AND DISCUSSION

The aim of this paper is to determine the causality between the state of air quality and the health status of the exposed population. Therefore, the first step was to consider the state of air quality in cities in which air quality is classified as the first, second, or third category. It is possible to search for causality between air pollution and health risk based on air quality state gradation and based on statistical indicators of the population's health status in specific Serbian cities.

Air quality in Serbia (Figure 1) is not the same in every city. There are cities with more prominent air pollution due to various pollution sources, such as industrial facilities, industrial and heating plant boiler facilities, traffic frequency, etc. Serbian cities of Bor, Užice, and Pančevo have high concentrations of SO_2, CO, NO_2, PM_{10} suspended particles, and ground-level O_3, and the air quality state assessment shown in Figure 1 was conducted based on these pollutants. The aforementioned cities are characterized by air quality in the second and third category. In keeping with the aim of the study, it is also necessary to consider a city with category I air quality, which is why Kikinda was selected, as its air quality belongs to the first category (Figure 1).

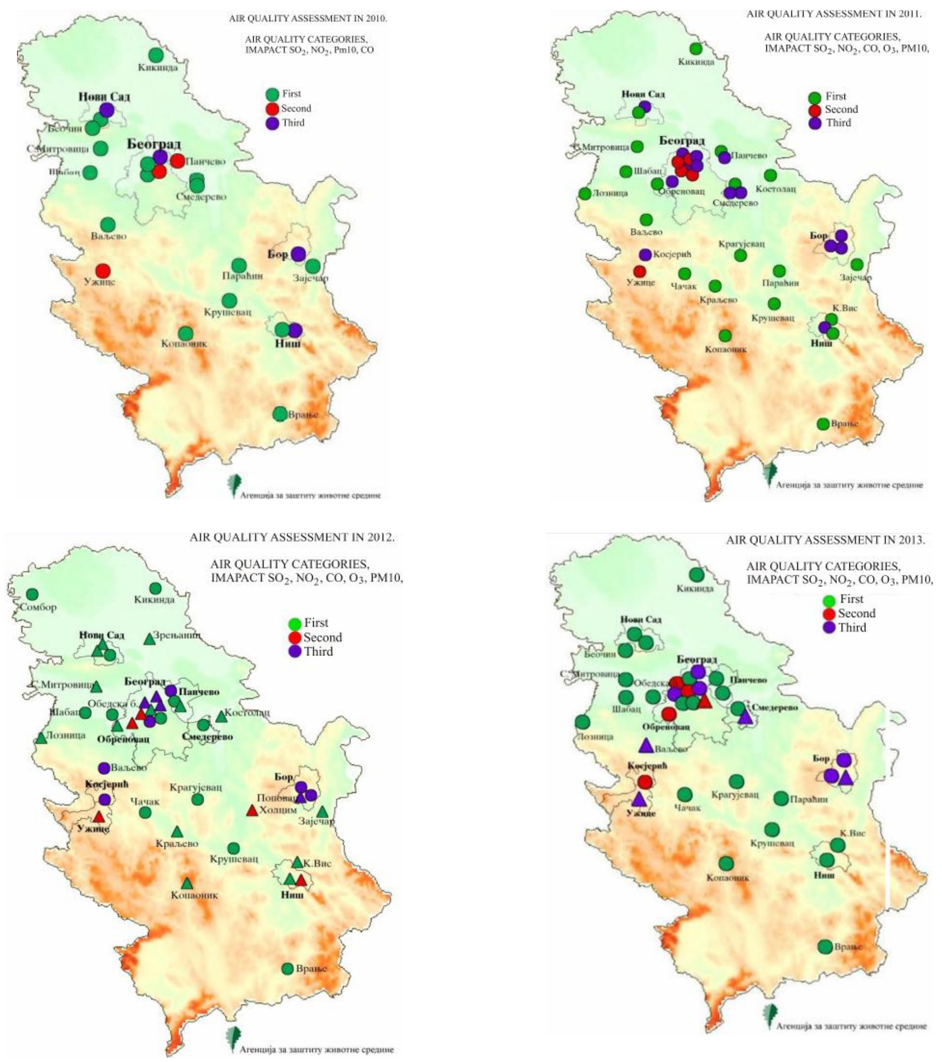

Figure 1. Air quality assessment in Serbian cities in 2010, 2011, 2012, and 2013

Bor is a municipality in Eastern Serbia in the Bor County, Timočka Krajina, which covers an area of 856 km². According to the 2011 census, the municipality has a population of 48,615 in 14 settlements.
The biggest air polluter in Bor is the industry, more specifically, the copper smelting plant located in the centre of the city. All year long sulphur dioxide concentrations substantially exceed the allowed limit values (Figure 2).

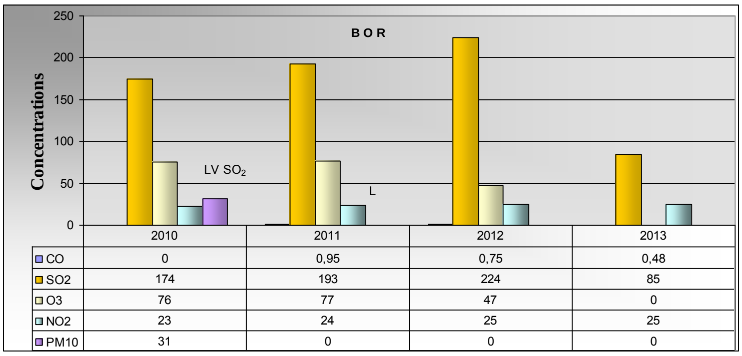

Figure 2. Mean annual values of pollutant concentrations in ambient air with limit values (LV) in Bor in 2010, 2011, 2012, and 2013

Figure 2 shows a comparison of mean annual values of pollutant concentrations between 2010 and 2013 [4].
Užice is a city in Zlatibor County, covering an area of 667 km². According to the 2011 census, its population is 52,646. Užice stretches over elevations from 411 to 600 masl.
The most important air pollution factor in Užice is its valley position and frequent temperature inversions. In Užice, Nitrogen dioxide and PM_{10} concentrations exceed their limit values (Figure 3) [4].

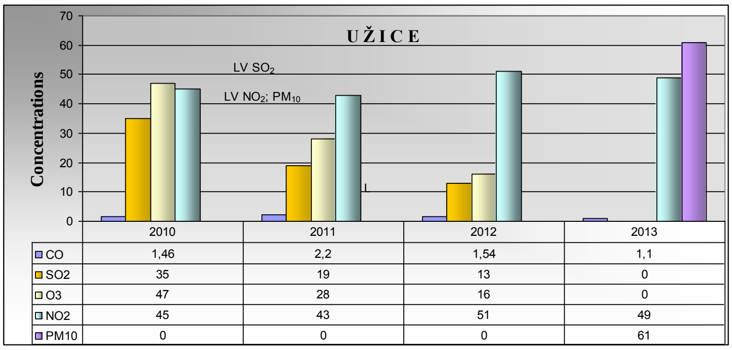

Figure 3. Mean annual values of pollutant concentrations in ambient air with limit values (LV) in Užice in 2010, 2011, 2012, and 2013

Pančevo is a city located in the Autonomous Province of Vojvodina, Republic of Serbia. According to the 2011 census, Pančevo has a population of 76,203, while the entire municipality has a population of 123,414. It covers an area of 148.8 km².
The biggest air polluter in Pančevo is the chemical industry, located along the direction of prevalent winds, and using obsolete technology in facilities that are usually older than 20 years. In Pančevo, PM_{10} particles commonly exceed their concentration limits (Figure 4) [4].
Kikinda is a city located in the Autonomous Province of Vojvodina, Republic of Serbia, covering an area of 189 km^2, at an elevation of 73 masl. According to the 2011 census, Kikinda has a population of 38,065.
Kikinda is one of the cities with the cleanest air in Serbia, i.e. there is no record of the monitored pollutants exceeding their limit values (Figure 5) [4].

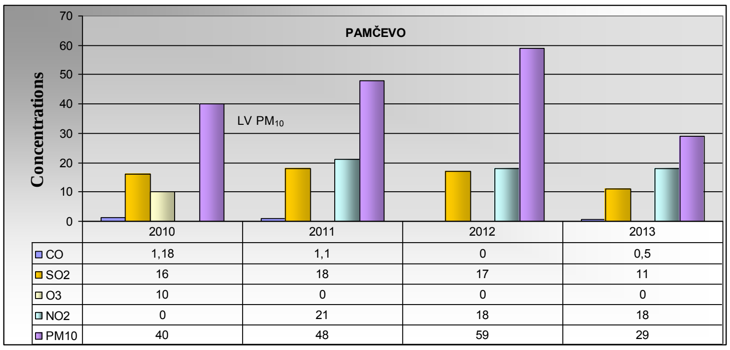

Figure 4. Mean annual values of pollutant concentrations in ambient air with limit values (LV) in Pančevo in 2010, 2011, 2012, and 2013

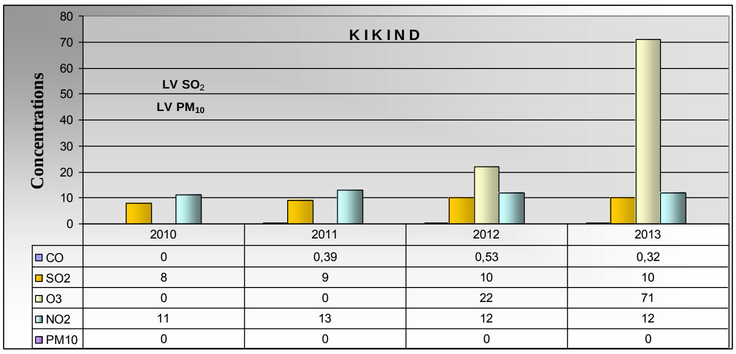

Figure 5. Mean annual values of pollutant concentrations in ambient air with limit values (LV) in Kikinda in 2010, 2011, 2012, and 2013

A comparison of pollutant concentrations in Bor, Užice, Pančevo, and Kikinda (Figure 6) reveals that the average carbon monoxide concentration from 2010 to 2013 was the highest in Užice (1.58 mg/m^3), which is 80.38% higher than in Kikinda, 55.70% than in Pančevo, and 65.19% than in Bor.

Sulphur dioxide concentration from 2010 to 2013 was the highest in Bor, with the average value of 169 µg/m^3, which is 90.09% higher than in Užice, 90.83% than in Pančevo, and 94.53% than in Kikinda.

The highest concentration of ground-level ozone was also registered in Bor at 50 µg/m^3, which is 54.5% higher than in Užice, 95% than in Pančevo, and 53.5% than in Kikinda.

Nitrogen dioxide concentration from 2010 to 2013 was the highest in Užice at 47 µg/m^3, which is 48.40% higher than in Bor, 69.68% than in Pančevo, and 74.47% than in Kikinda.

From 2010 to 2013, Pančevo had the highest value of PM_{10} suspended particles at 44 (µg/m^3), which is 83.52% higher than in Bor, 65.34% higher than in Užice, and 100% than in Kikinda [4].

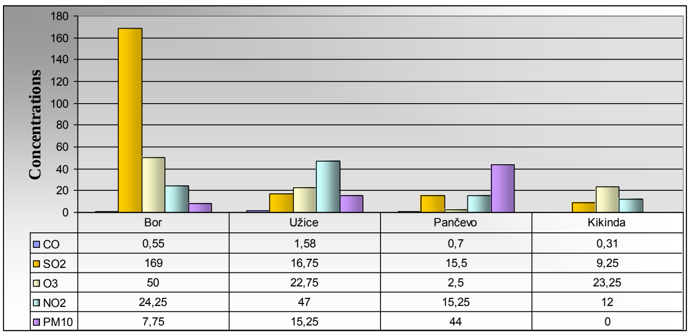

Figure 6. Pollutant comparison in the cities of Bor, Užice, Pančevo, and Kikinda

Air quality in the analyzed cities from 2010 to 2013 is given according to air quality categories in Table 1 below.

Table 1. Air quality in Užice, Pančevo, Bor, and Kikinda from 2010 to 2013

City	**Population**	**Year**			
		2010	2011	**2012**	2013
		Air quality category			
Užice	78,040	II	II	II	III
Pančevo	123,414	II	III	III	I
Bor	48,615	III	III	III	III
Kikinda	59,453	I	I	I	I

In Bor, air quality during the observed period was in the third category. During 2013, 73% of the population, which reside in a densely populated area or near industrial polluters, were potentially exposed to high pollutant concentrations that exceeded their limit values (LV) and tolerable values (TV) (Figure 6).
From 2010 to 2013, Bor had the highest sulphur dioxide concentrations (in 2012 specifically) of 224 ($\mu g/m^3$). Equation (4) was used to calculate the health risk *HQ* values for preschool children aged 3 to 6 for a two-hour exposure during the day, and it amounted to 5.2. *HQ* for the population aged 18 or over for a two-hour exposure was 6.67. Based on these *HQ* values, it is estimated that the health risk in Bor is high.
Over the observed period, an increase in nitrogen dioxide concentrations was registered in Užice, with the highest levels in 2012 at 51 $\mu g/m^3$ (annual LV is 40 $\mu g/m^3$). *HQ* value in relation to NO_2 for a two-hour exposure during the day was 1.59 for preschool children aged 3 to 6 and 2.31 for people aged 18 or over.
Therefore, the value of nitrogen dioxide is 1.27 times higher than the limit value. Since health risk in this city is assessed based on the increase of annual NO_2 concentrations, the health risk in Užice is moderate.
Comparison of *HQ* values for Bor and Užice reveals that the health risk from air pollution is higher in Bor by a range from 30.58% to 34.63%.
Higher probability of health risk in Bor as opposed to Užice is causally connected to the number of registered respiratory diseases in the two cities. Namely, out of the total number of registered disease cases in Bor, 24 % are respiratory diseases, which is about 38 % more than in Užice, where the share of respiratory diseases is only 9.3 %.
During 2013 in Bor, the most common diseases registered in the primary healthcare services were respiratory and vascular diseases (Figure 7) [5].

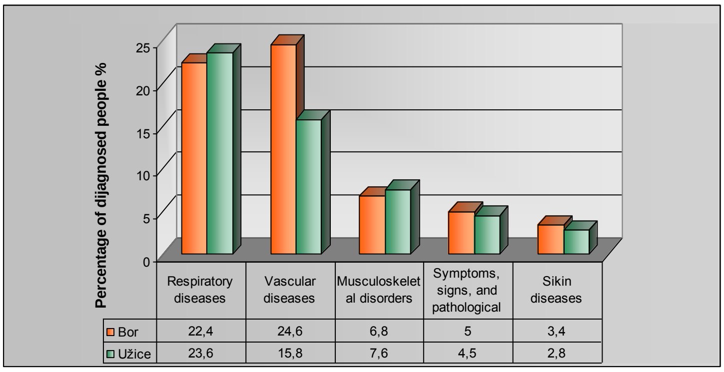

Figure 7. The most common disease groups registered in Bor and Užice

The most common diseases in Užice in 2013 were also respiratory (23.6%) and vascular diseases (15.8%). Figure 7 shows the distribution of the most common diseases in Užice.
According to the available statistical indicators, the most common diseases among adults in the Municipality of Pančevo (Figure 8) are respiratory (22 %) and vascular (19 %) diseases, which is similar to Bor and Užice.

Analysis of diseases among preschool children in Pančevo reveals that preschool children most commonly suffer from respiratory diseases, with as much as a 57% share [5].

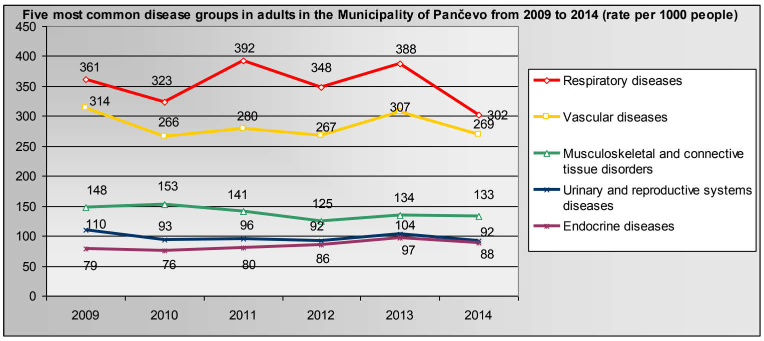

Figure 8. The most common disease groups registered in Pančevo from 2009 to 2014

Pančevo is characterized by excessive concentrations of PM_{10} suspended particles in ambient air, with the highest concentrations registered in 2012 – 59 μg/m^3 (annual LV 50 μg/m^3). Based on the mean annual PM_{10} concentrations, and using equations (1) and (3), the individual risk and the probability of cancer were calculated for a two-hour daily exposure of the exposed population (Table 2).

Table 2. Individual risk and probability of cancer in the population exposed to PM_{10} particles in Pančevo

Exposed population age	Individual risk Ri	Incremental cancer risk ICR
Under 1	1.29 %	$3.083 \cdot 10^{-5}$
1 to 3	7.05 %	$4.793 \cdot 10^{-5}$
3 to 6	17.34 %	$5.577 \cdot 10^{-5}$
Over 18	24.27 %	$7.80 \cdot 10^{-5}$

The calculated probability of cancerous disease risk in the exposed children ranges from $3.083 \cdot 10^{-5}$ to $5.577\ 10^{-5}$, which means that under this exposure the disease could strike three to nine per a million exposed preschool children. The probability of cancer risk due to PM_{10} exposure in the population over 18 in Pančevo is $7.80 \cdot 10^{-5}$, which means that eight out of a million adults could become sick.
In Kikinda, none of the pollutants exceeded their limit values from 2010 to 2013, which means that *HQ* is lower than 1 and that there is no health risk from the standard pollutants in ambient air. Statistical data show that the share of respiratory diseases is 12.6% and the share of vascular diseases 18.3% (data for 2013). Comparison of disease incidence in the analyzed areas reveals a significant difference, which suggests that there is causality between the incidence of (most commonly respiratory) diseases and ambient air quality (Table 3).

Table 3. Air quality and the percentage of respiratory disease cases in Bor, Užice, Pančevo, and Kikinda

City	**Population**	**Year**				
		2010	2011	2012	2013	2013
		Air quality categories				Percentage of respiratory disease cases
Bor	48,615	III	III	III	III	24.0 %
Užice	78,040	II	II	II	III	23.6 %
Pančevo	123,414	II	III	III	I	22.0 %
Kikinda	59,453	I	I	I	I	12.6 %

In recent years, due to increased air pollution, Serbia has had more registered cases of respiratory, vascular, as well as reproductive diseases that diminish the reproductive ability.
Bor, Pančevo, and Užice are among the most polluted cities in Serbia. In the past, the analysis of the health status of the population was based solely on mortality rate data until morbidity rate data were

included in the 20th century. Over the last couple of decades, population health assessment has begun to include the data on the use of healthcare services. Since many diseases and conditions occur not only due to biological factors, but also due to numerous environmental factors, the population health assessment is not complete unless these factors are also considered.

CONCLUSION

Based on this study, it can be concluded that Bor has the highest air pollution, with sulphur dioxide substantially exceeding its limit values over the observed period, from 2010 to 2013, which is directly associated with the large number of respiratory disease cases. As regards the *HQ*, the highest value was calculated for Bor – 4.48 – which represents a quadruple increase of the concentration in relation to the reference dose.

Analysis of the impact of ambient air quality on the health of the exposed population in Bor revealed that the number of people suffering from a respiratory disease is considerably higher than in Kikinda, where the observed standard pollutants did not exceed their limit values.

In Bor, air quality from 2010 to 2013 was in the third quality category, whereas in Kikinda it was in the first category over the same period. Even though Kikinda has a larger population than Bor, the number of respiratory disease cases was much lower, which is apparently due to the absence of large-scale polluters in the city, unlike in Bor, where the main polluter is located in the central part of the city.

REFERENCES

[1] Law on Air Protection, Official Gazette of the Republic of Serbia, No. 36/09 and 10/2013
[2] Regulation on Monitoring Conditions and Air Quality Requirements, Official Gazette of the Republic of Serbia", No. 11/2010, 75/2010 и 63/2013
[3] Richard W. Baldauf, Denis D. Lane and Glen A. Marote: Ambient air quality monitoring network design for assessing human health impacts from exposures to airborne contaminants, University of Kansas, Department of Civil and Environmental Engineering, Lawrence, Kansas, *U.S.A.*, March 1999
[4] Annual report on the state of air quality in the Republic of Serbia.
[5] http://www.batut.org.rs/download/publikacije/pub
[6] http://www.zavodki.org.rs/
[7] Integrated Risk Information System (IRIS). Duluth, MN. U.S. EPA. 2002.
[8] Andrew G. Salmon, M.A., D.Phil.: *Determination of Noncancer Chronic Reference Exposure Levels* - Air Toxicology and Epidemiology Section, Office of Environmental Health Hazard Assessment, California Environmental Protection Agency, February 2000.

APPLICATION OF GAUS MATHEMATICAL MODEL IN DETERMINATION OF GROUND CONCENTRATION AND DISTRIBUTION OF SUMPOR DIOXIDE BEFORE AND AFTER DESULPHURISATION OF CHIMNEY IN THE THERMAL POWER PLANT KOSTOLAC B

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Abstract: The most widespread and harmful pollutant for human health is sulphur dioxide. Coal power plants are the main pollutants of sulphur dioxide. According to the Climate Action Network (CAN), the largest sulphur dioxide pollutant in Europe is the Kostolac B thermal power plant from Serbia, which in 2016 emitted 128,000 tonnes of SO_2 into the atmosphere. For these reasons, the Power Company of Serbia completed the flue gas desulphurisation plant in Kostolac B TPP in 2017, which reduces sulphur dioxide emissions. The paper analyzes the impact of different scenarios (before and after the construction of the desulphurisation plant) of sulphur dioxide emissions from TPP Kostolac B using a Gaussian dispersion model. Ground concentrations of SO_2 at different distances from the thermal power plant were calculated. Based on this, the results of the flue gas dispersion and the distribution of ground concentrations of SO_2 are presented in the paper.
Key words: Kostolac thermal power plant, sulphur dioxide, Gaussian model

INTRODUCTION

Sulphur dioxide (SO_2), one of the most common air pollutants, results from the combustion of fossil fuels rich in sulphur content. Sulphur compounds, as pollutants, emit natural and anthropogenic processes into the atmosphere. Natural systems (atmosphere, biosphere, ocean systems) emit about 1.5 million tonnes of sulphur dioxide annually, accounting for only 1-2 percent of the total amount of SO_2 present. The remaining 98-99 percent come from human activity. In this way, an additional amount of about 140-150 million tonnes per year is introduced into the atmosphere. The most important anthropogenic sources of sulphur dioxide are fossil fuel combustion plants, especially coal. The sulphur content of fossil fuels varies from 1-5%. Most often, about 95% of the sulphur in the fuel is emitted as SO_2, 1-5% as SO_3, and 1-3% as sulphate particles. This is why thermal power plants are considered the largest SO_2 emitters. The highest concentration of SO_2 occurs in urban areas and large industrial centers. Average annual concentrations of SO_2 in urban areas of developing countries are 40-80 $\mu g / m^3$, in urban areas of North America and Europe 10-30$\mu g / m^3$, and in EU Member States 6-35$\mu g / m^3$ (Cho, 2014). Due to its high chemical reactivity, these significant amounts of sulphur dioxide in the atmosphere do not last long. It is estimated that a certain amount of it brought into the atmosphere retains an average of four days. But if new amounts of sulphur dioxide are introduced daily, then high concentrations can be maintained for days. Its toxicity is enhanced under conditions of increased humidity due to the formation of sulfuric acid. Precipitation with a pH below 5.6 is acidic precipitation ("acid rain").

It is estimated that pollution caused by coal-fired power plants leads to almost 4,000 premature deaths in the non-EU Western Balkan countries, as well as more than 2,000 premature deaths in countries within the European Union. Six well-known European organizations and international coalitions dealing with ecology, climate change and energy (HEAL, Sandbag, CAN Europe, CEE Bankwatch, Europe Beyond Coal, Agora Energiewende) have presented a new report on the impact of coal-fired power plants in the Western Balkans. Sixteen coal-fired power plants in this area emit more than 250 power plants in Europe through sulphur dioxide emissions. The reason is outdated technology, poor filtration, but also the use of low quality coal, ie insufficient removal of sulphur from the fuel. (HEAL, 2018).

Concentrations of harmful substances, according to EPS data, in four settlements around the Kostolac thermal power plant, from June 2016 to February 2018, are higher than the permitted values on average every fourth day.

The emission of SO_2, which influenced the presence of SO_2 in the atmosphere 10 to 15 times higher than allowed, stands out. As a consequence of the shown, there is an adverse impact on the health status of the residents of the Branicevo district, which includes Pozarevac, Kostolac and seven smaller municipalities. According to the results of the Public Health Institute Pozarevac for 2016th, from 2007 to 2016, the number of patients increased by 13.4%. The most numerous patients with respiratory problems and the most common cause of death are diseases of the circulatory system. Respiratory system diseases in 2016 affected 29.4% of the district's population, significantly higher than the national average of 16.8%, which was the biggest problem in the previous ten years. School-age children (7-18 years old) have the most respiratory problems, and in 2016 every other child was treated for such problems (Public Health Institute Pozarevac, 2016).

METHODS

The establishment of a monitoring system for air quality control is based mainly on two approaches, measurements and mathematical modelling. Measuring concentrations of pollutants using monitoring networks is a technically complex and expensive procedure, in the case of systems that provide real-time information, or is obtained by subsequent analysis in laboratories. Requirements for the rapid obtaining of results on the spatially - temporal distribution of pollutant concentrations in the ground layer of the atmosphere, with minimal cost, have accelerated the application of abbreviated methods, that is, mathematical modelling. With the development of software engineering, mathematical models are gaining in importance and mainly dominate the contemporary modelling of atmospheric dispersion of pollutants. The most commonly used dispersion models are based on a thorough understanding of the physical, chemical and dynamic processes in the atmosphere (A. Leelossy i dr. 2014.). The basic meteorological quantities that must be known for modelling atmospheric dispersion of pollutants are wind, i.e. its speed and direction, as they determine the process of horizontal transport of pollutants. The process of transport and the intensity of the movement of matter up or down is closely related to the stability of the atmosphere. It is of great importance for the vertical dispersion of pollutants. Stability refers to changes in temperature with altitude and wind speed. Atmospheric stability classes are defined for various meteorological situations, characterized by the speed of wind and solar radiation during the day, and cloud cover during the night. The Pasquill stability class method is used to determine the degree of atmospheric stability (F. Pasquill, 1961.).

Due to the complexity of the atmospheric processes, it is virtually impossible to conceptualize a universal dispersion model, so today a large number of variants of these models that are constantly being refined are being applied. The accuracy of a model depends both on its ability to simulate real physical processes in the atmosphere and on the validity of the input data. In the Gaussian method, smoke with pollutants is currently released from a point source. The Gaussian model assumes that the substances emitted do not participate in chemical reactions in the atmosphere, that they are perpendicular to the wind-borne sources and that they mix with the surrounding air both vertically and horizontally (F. Pasquill, 1976.).

The effect of sulphur dioxide emissions from TPP Kostolac B blocks before and after desulphurisation of thermal power plant chimneys is analyzed in the paper. Using the Gaussian statistical model, the ground concentrations and their dispersion were calculated in both cases. The Kostolac B thermal power plant, with its emission of pollutants, primarily flue gas and ash, is the dominant source of atmospheric pollution. The most abundant element in the flue gas is sulphur dioxide with about 97% of the total impurities. The measured maximum value of SO_2 concentration in waste gas for chimneys of units B1 and B2 is 4746,4 mg / Nm3, which is significantly higher than the limit value of 400 mg / Nm^3 (Regulation on limit values of pollutant emissions into the air from combustion plants - Fig. Gazette No. 6/16), and far beyond the limit value set by EU regulation 2016 of 200 mg / Nm^3 (Laboratories for Thermal Engineering and Energy, Vinca Institute of Nuclear Sciences, Belgrade, 2018).

The paper analyzes the data on sulphur dioxide emissions from the chimney of TPP Kostolac B in December 2008 and the sulphur dioxide emissions of the same thermal power plant using the desulphurisation plant during the April 2017 trial. In analyzing the impact of the Kostolac B thermal power plant on air quality (mean one-hour concentrations), the software of the US Environmental Protection Agency SCREENVIEW 4 was used, which allows estimation of the pollution concentration at the ground level originating from a single source. The following input quantities were used to calculate the sulphur oxide concentrations:

1. Chimney height
2. Inner diameter of chimney
3. Mass flow rate and flue gas velocity at chimney outlet
4. Flue gas temperature at the outlet
5. Terrain characteristics around thermal power plants (rural and urban areas, absolute height, topographic features)
6. Condition of the atmosphere in terms of stability and wind speed.

DISCUSSION

Modelling for the calculation of ground-level concentration of aerosol pollution used data of long-term measurements made by the Republic Hydrometeorological Institute of Serbia at the Main meteorological station Veliko Gradiste, 25 km east of the thermal power plant, which is climatologically representative for the subject area. The mean monthly temperature in December 2008 in the Kostolac basin was 3.30^0C. In December of the same year, stability class D and stability class F predominated. It was also adopted that TPP Kostolac B is located in a rural area.

Table 1. Production parameters at Kostolac B TPP in December 2008

PARAMETER	KOSTOLAC B
Chimney height[m]	250
Inner diameter of chimney at the outlet [m]	9,8
Flue gas temperature at the outlet [^{0}C]	170
Flue gas velocity at chimney outletvs [ms^{-1}]	25,7
Mass flow rate (g/s)	1410,8

Source: Production parameters in TPP Kostolac B in December 2008
(J. Djordjevic-Miloradovic, 2012)

After the analyzes for these parameters have been done, the results are as following.

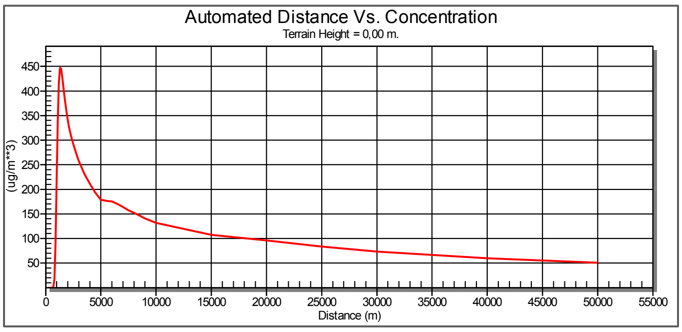

Figure 1. SO_2 concentration as a function of source distance at Kostolac B thermal power plants in December 2008.

Figure 1 shows that at TPP Kostolac B the maximum concentration is 410.2 µg / m^3 at a distance of 1381 m. The SO_2 concentration is above the limit and is 150 µg / m^3 over a distance of 600 m to 7500 m. Enforcement of environmental laws implies the harmonization of our legislation with the legislation of the European Union. One of the priority tasks is the adoption of measures and procedures for air protection by reducing the emission of dangerous substances at the source of pollution. Considering the limit values for SO_2 emissions in flue gas, the Kostolac thermal power plants with regard to installed power, the construction of a desulphurisation system for SO_2

concentrations in the air should be reduced more than 10 times, at full load of the blocks and at burning of poor quality coal. The results of the test measurements of the desulphurisation system in April 2017 are presented on the basis of the report of the Laboratory for Environmental and Environmental Protection of the Belgrade Mining Institute, which is officially authorized to perform warranty tests at the waste gas desulphurisation plant at TPP Kostolac B values we defined the production parameters.

Table 2. Production parameters of TPP Kostolac B in the trial run of the desulphurisation system (April 2017)

PARAMETER	KOSTOLAC B (blocks B1 and B2)
Chimney height[m]	**180**
Inner diameter of chimney at the outlet [m]	**13,4**
Flue gas temperature at the outlet [^{0}C]	**63,8**
Flue gas velocity at chimney outletvs [m/s]	**21**
Mass flow rate (g/s)	**80,8**

Mining Institute D.O.O. Belgrade, Laboratory for Environmental and Environmental Protection, 2018.

When modelling to calculate the concentration and distribution of sulphur dioxide after using the desulphurisation system, we used meteorological data for April 2017, for the main meteorological station in Veliko Gradiste. The average monthly temperature in April was 11.7^{o}C. The maximum temperature in April of the same year was 18.3^{o}C and the minimum 3.2^{o}C. In this area, the prevailing wind direction is south - southeast and southeast, followed by winds from west and west-north-west direction. The strongest winds are from southeast with mean speed 3, 8 m/s, then from east with mean speeds of 2, 94 m/s, from northwest with average speed of 2, 24 m/s from west with mean speed 1,3 m/s. In April, stability class D and stability class F prevailed. The other parameters, such as the relief and urbanization of space, were identical to those of the previous modelling. The same input sizes were used to calculate the concentration of sulphur oxides in the trial run of the desulphurisation system. Modelling obtained the following results.

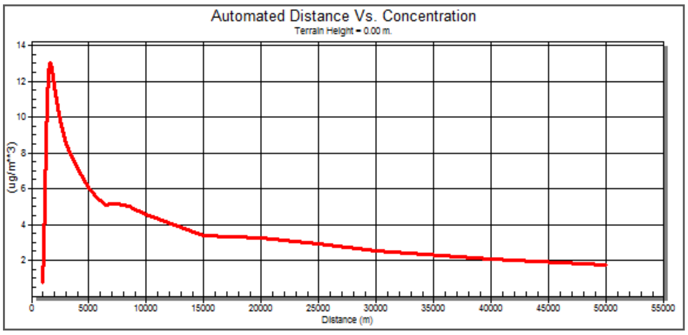

Figure 2. SO2 concentration as a function of source distance at Kostolac B thermal power plants in April 2017 (after chimney desulphurisation)

Figure 2 shows that the SO_2 concentration is more than 90% lower than in 2008. The maximum concentration is 13.06 μg / m^3 at a distance of 1642 m. The modelling results show that the flue gas desulphurisation system fully meets the requirements for the reduction of ground-level SO_2 concentrations in the area around the source of the pollution. Comparisons have also been made of the effects on air quality of certain atmospheric stability classes, for different wind speeds and different temperatures. In December 2008, atmospheric stability classes D and F represented the highest percentage, so comparisons were made for these stability classes.

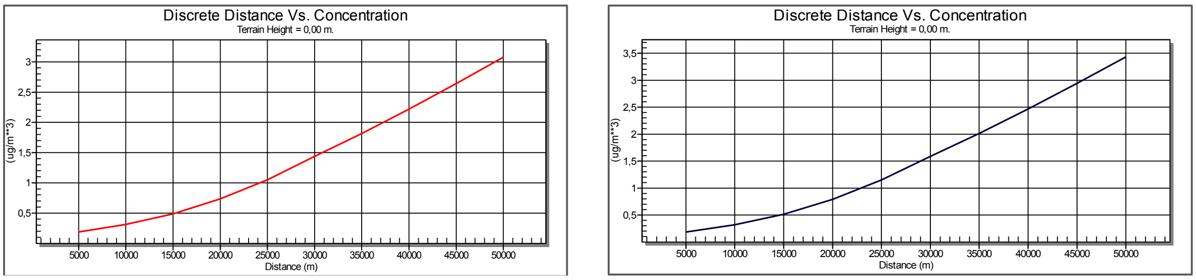

Figure 3. Distribution of SO_2 concentrations for stability class F at 3.30 ºC and wind speed of 1m / s (left) and wind speeds of 4m / s (right) in December 2008.

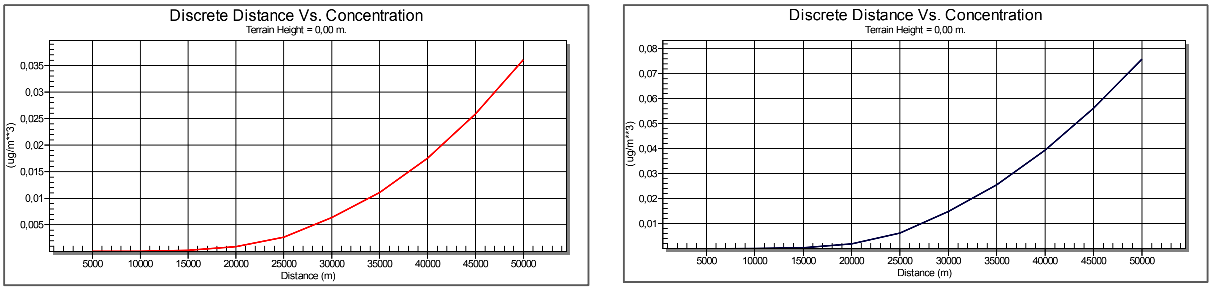

Figure 4. Distribution of SO2 concentrations for stability class D at 3.30ºC (left) and 11.26ºC (right) in December 2008.

The graphs in Figures 3 and 4 show that an increase in ambient air temperature for the same atmospheric stability class leads to an increase in the concentration of pollutants compared to the lower temperature values. Although higher wind speeds should lead to lower concentrations, the modelling results indicate an increase in concentration with an increase in wind speed for the same atmosphere stability class. This indicates that other factors affecting the concentration distribution are prevalent. In windy periods, aeolian erosion of the surface occurs, raising and carrying tiny ash fractions. Measurements have shown that the largest exceed of deposition of particulate matter are in the towns of Stari Kostolac and Kostolac, which are closest to the ash dump. In the case of the Kostolac B thermal power plant, the largest pollutants are surface sources of the discovery, open limestone landfills, ashes and gypsum landfill. Landfill particles generally pollute the immediate environment. The graphs in figures 3 and 4 show that, under the same conditions, the concentration of pollutants is higher for the atmospheric stability class D (neutral) than for the class F (very stable) (Jacimovski i dr,2013.).In the comparative analysis of the results when operating the desulphurization system, examples are given for the two most common stability classes D and F, with an average air temperature in April of 11.7ºC and an average wind speed of 2.2 m / s.

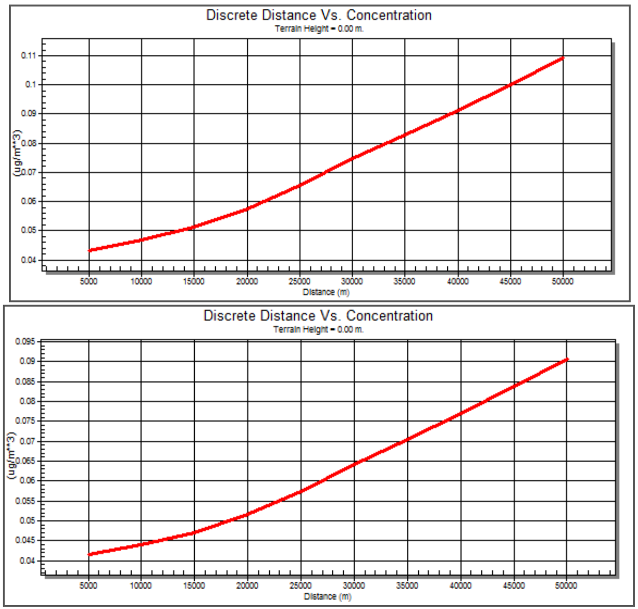

Figure 5. Distribution of SO_2 concentrations for stability class D at 11.70 °C and wind speed 2.2m / s (left) and stability class F for temperature 11.7 °C and wind speed 2.2m / s (right) in April 2017

The maximum SO_2 concentration for stability class D is 0.1006 μg / m^3 at a distance of 50000 m, and for stability class F 0.021 μg / m^3 also at a distance of 50000 meters. In both cases, it is observed that SO_2 concentrations are extremely low. Maximum concentrations occur at the same distances from the emission source. There is no pollution in Class D at ground level, which confirms the theory that in this class there is minimal soil pollution if the chimney is high enough and the terrain is flat. The increase in pollution is observed5 km from the chimney. Stable atmospheric conditions, class F, cause more resistance to vertical movement and thus less dispersion in the vertical direction. The increase in SO_2 concentration is about 8800m from the chimney.
Comparisons were made for a maximum air temperature of 18.3 °C and a minimum temperature of 3.2 °C in April 2017 and wind speed of 2.2 m/s for stability class D.

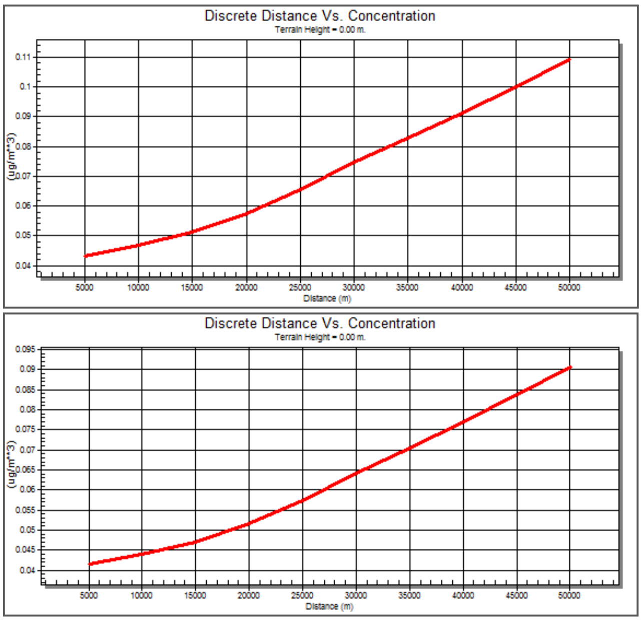

Figure 6. Distribution of SO_2 concentrations for stability class D at 18.3°C (left) and 3.2.°C (right) in April 2017.

Figure 6 shows that as the temperature increases, pollution increases. The maximum concentration of SO_2 at a temperature of 18.3 ^{0}C is 0, 1094 μg /m^3, and at a temperature of 3.2^{0}C is 0.9078 μg /m^3. Since these are small values, the differences are small, but they confirm the rule that with increasing air temperature the concentration of pollutants increases. In both cases, the pollution increase is 5000 meters from the source and the maximum values are at 50000 meters.

We also analyzed the impact of wind on the spread of pollution for stability class F. We compared the maximum and minimum wind speeds in this area. According to meteorological data, the maximum wind speed for the ten-year period was 3.8 m/s and the minimum was 1.3 m/s. As a temperature value, we took the monthly average for April 2017, which was 11.7^{0}C.

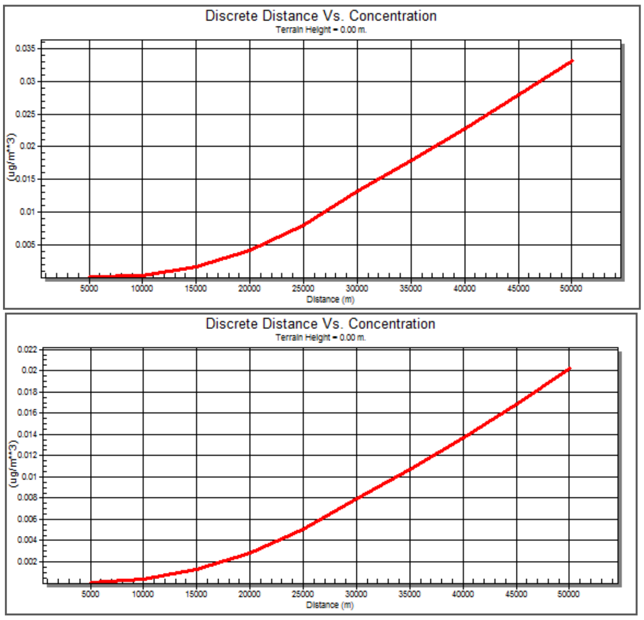

Figure 7. SO_2 concentration distribution for stability class F at wind speeds of 3.8 m/s (left) and 1.3 m/s (right) in April 2017.

As with the December 2008 sulphur dioxide spread analysis (Figure 3), the modelling results indicate an increase in the concentration of pollution with an increase in wind speed for the same atmosphere stability class. The maximum concentration of SO_2 when the wind speed is 3.8 m/s is 0.3313 μg / m^3 and at a wind speed of 1.3 m/s it is 0.2021 μg / m^3. There is also a difference in the distance of pollution from the source. In higher winds, the increase in pollution starts at a distance of 10 kilometers, and in the lower wind at 7.5 kilometers.

The results obtained by modelling sulphur dioxide spread from TPP Kostolac B show that the desulphurisation system with a new wet chimney fully meets the requirements prescribed by law and that the ground concentrations around the emitters are minimal. Based on the results of SO_2 emissions in the trial run, the newly built desulphurisation system will significantly reduce the sulphur dioxide emissions from TPP Kostolac B. According to our calculation, the desulphurisation rate at TPP Kostolac B is 94.3%.

CONCLUSION

Using the Model of the US Environmental Protection Agency SCREENVIEW 4, we compared the effects of one source under different operating conditions on air quality (mean hourly concentrations), operation of the Kostolac B thermal power plant without a desulphurisation plant and operation with a desulphurisation plant and a new wet chimney as a broadcaster. Examples of the results of the performed analysis for the two most represented stability classes in the measurement period are given. Comparisons have been made for sulphur dioxide emissions that have the greatest impact on air pollution. The results obtained indicate that the construction of the desulphurisation system reduced the emissions of sulphur dioxide by 94.3%, on average for both units, thus fulfilling the condition that the minimum degree of desulphurisation according to the Regulation on limit values of pollutant emissions into the air from the combustion plant ("Fig. Gazette RS ", No. 6/16), for existing large combustion plants with a thermal power exceeding 500 MWth, is 94%. This was reflected in the mean one-hour concentrations obtained by modelling. They are well below 200 mg / Nm^3 or less, as foreseen by the European Industrial Emissions Directive, which has started to apply from 2016. This analysis considers only emissions from units B1 and B2 of Kostolac B, which accounts for 52% of total sulphur dioxide pollution energy system of TEKO “Kostolac”. The distributions shown represent the usual results of modelled dispersion. For example, an increase in air temperature leads, as expected, to an increase in the concentration of sulphur dioxide compared to values at a lower temperature. It is also confirmed that higher wind speeds do not contribute to lower concentrations. Maximum ground concentrations occur at distances of about 50 km from the source (chimney), at appropriate wind speeds. The release of the flue gas desulphurisation system at TPP Kostolac B will significantly reduce the sulphur dioxide emissions of the Kostolac energy complex, thereby significantly improving the quality of the environment, which is in great danger.

REFERENCES

[1] Cho H.S., Choi M. J. (2014) “Effects of Compact Urban Development on Air Pollution: Empirical Evidence from Korea”, Sustainability, Vol. 6, Issue 14, pages 5968-5982.
[2] Health and Enviroment Alliance (HEAL), Brissels, Belgium
[3] Republika Srbija, Zavod za javno zdravlje, Požarevac, 2018.
[4] A. Leelossy, F. Molnar, F. Izsak, A. Havasi, I. Lagzi, R. Meszaros: Dispersion Modeling of Air Pollutants in the Atmosphere: a review. Central European Journal of Geosciences, 6(3) (2014), 257-278.
[5] Pasquill, F., The estimation of the dispersion of windborne material, The Meteorological Magazine, Vol. 90, No. 1063, 1961 , pp. 33–49
[6] F. Pasquill: Atmospheric dispersion parameters in Gaussian plume modeling. EPA-600/476-030b, (1976), 53.
[7] Institut za nuklearne nauke „Vinča“, Laboratorija za termotehniku i energetiku, Izveštaj o periodičnom merenju zagađujućih materija u vazduh na blokovima B1 i B2 termoelektrane „Kostolac“ u Kostolcu I serija merenja, Beograd, 2017.
[8] Uredba o graničnim vrednostima emisija zagađujućih materija u vazduh iz postrojenja za sagorevanje “Službeni glasnik RS”, broj 6 od 28 januara 2016. god. www.pravno- informacioni-sistem.rs › SlGlasnikPortal › reg › viewAct
[9] https://www.weblakes.com/download/freeware.html
[10] Đorđević-Miloradović J., Savić N.: (2012). Rekultivacija i ozelenjavanje deponija, pepelišta i jalovišta u Kostolcu RIO Kostolac str 72-84
[11] Rudarski institut D.O.O. Beograd, Laboratorija za zaštitu životne i radne sredine, *Izveštaj o ispitivanju BR. E-04/17/CMEC/TEKO- B1*, 2018.
[12] S.Jaćimovski, S.Miladinović, R.Radovanović, V.Ilijazi, Distribution of the Concentration of Sulphur Dioxide Into the Atmosphere From Point Source, Urban Eco, Ečka, 2013.
[13] Republički hidrometeorološki zavod, Meteorološki godišnjak, meteorološki podaci za 2017. godinu, office@hidmet.gov.rs

SORPTION OF LINURON AND ISOPROTURON ONTO ACTIVATED CARBON PREPARED FROM DATE STONES

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Abstract: Activated carbon is common selection as an adsorbent for the elimination of pesticides from water medium, but it is a cost-effective economic problem. This work represents a possibility of application of newly developed adsorbent medium prepared from date seed for removal of linuron and isoproturon. The different operation parameters such as adsorbent dosage, contact time and initial concentrations of pesticides were examined in order to provide optimal parameters for adsorption process. According to obtained results, application of date stone as alternative adsorbent could be considered as efficient remediation technology for water which is polluted with this type of pesticides.
Key words: pesticides, water treatment, date stones

INTRODUCTION

Most of the pesticides are consumed to improve fruit production and vegetable crops in different countries. For the countries of the developed world, the focus is on the use of herbicides to increase maize production [1].
Linuron, is a systemic herbicide used in the pre- and post-emergence control of annual grass and broad-leaved weeds, such as soybean, cotton, potato, corn, bean, pea, winter wheat, asparagus, carrot, and fruit crops. It is also used on crops stored in warehouses and storerooms [2]. Linuron has been classified as toxic to reproduction (category 2) and carcinogenic (category 2), whose target organs are liver and red blood cells and with the capability of inducing malformations, infertility or cell tumors.
Isoproturon (IPU, 3-(4-isopropylphenyl)-1,1-dimethylurea) is a worldwide extensively used phenylurea herbicide for pre- and post-emergence control of annual grass and broadleaved weeds in cereal crops [3]. The active substance is considerably discovered in surface- and groundwater overriding the threshold concentration of pesticides in drinking water ($0.1 \mu g\ L^{-1}$) in EU [4].
The elimination of pesticides from aqueous medium is one of the great environmental concerns today. In the past few years pesticide residues in the ground water resources has grown considerably and has become an important question of debate. Recently, many researchers are interested in removal of pesticides by activated carbon. Adsorption is a well-known equilibrium separation process and an efficient method for water purification application. Adsorption has been found to be superior to other techniques for water re-use in terms of initial cost, flexibility, and simplicity of design, ease of operation, and insensitivity to toxic pollutants [5].
Activated carbon is considered as efficient in removing different varieties of pesticides from water and wastewater, due to the high surface area and porosity. It is a multilateral material that can be applied in many technological processes. Recently, the researchers have focused on preparation of activated carbons for elimination of assorted pollutants using renewable and cheaper precursors, which were fundamentally manufacturing and agricultural by-products. Various types of carbons have been obtained from biomass and other wastes. The adsorption capacities of carbonaceous materials depend on the raw materials selected, preparation and treatment conditions such as pyrolysis temperature and activation time. Other factors such as surface chemistry (heteroatom content), surface charge, and pore structure can effect on adsorption capacity. A proper carbon should possess not only a porous structure, but also high surface area.
The objective of this study is to investigate the possibility of efficient removal of linuron and isoproturon from aqueous medium by low-cost adsorbent prepared from date stones. The main operational parameters that have influence on adsorption process such as adsorbent dosage, contact time and initial concentrations of pesticides were investigated.

MATERIAL AND METHODS

Chemicals

Phosphoric acid, acetonitrile and methanol were purchased from Sigma-Aldrich Co. (St. Louis, USA). Linuron, isoproturon were obtained from LGC (Germany). HCl and NH_4OH were obtained from J.T. Baker (USA) and Centrohem (Serbia), respectively.

Preparation of activated carbon from date stones (DSAC)

The date stones were washed with boiled water to eliminate the impurities. The washed date stones were dried in the oven (Memmert, Germany) at 60˚ C for 24 h before their carbonization at 300 ˚C for 30 min. Afterward, dried date stones were milled in the grinder in order to obtain a powder date stones and washed with boiled water several time before dried over night at 110 ˚C. The resulting product was ready to activation by H_3PO_4 solution at concentrations of 30 %.

Determination by HPLC-DAD

The target pesticides were analyzed by HPLC-DAD (Agilent 1260). Separation was performed with a reversed phase column Eclipse XDB-C18 (3 x 150 mm, particle size 3.5µm). The operating conditions were: the flow of 0.4 mL min^{-1}, the temperature of the column was 30 ˚C and injection volume of 10 µL. The mobile phase consisted of water (A) and acetonitrile (B). The binary gradient elution started at 25% B in the 1st minute, then linearly increased to 50 % B in the 5th minute, and at the end, initial condition was applied, 25 % B in the 7th minute. The maximum wavelength of 215 nm was used.

Batch Adsorption Experiments for DSAC

Impregnation ratios of H_3PO_4/date stones was (w/w) 3:1 and concentration of H_3PO_4 was 30 %. The uptake per mg of adsorbent, q_e and the percentage of linuron and isoproturon adsorbed were calculated using equations 1 and 2:

$$qe = \frac{(C_o - C_f)}{m} * V \quad (1)$$

$$\%Ads = \frac{(C_o - C_f)}{C_o} * 100 \quad (2)$$

Where q_e is the adsorption capacity (mg g^{-1}), C_0 and C_f are the initial and final isoproturon or linuron concentrations, respectively (expressed in mg L^{-1}), V is the solution volume (mL) and m is the adsorbent dosage (g).

Adsorbent dosage

Adsorption experiments were carried out by adding a various amount of sorbent DSAC (0,01 to 3 g) to linuron and isoproturon solutions into conical flasks at pH 7. The flasks were placed in an orbital (Unimax 1010) and agitation was provided at 140 rpm for 30 min at room temperature.

Contact time

Adsorption experiments were carried out by adding a fixed amount of sorbent and concentration of pesticides into conical flasks, at optimum impregnation ratio of the H_3PO_4/date stone of 3:1 where the concentration of H3PO4 was 30 %. The experiments were processed at room temperature and pH was 7. Already impregnated DSAC was added to the conical flasks. The flasks were placed in an orbital shaker and agitation was done at 140 rpm. The samples were taken at defined time intervals after 5 - 90 min for selected pesticides.

Initial linuron and isoproturon concentrations

The initial linuron and isoproturon concentrations were 2, 4, 5, 6, 8 and 10 mg L^{-1}. The adsorbent dosage, contact time and pH were remained constant at optimum values. The conical flasks were shaken on the orbital shaker at 140 rpm at room temperature. The reaction of samples was conducted followed by filtration through (Ø125 mm) membrane filters followed by filtration using a syringe to make sure to get rid of colour before the measurement of linuron and isoproturon.

RESULTS AND DISCUSSION

Influence of adsorption dosage (DSAC)

The removal efficiencies of selected pesticides (linuron and isoproturon) by DSAC ranged from 87,15 % to 95,98 % and from 54,00 % to 88,25 %, respectively. The masses of adsorbent from 1,00 to 4,00 g L^{-1} were used to study the influences of different mass on the removal of selected pesticides. The optimum chosen doses were 2,00 and 3,00 g L^{-1} for linuron and isoproturon, respectively. An increase in the concentrations of DSAC from 1,00 to 4,00 g L^{-1} resulted in decrease of the adsorption capacity for linuron and isoproturon. Any additional increment in the concentration of DSAC up to 4,00 g L^{-1} did not result in a remarkable reducing in the adsorption capacity, for any of the selected pesticides investigated.
The removal efficiency and adsorption capacity of linuron and isoproturon do not raise at higher doses of DSAC due to overlapping and aggregation, on the another hand, due to the electrostatic refusal of the adsorbent particles, which results in a reduction of the effective DSAC surface area and the number of available active sites. Moreover, the higher doses of the DSAC also reduce the efficiency of suspension mixing, causing a slow transfer of mass.

Influence of contact time (DSAC)

The contact time is a fundamental parameter in any transfer phenomena such as adsorption. The equilibrium adsorption capacity of linuron and isoproturon on DSAC was investigated to determine the time required to reach the equilibrium between adsorbent and selected pesticides solution (5 mg L^{-1}) and pH 7,00. The removal percentage of linuron and isoproturon increased from 82,51 % to 95,11 % and 33,63 % to 91,81 % with increase in the contact time from 5.00 to 120 min.
During the first 10 min, the removal percentages of linuron and isoproturon were 82,55 % and 57,94 %, respectively. After 10 min, it can be observed that the removal efficiency increase with the contact time until equilibrium state is reached at 40 and 90 min for linuron and isoproturon, respectively. Then, it increases slightly for the time period of 30 to 120, 40 to 120 and 90 to 120 min, respectively. This indicates that initial concentrations and different contact time played an important role in the adsorption of selected pesticides on DSAC.

Influence of initial concentration (DSAC)

Initial adsorbate concentration of linuron and isoproturon pesticides onto DSAC was investigated at various initial concentrations, from 2 to 15 mg L^{-1} (at pH 7, DSAC doses 2,00 and 3,00 g L^{-1}, room temperature 25 ± 1 ˚C and contact time 40 and 90 min), respectively. The effect of the initial concentrations of linuron and isoproturon pesticides on adsorption is presented in Fig. 1 and 2. With increase in the initial concentration of linuron and isoproturon, adsorption capacity also increases, due to the increased concentration gradient between the selected pesticides and the DSAC.

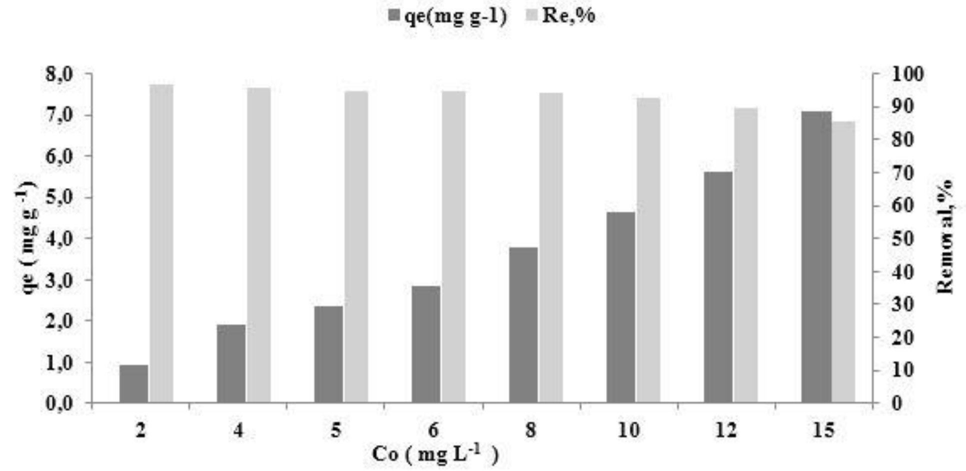

Figure 1. Influence of linuron concentration on the adsorption process (contact time= 40 min, mass of adsorption 2,00 g L^{-1}, pH 7.00)

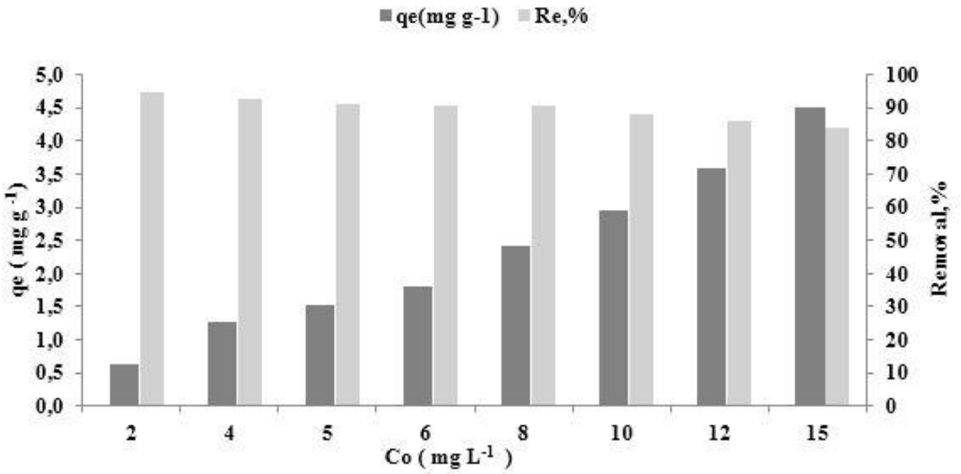

Figure 2. Influence of isoproturon concentration on the adsorption process (contact time= 90 min, mass of adsorption 3,00 g L^{-1}, pH 7,00)

The adsorption capacities for linuron and isoproturon were 7,07 and 4.50 mg g^{-1} onto DSAC, respectively. This is due to the limited availability of active adsorption sites on the DSAC surface. Adsorption capacity increases with an increase in initial concentration due to the increased probability of cavity collisions with active centers or functional groups. In a solution with high initial concentrations, rapid saturation of functional groups on the surface of activated carbon occurs. The removal efficiency of linuron and isoproturon pesticides decreased from 96,78 % to 85,32 % and from 94,67 % to 83,95 %, respectively, when the linuron and isoproturon concentrations increased from 2 to 15 mg L^{-1}.

CONCLUSION

The adsorption capacities of carbonaceous materials depend on the raw materials selected, preparation and treatment conditions such as pyrolysis temperature and activation time. Activated carbon prepared from date stone waste was prepared by chemical activation. The main operational parameters that have influence on adsorption process were investigated. In case of influence of initial concentrations of linuron and isoproturon, maximum removal efficiencies were 96,78 % and 83,95 %, respectively. In order to realize nature of adsorption process, higher concentrations of pollutants were used than detected in water systems.

According to obtained results, application of date stone as alternative adsorbent could be considered as efficient remediation technology for water which is polluted with this type of pesticides.

ACKNOWLEDGEMENT

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REFERENCES

[1] Zhang, W., Jiang, F., Ou, J.: Global pesticide consumption and pollution: with China as a focus, Proc. Int. Acad. Ecol. Environ. Sci., vol. 1, no. 2, p. 125, 2011.
[2] Malenčić, D., Miladinović J., Popović M.: Effects of linuron and dimethenamid on antioxidant systems in weeds associated with soybean, Open Life Sci., vol. 3, no. 2, pp. 155–160, 2008.
[3] Hussain, S.: Abiotic and biotic processes governing the fate of phenylurea herbicides in soils: a review, Crit. Rev. Environ. Sci. Technol., vol. 45, no. 18, pp. 1947–1998, 2015.
[4] Fenner, K., Canonica, S., Wackett, L. P., Elsner, M.: Evaluating pesticide degradation in the environment: blind spots and emerging opportunities, En: Science, vol. 341, no. 6147, pp. 752-758, 2013.
[5] Dąbrowski, A.: Adsorption—from theory to practice, Adv. Colloid Interface Sci., vol. 93, no. 1–3, pp. 135–224, 2001.

ENVIRONMENTAL RISK HIERARCHY OF PESTICIDES IN DANUBE RIVER BASIN IN THE VICINITY OF NOVI SAD: A PRIORITIZATION METHOD BASED ON MONITORING AND HAZARD ASSESSMENT

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Abstract: The paper presents the application of the prioritization method in order to determine the risk of individual pesticides on environmental quality, based on two conducted target analyzes of pesticides at five selected locationsof the Danube surface water near Novi Sad. Based on the monitoring and hazard assessment,calculations were performed and it was concluded that the Pentachlorobenzene is the only compound exceeding the priority quotient of 1 with the possibility to pose the risk. The calculation data of impact assessment of selected pollutants facilitate recognition of the surface water quality for the implementation of appropriate regulatory measures and determination of adequate method for the Danube Basin management in the Republic of Serbia.
Key words: ecotoxicological risk, priority pollutants, Danube, impact assessment.

INTRODUCTION

The increasing pollution of freshwater resources with vast variety of industrial and natural chemical compounds is one of the key environmental problems facing humanity today. Although most of these compounds are detected in low concentrations, many of them raise concerns due to the hazardous and toxic effects they can have, particularly as complex mixtures of compounds and metabolites [1].
The Water Frame Directive (WFD), Article 16, establishes a strategy for reducing chemical pollution in European waters, using an assessment of chemical and ecological status in determining the overall quality of water bodies [2, 3]. Since Serbia is in the process of joining the EU, it is obliged to gradually adapt its strategic decisions in the field of water resources protection and management to the EU Directives [4].
The pollution reduction program involves the identification of substances that need to be controlled, the setting of environmental quality standards, the identification of the pollution sources, and measures for their control and monitoring. The developed program should be renewed and revised every 6 years. The Environmental Standards Directive (EQS Directive) encloses the Annual Average (AA) and Maximum Allowable Concentration (MAC) for 33 priority substances, including the 8 pollutants classified as other pollutants. If there is compliance with AA-EQS and MAC-EQS the water body is defined as of good quality. According to the WFD, Member States have to set a quality standard and take measures to achieve these quality standards for specific pollutants that are not included in the scope of the Directive, but are present in the significant quantities for specific location and river basin. EQS is a key tool for assessing and classifying chemical and ecological status [2, 3].
The environmental risk assessment (ERA)is based onthe assessment whether the Predicted Environmental Concentration (PEC) is higher than the Predicted No-Effect Concentration (PNEC) with the biological effects [5-7]. The prioritization process established at European level, required for the chemical status assessment, is based on the application of data obtained from monitoring and modelling and is in accordance with the prioritization principles described in Article 16 of the WFD.
In this approach, a tree method developed by the NORMAN Working Group is applied, in which chemicals were first classified into 6 categories depending on the information available [8, 9]:

- Category 1 - enough data; monitoring program;
- Category 2 - sufficient toxicity; several observations;
- Category 3 - P-PNEC based on toxicity; 20 sampling sites > LOQ (Limit of Quantification);
- Category 4 - lowest PNEC < LOQ;
- Category 5 - P-PNEC based on toxicity, several observations;

- Category 6 - enough data; no attention is required.

The aim of this paper is to apply the prioritization method and to determine the risk of individual pesticides on environmental quality, based on two conducted target analyzes of pesticides in the surface water of the Danube near Novi Sad. Five sampling locations were selected as representative for analysis. The first sampling site representsupstream contamination, as none of the city sewage network discharges are located before this site. The other four locations were selected 100 m downstream from the wastewater discharges.

MATERIALS AND METHODS

With the presented classification approach, compounds can be located into 6 categories. In order to prioritize the compounds within the category, two indicators have been proposed for the purpose of the individualcompound risk assessment:

- Frequency of sites where the Maximal Environmental Concentration (MEC sites) is exceeding the lowest PNEC value, thereby indicating the spatial aspect of exposure;
- Risk Assessment Ratio (the ratio of the 95th percentile of the maximum environmental concentration at a site (MEC_{95}) and the lowest PNEC value) that represents the intensity of impacts on the specific location.
-

The values obtained are scaled to range from 0 to 1 to allow a direct comparison of obtained indicators. The resulting indicators can then, if necessary, be summarized to obtain an overall risk, ranging from 0 to 2.

The first indicator exposes the spatial distribution of potential effects that a particular compound may cause and the frequency of sites with a recorded concentration over a given threshold. For the calculation of this indicator, the maximum concentration of compounds recorded at each location (MEC_{site}) is compared with the lowest PNEC value. The number of sampling locations where the threshold was exceeded is divided by the total number of sites at which the corresponding compound is monitored, shown via equation 1:

$$\text{Frequency of exceedance} = \sum \frac{n}{N} \quad (1)$$

wheren is the number of sampling siteswith the ratio of MEC_{site} and $PNEC_{lowest}$ above 1 and N is total number of sites where analytical measurement of the compound was performed.

This index can be applied independently of the number of sites with concentration beyond the quantification limit, which is necessary for the second indicator. End values denote the fraction of a location where potential effects are expected and range from 0 to 1. Therefore, these values can be directly used for overall prioritization.

The second indicator ranks the compounds according to the extent of the expected effects. Whilst the previous indicator holds that some compounds may be widespread, it can be predicted that some of these chemicals only occur at fairly low concentrations near the thresholds that cause the effects.

Henceforth, the ratio of the MEC_{95} for each compound was also calculated and then divided by the lowest PNEC according to the equation 2.

$$\text{Range of exceedance} = \frac{MEC_{95}}{PNEC_{lowest}} \quad (2)$$

The indicator expressed via equation 2 can only be calculated for compounds belonging to the categories 1, 3 and 6, as there is sufficient monitoring data.

The final quotient is then ranked from 0 to 1, according to the obtained value of exceedance (e):

- e < 10 is awarded with 0.1 point;
- 10< e <100 is awarded with 0.2 points;
- 100< e < 1000 is awarded with 0.5 points;
- e> 1000 is awarded with 1 point.

RESULTS AND DISCUSSION

In order to determine the water quality, two target analyses of the Danube surface water have been conducted at five sampling locations in the city of Novi Sadto detect the pesticides (Table 1).

Table 1. Pesticides analyzed in Danube surface water

Compound	AA-EQS for surface water	RI	GC1"	GC2"	RO"	RP"
The First Target analysis						
Concentration (ng/l)						
Pentachlorobenzene	**7**	<7	**40**	<7	<7	<7
Hexachlorobenzene	**10**	<3	**50**	**30**	<3	<3
Lindane (γ-HCH)	**20**	<20	<20	<20	<20	<20
Heptachlor	**200**	<50	**420**	<50	<50	<50
Trifluralin	**30**	**30**	<30	<30	**30**	<30
Chlorpyrifos	**30**	<30	<30	<30	<30	<30
Dieldrin	**10**	<10	**270**	**100**	**30**	<10
Endrin	**10**	<10	<10	<10	**100**	<10
Endosulfanalfa	**5**	<5	**230**	<5	<5	<5
Endosulfan beta	**5**	<5	<5	<5	**40**	<5
p,p'-DDD	**25**	<25	**400**	<25	**220**	<25
p,p'-DDE	**10**	**80**	**25**		**80**	<25
p,p'-DDT	**10**	<10	**310**	<10	<10	<10
Σ DDT	**25**	**80**	**735**	<25	**300**	<25
The Second Target analysis						
Pentachlorobenzene	**7**	**10**	**11**	**9**	**14**	**7**
Hexachlorobenzene	**10**	<3	<3	<3	<3	<3
Trichloromethane	**2500**	<500	<500	<500	<500	<500
Trichloroethylene	**10000**	<10	<10	<10	<10	<10
Tetrachloroethylene	**10000**	<100	<100	<100	<100	<100

Results of the first target analysis point out on the exceedance of AA-EQS values for Pentachlorobenzene at sampling location GC1" almost six times higher than the threshold. Concentration level of Hexachlorobenzene also exceed the threshold at GC1", five times over the quality standard value, and also on GC2", where it was three times higher than AA-EQS. Gamma-hexachlorocyclohexane (Lindane) and Chlorpyrifos are the only measured compounds whose concentrations did not exceed AA-EQS values at any of the five measurement sites. The concentration of Heptachlor was more than two times higher at GC1" in the amount of 420 ng/l, than the AA-EQS of 200 ng/l. Trifluralin was detected at the level of 30 ng/l at RI and RO", while Dieldrin was detected at significantly elevated concentrations at GC1", GC2" and RO" in the concentration range 3 - 27 times higher than AA-EQS. The Endrin and Endosulfan beta were only detected at RO".The increased concentrations of these compounds were expected, since the sampling site is located near agricultural area. Endosulfan alpha was detected only at GC1" at an extremely high concentration, 46 times higher than the AA-EQS value.

p,p'-DDE was detected at RI, GC1" and RO"in concentrations 2,5 - 8 times higher than AA-EQS.

In the second target analysis, Chlorobenzenes and Chloroalkanes (Trichloromethane, Trichloroethylene, Tetrachloroethylene) were detected, but only Pentachlorobenzene exceeded AA-EQS value in both target analyzes, indicating poor chemical status of the Danube.
Seven compounds were selected for prioritization procedure in order to determine the effect of measured concentration levels in surface water on the species of the aquatic ecosystem and humans (Table 2).

Table 2. Calculation of impact assessment values for the selected pesticides

Compound	Lowest PNEC	Max conc	MEC_{95}	Exceed.	Frequency	Exceed. coef.	Ratio > 1	No. of sites	Priority
Concentration (ng/l)									
Pentachlorobenzene	7	40	33,5	5,714	1,2	0,1	6	5	**1,3**
Hexachlorobenzene	10	50	49	5	0,4	0,1	2	5	0,5
Lindane (γ-HCH)	5,5	<20	0	0	0	0	0	5	0
p,p'-DDD	25	400	391	16	0,4	0,2	2	5	0,6
p,p'-DDT	10	310	310	31	0,2	0,2	1	5	0,4
Dieldrin	10	270	253	27	0,6	0,2	3	5	0,8
Endosulfan alpha	5	230	230	46	0,2	0,2	1	5	0,4

Based on the calculations presented in the Table 2, it can be concluded that the Pentachlorobenzene is the only compound exceeding the priority quotient value of 1. Therefore,Pentachlorobenzenecould be listed as a priority and requires the implementation of additional regulatory measures.

CONCLUSION

According to the monitoring data from two target analyses of pesticides at five sampling locations in the vicinity of Novi Sad and hazard assessment based on PNEC values, the prioritization method was performed to define the environmental risk hierarchy of selected pesticides. Among the sixteen analyzed pesticides, seven were selected for calculation and only for Pentachlorobenzene priority quotient expressed the possibility to pose the risk. This type of prioritization method could be applied on the other pollutants and could be useful for the implementation of appropriate regulatory measures for the Danube Basin management in the Republic of Serbia.

ACKNOWLEDGEMENT

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REFERENCES

[1] VojinovicMiloradov, M.,Mihajlovic, I.,Vyvirska, O., Cacho, F., Radonic, J.,Milic, N., Spanik, I.: Impact od wastewater discharges to Danube surface water pollution by emerging and priority pollutants in the vicinity of Novi Sad, Fresenius environmental bulletin, vol. 23, no. 9, pp. 2137-2145, 2014.
[2] European Commission, Common Implementation Strategy for the Water Framework Directive (2000/60/EC): Guidance document no 7, Monitoring under the Water Framework Directive.
[3] European Commission, Directive 2008/105/EC of the European Parliament and of the council of 16 December 2008 on environmental quality standards in the field of water policy, amending and subsequently repealing Council Directives 82/176/EEC, 83/513/EEC,

84/156/EEC, 84/491/EEC, 86/280/EEC and amending Directive 2000/60/EC of the European Parliament and of the Council, OJ L 348, 24.12.2008: 84-97.

[4] Milovanovic, D., Spanik I., VojinovicMiloradov, M., Mihajlovic, I., Radonic, J., Machynakova, A., Petrovic, M.: Risk assessment approach for prioritization of Danube basin specific pollutants: A case study in Novi Sad region, Polish Journal of Environmental Studies, vol. 28, no. 6, 2019.

[5] Milovanovic, D., Radonic, J., Mihajlovic, I., VojinovicMiloradov, M., Zivancev, M., Bezanovic, V., Petrovic, M.: Selection of the most relevant aquatic pollutants in the city of Novi Sad and risk assessment, International conference the holistic approach to environment, Sisak, ISSN: 2623-677X, p. 490-496, 2018.

[6] Milovanovic, D., Sremacki, M., Strbac, D., Mihajlovic, I., VojinovicMiloradov, M., Petrovic, M.: Overview of harmonization of water monitoring legislation in Serbia with WFD requirements: Case Study in Novi Sad, International Conference Ecological Truth and Environmental Research – EcoTer, Bor, ISBN: 978-86-6305-076-1, p. 151-157, 2018.

[7] Milovanovic, D., Sremacki, M., Mihajlovic, I., VojinovicMiloradov, M., Spanik, I., Petrovic, M.: Process of prioritization of the most relevant aquatic pollutants in the vicinity of Novi Sad, Eastern European Young Water Professionals Conference, Zagreb, p. 107-113, 2018.

[8] Von der Ohe, P.C., Dulio, V., Slobodnik, J., De Deckere, E., Kuhne, R., Ebert, R.U., Ginebreda, A., De Cooman, W., Schuurmann, G., Brack, W.: A new risk assessment approach for the prioritization of 500 classical and emerging organic microcontaminants as potential river basin specific pollutants under the European Water Framework Directive. Science of the total Environment,vol. 409, pp. 2064-2077, 2011.

[9] Slobodnik, J., Mrafkova, L., von der Ohe, P.C.,Carere, M.,Ferrara, F.,Pennelli,B.:Identification of river-basin-specific pollutants and derivation of environmental qualitystandards, with a case study in the Slovak Republic, Trends in Analytical Chemistry,vol. 41, pp. 133-145, 2012.

EXPERIMENTAL APPROACH IN TERMS OF BIOGAS PRODUCTION FROM DEGRADED MATERIALS

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Abstract: The biomass is one of the most used renewable sources of energy nowadays and biogas represents a versatile energy carrier which can be used for industrial and household applications. In this context, the present paper presents a small scale application in terms of studying the potential for two different substrates in combination with wastewater from a beer factory.
Key words: residual biomass, biogas, waste waters

INTRODUCTION

Biogas as a renewable source of energy has advantages from both environmental and economical points of view. Because of the large variety of substrates, biogas can play an important role inside the renewable energy carriers. It also can have an important role in obtaining energetic independence from energy imports and can create local values on long term [1].
According to European Legislation, the objective established for 2030 is that 40% of the municipal residues to be burned in cogeneration units and this involves an increased municipal residues management [2].
Because of its main components like water vapours, hydrogen sulphate, carbon dioxide and dust particles, biogas cannot be used first hand after being produced, and treatment is needed for it to be further used as a normal fuel [3].
In the tables 1 and 2 are presented some overall characteristics of different biomasses [4].
Other literature documentation was also made in regards to determining the possibilities of using waste waters and co ferments in biogas production processes, the usage of brewery effluents inside the same mentioned process [5 - 11].
According to literature, almost all the residual material used inside milk industry, brewery industry or water treatment can be used alone or in co fermentation processes for studying its potential for biogas production.

Table 1. Comparative properties of whey with other biomass types (part 1)

Biomass	pH	TS (%)	VS (% TS)	TN (% TS)
Tomato skin and seeds	4.7	32.0	97.8	3.34
Barley straw	7.87	90.5	94.3	0.99
Rice straw	8.14	88.7	91.9	0.88
Grape stalks	4.40	31.1	91.9	1.99
Maize drying up residues	5.05	81.8	97.5	1.29
Whey	5.20	6.86	91.1	1.83
Grape marcs	3.58	61.4	90.7	2.30
Inoculum	8.00	7.62	70.0	5.93

Table 2. Comparative properties of whey with other biomass types (part 2)

Biomass	NDF (% TS)	ADF (% TS)	ADL (% TS)	HC (% TS)	CE (% TS)
Tomato skin and seeds	45.3	36.6	3.56	8.70	34.0
Barley straw	86.4	56.4	9.60	30.0	46.8
Rice straw	78.4	28.0	8.33	50.4	19.6
Grape stalks	62.6	46.7	23.3	15.9	23.5
Maize drying up residues	44.9	14.7	2.33	30.2	12.4
Whey	–	–	–	–	–
Grape marcs	60.4	39.4	23.9	21.0	15.5
Inoculum	–	–	–	–	–

Where: total solids (TS), volatile solids (VS), total nitrogen (TN), neutral detergent fiber (NDF), acid detergent fiber (ADF), acid detergent lignin (ADL), hemicelluloses (HC), and celluloses (CE).
In this regard, the laboratory determination at small scale were made for determining if there can be produced biogas with good properties in terms of partial composition and quantities using the presented materials above.
The present paper will underline the possibilities of using residual materials from an agricultural point of view at small scale and conclusions will be traced relative in order to establish the biogas production potential of used biomass substrates.

MATERIAL AND METHODS

The used installation is presented in the Figure 1.

Figure 1. Frontal view of reactor

The used test bench is composed mainly from a stainless steel cylinder with the total capacity of 5 L and the used capacity of 4 L. The cylinder is enclosed in the upper part with a lid that assures both sealing and suspension control.
On the lid there can be observed the syringe system used for sampling and pH control and the connection with the gas bags used for storing the produced biogas. The total capacity of the gas bag is approximately 2 L.
The lower part of the cylinder is connected with a temperature measurement device connected with a heating plate and a control panel for temperature control.
In order to have a homogenous mixture, the test rig is provided with an electric stirrer. The pH was collected on a daily basis and corrected is necessary. pH correction was made with ammonia 25% concentration.

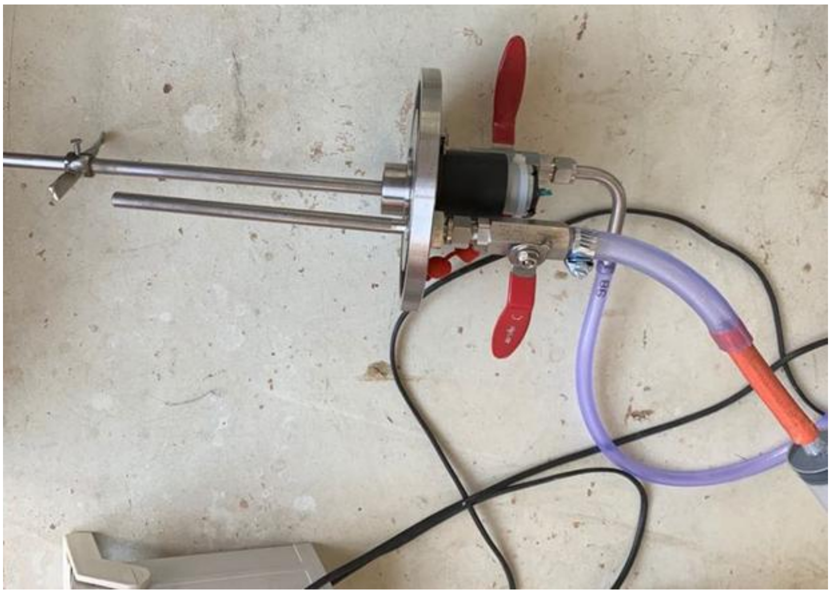

Figure 2. Agitation and pH sampling systems

The temperature regime was about 33 – 36 °C, and the measured parameters were temperature, pH, agitation (rpm), biogas produced quantity and biogas components (methane, carbon dioxide, hydrogen sulfide).
The used materials have an overall granulation of about 1-2 mm and the used batches were composed of waste water from beer factory and corn grains (one batch), while the second batch contained waste water from beer factory and barley.
The residence time was about 30 days inside the reactors.

RESULTS AND DISCUSSION

The main characteristics of degraded barley and degraded corn used in the anaerobic digestion are listed in Table 3.

Table 3. Main parameters of biomasses used in the anaerobic digestion process

	Degraded barley	Degraded corn
Moisture content (db) (%)	10.5	10
Ash content (db) (%)	2.5	1.55
Gross calorific value (db)(J/g)	18600	18400
Net calorific value (db)(J/g)	17300	16800
Carbon content (%)	40.4	40.3
Hydrogen content (%)	6.1	6.6

Table 3. Main parameters of biomasses used in the anaerobic digestion process (continuation)

	Degraded barley	Degraded corn
Nitrogen content (%)	1.45	1.3
Volatile matter content (db) (%)	82.7	85.7
C/N ratio	27.86	31

It can be observed from the table above, the net calorific value indicates a good energetic potential for both materials, while the C/N ratio is a little higher for degraded corn than degraded barley, which makes the degraded barley more suitable for anaerobic processes.
pH variation during the fermentation process is showed in Figure 3.

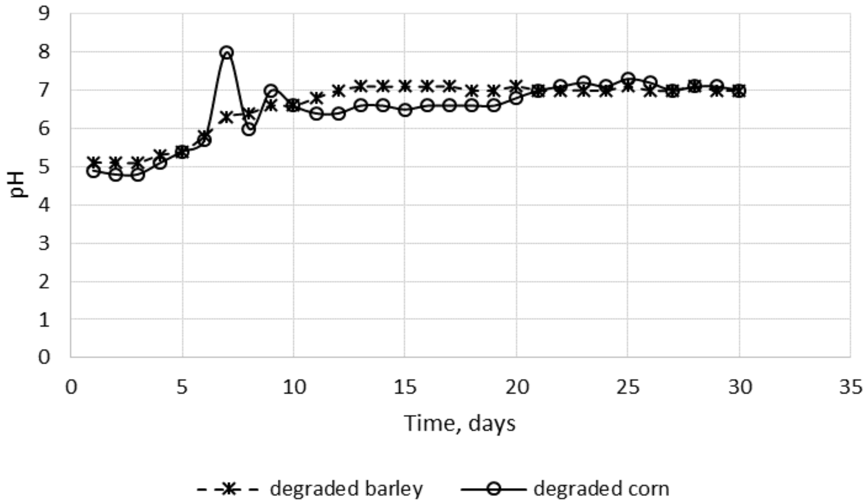

Figure 3. pH variation during anaerobic digestion of degraded barley and degraded corn

The pH for the analyzed batches was initially an acid one, which is specific for anaerobe fermentation processes, when in the initial phase the agricultural material passes to an acid phase. After about 9 days the pH enters in the neutral regime, with 3-4 days later than expected, fact that had a negative impact over the obtained biogas for both batches of material.

Throughout the digestion process, the temperature eas kept in a mesophilic range between 35 and 37^{0}C. The variation is preesented in Figure 4.

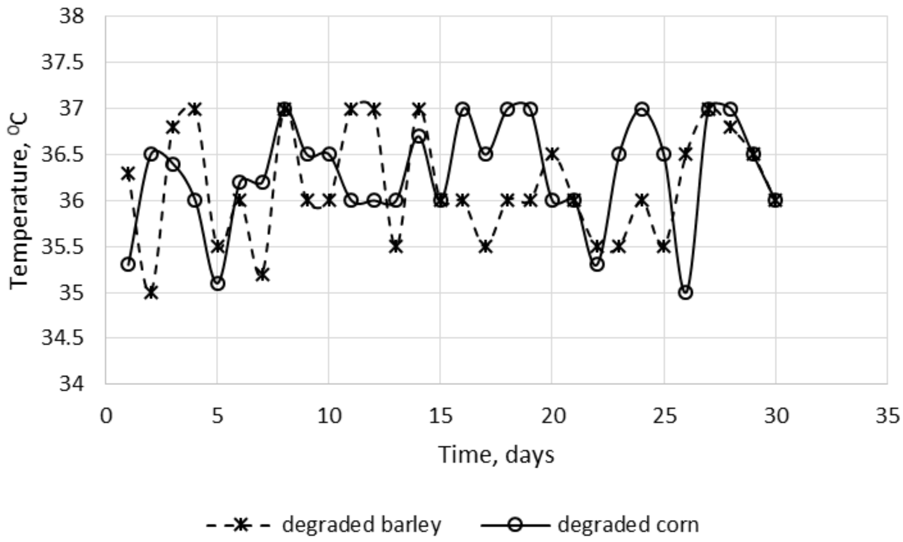

Figure 4. Temperature variation during anaerobic digestion of degraded barley and degraded corn

It can be observed that the temperature variation is between 35 °C and 37 °C, which is the optimum value for mesophilic temperature regime.
The total biogas produced in the end of the anaerobic process as well as the biogas composition in methane is presented in Figure 5.

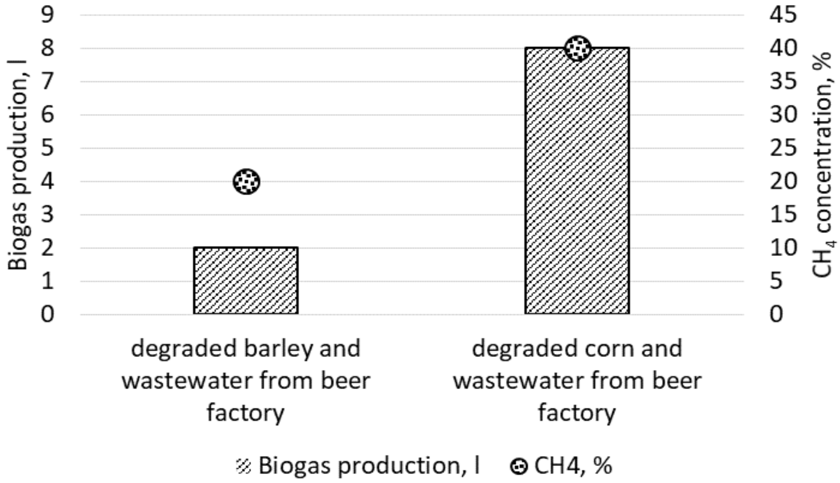

Figure 5. Biogas production and methane composition

For the batch with barley and wastewater from beer factory, the total biogas production was about 2 L and the overall methane concentration was under 20% by volume. This aspect is explained due to the low pH buffer capacity during the initial phase of the anaerobe fermentation process.
For the second batch, the total amount of produced biogas was about 8L and the overall methane concentration was around 40% by volume, which is still a low value relative to the expected concentration which had to be over 55 – 60% by volume.

CONCLUSION

The present paper analyzed the potential for using different types of agricultural residual materials at small scale using a new type of test rig. The preliminary results indicate that the process lacked the optimum values for the produced biogas in both cases, the main possibility being that the process was partially inhibited at an initial point during the process and thus the produced quantities and the biogas quality was less than expected. Further tests are being performed in order to establish the exact cause of the process inhibition but form a constructive point of view, the new testing rig is better in controlling the process both in terms of pH, temperature and biogas production.

REFERENCES

[1] ***, What biogas is?, Biogest, http://www.biogest.at/info/ro/37/Ce-este-biogazul.html, 2019.
[2] ***, Biogas, Cyclon, https://www.cyclon.ro/biogaz_2_568_0.htm, 2019.
[3] ***, Biogas plants, PEV, http://www.pev.ro/furnizarea-sistemelor-pentru-producerea-energiei-regenerabile/centrale-biogaz, 2011
[4] Dinuccio E., Balsari P., Gioelli F., Menardo S.E., Evaluation of the biogas productivity potential of some Italian agro-industrial biomasses, Bioresource Technology, 101, pp 3780 – 3783, 2010.
[5] Daelman M.R., van Voorthuizen E.M., van Dongen U.G., Volcke E.I., van Loosdrecht M.C., Methane emission during municipal wastewater treatment, Water Research, 46, pp 3657 – 3670, 2012.

[6] Luostarinen S., Luste S., Sillanpää M., Increased biogas production at wastewater treatment plants through co-digestion of sewage sludge with grease trap sludge from a meat processing plant, Bioresource Technology, 100, pp 79 – 85,2009.
[7] Appels L., Baeyens J., Degre`ve J., Dewil R.., Principles and potential of the anaerobic digestion of waste-activated sludge, Progress in Energy and Combustion Science, 34, pp 755–781, 2008.
[8] Díaz I., Lopes A.C., Pérez S.I., Fdz-Polanco M., Performance evaluation of oxygen, air and nitrate for the microaerobic removal of hydrogen sulphide in biogas from sludge digestion, Bioresource Technology, 101, pp 7724–7730, 2010.
[9] Simate G. S., Cluett J., Iyuke S. E., Musapatika E.T., Ndlovu S., Walubita L. F., Alvarez A.E., The treatment of brewery wastewater for reuse: State of the art, Desalination, 273, pp 235–247, 2011.
[10] Parawira W., Kudita I., Nyandoroh M. G., Zvauya R., A study of industrial anaerobic treatment of opaque beer brewery wastewater in a tropical climate using a full-scale UASB reactor seeded with activated sludge, Process Biochemistry, 40, pp 593–599, 2005.
[11] Connaughton S., Collins G., O'Flaherty V., Psychrophilic and mesophilic anaerobic digestion of brewery effluent: A comparative study, Water Research, 40, pp 2503 – 2510, 2006.

AEROBIC BIODEGRADATION OF PLASTIC MATERIALS: LABORATORY-SCALE STUDIES

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Abstract: In the frame of increased plastic waste impact onto environment, new technologies have to emerge in order to improve polymeric materials and their disposal methods. This work represents a laboratory set-up for the treatment of polymeric materials derived from renewable feedstocks (herein D-mannose) inside an aerobic bioreactor fed with water from Bega River. The studied material revealed good susceptibility to natural occurring microorganism attack, at 37°C, under continuous stirring and aeration. The weight loss profile in time was assessed and compared against mathematical models: Cone and Dual pooled first-order kinetic. The experimental data and the mathematical models displayed good correlation coefficients.

Key words: aerobic biodegradation, plastic materials, bioreactor, renewable feedstock, mathematical modeling

INTRODUCTION

Plastic materials are one of the most important class of pollutants which affect the environment [1]. Certain efforts have been paid lately for the limitation of polymeric materials' impact on the environment as they turn into plastic waste: recycling/reuse, novel materials with enhanced biodegradability, limitation of single-use plastic packaging, etc [2]. The phenomenon of plastic deterioration in the environment and under controlled conditions has become an intensively studied process and scientific community has a keen interest in manipulating the biodegradation susceptibility of certain materials into technology for waste treatment [3].

There are several factors which favor the degradation of polymeric materials: water permeability and solubility depending on the hydrophilicity of the given material; the crystallinity degree; glass transition temperature and its physical dimension, e.g. size, surface to volume ratio [4]. However, understanding the mechanism of polymer degradation is a challenge given the changing properties of each material, environmental conditions (moisture, temperature, sunlight, etc.) and microbial media [5].

In order to intensify the process, materials with increased biodegradability have been developed, i.e. polyolefins blended with starch [6], polylactic acid [7], polycaprolactone [8], polyhydroxybutyrate [1], natural fibers composites [9] etc. The trend is to use natural occurring materials (sugars, fats) and to combine them to synthetic monomeric backbones in order to turn them into competitive plastic materials with enhanced biodegradability.

Our research group has been involved in the synthesis of sugar derived polymers and their characterization. D-glucose and D-mannose oligomers have been synthesized by chemical altering of the sugar backbone, in order to insert it into the main polymeric chain [10-12]. The obtained sugar oligomers were valorized as plastic materials by means of free radical copolymerization with synthetic co-monomers (herein 2-hydroxypropyl methacrylate), in different weight ratios, resulting glycopolymers with good physico-chemical properties [13-15]. Due to their natural raw material, these glycopolymers displayed good susceptibility to biodegradation *in vitro*, in liquid media, by using pure microbial cultures (i.e. *Trichoderma reesei*, *Zymomonas mobilis*, *Proteus mirabilis*) [16] or microorganisms consortia from environment (i.e. water from Bega River) [17]. In this respect, we present herein the aerobic biodegradation of a glycopolymer derived from D-mannose oligomer (MI_HPMA1) inside a laboratory scale bioreactor fed with water from Bega River. The polymeric samples were placed inside the bioreactor, under continuous stirring, at 37°C, for 23 days. The weight loss of the samples indicated that it had degraded with more than 90% in this period of time. The kinetic profile was fitted against different mathematical models and the correlation parameters displayed adequate concordance between the experimental data and the calculated values.

MATERIAL AND METHODS

Materials

The glycopolymer samples (M_HPMA1) were synthesized based on a method presented elsewhere [13-14]. This polymer is obtained by copolymerization between a D-mannose oligomer (M) and 2-hydroxypropyl methacrylate (HPMA) in weight ratio of 1:1, using benzoyl peroxide as initiator. All other reagents were used as purchased.

Methods

The biodegradation process was studied using a batch bioreactor equipped with a thermoset unit, an aeration pump performing a 2 L/min air flow and a continuous stirring device. The incubation process was carried out for 23 days at 37°C.
The glycopolymers were tested for biodegradability in natural aqueous media provided by water from the Bega River that crosses Timişoara**.** Most probable number of bacteria from Bega River was analyzed and expressed as colony forming units (CFU). Bacteria cultures were obtained on a solid non-selective growth medium - Plate Count Agar, and inoculations method was performed by incorporation into Plate Count Agar growth medium, in sterile Petri dishes, which were incubated at 303 K for 48 hours.
The polymeric samples were weighted from time to time in order to calculate the weight loss during biodegradation process. The weight loss was calculated as the following:

$$\%Weight\ loss = \left(\frac{w_0 - w}{w_0}\right) \times 100 \tag{1}$$

where: w_0 is the initial weight of the sample (before biodegradation) and w is the weight of the glycopolymer sample at the given time, t. The experiments were performed in duplicate.
The kinetic simulation of the biodegradation process was performed by MATLAB R2018a Software Package.

RESULTS AND DISCUSSION

The biodegradation process of the polymeric samples was carried out in aerobic environment under continuous stirring and constant temperature (37°C). The microbial population was provided by the water from Bega River and was assessed as colony forming units (Figure 1).

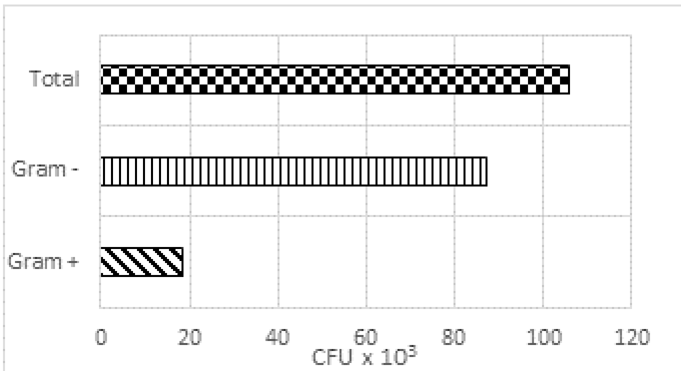

Figure 1. The colony forming units found in the water from Bega River

Under the direct action of the microorganisms, the glycopolymers lost more than 90% of their weight in just 23 days of incubation. The glycopolymers have high susceptibility for biodegradation in liquid media, partly because of their hydrophilic groups which facilitate the microorganisms' development inside the polymeric matrix.

The process was investigated from kinetics point of view following two mathematical models: Cone model and Dual-pooled first order kinetics model. The mathematical expression for the Cone model is given by the equation (2):

$$W(t) = \frac{W_m}{1 + (k \cdot t)^{-n}} \tag{2}$$

Where: W(t) is the cumulative weight loss at the given time, t (%), W_m is the maximum weight loss potential (%), k is the biodegradation rate constant (1/days), t is the time (days), n is the shape factor [18]. The superimposed experimental data over the simulated values using the Cone model are presented in fig. 2. The model's parameters and the calculated correlation coefficients are displayed in Table 1.

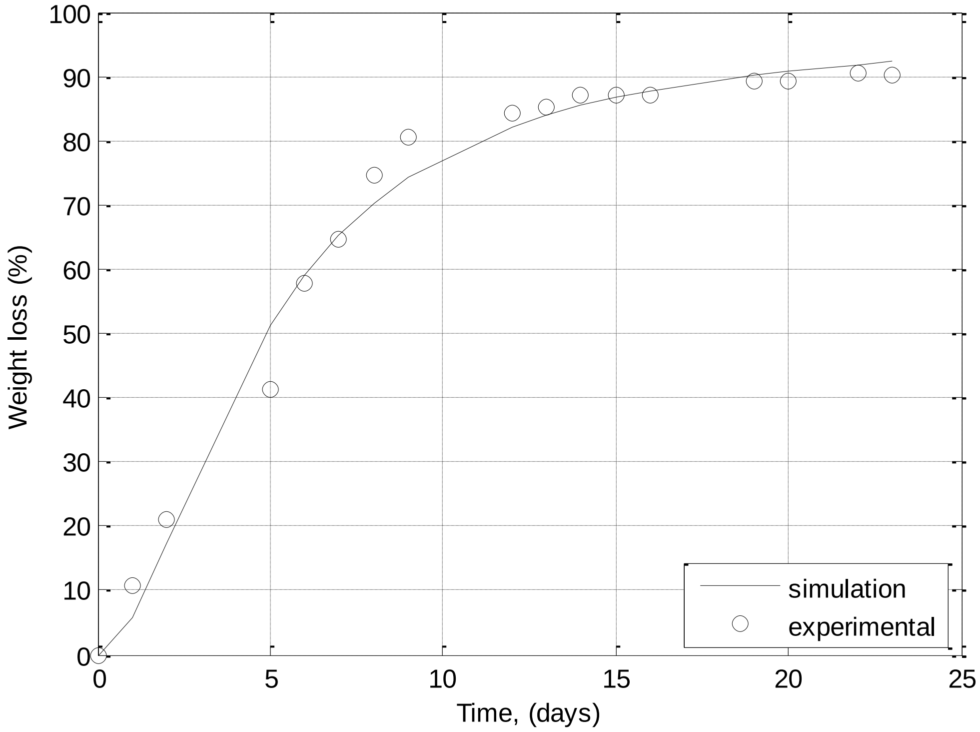

Fig. 2. The experimental data vs. simulation values using Cone model

Dual pooled first-order kinetic model was also employed for the simulation of the biodegradation process. Its mathematical expression (3) takes into account both the quick and the rate-determining step of the process.

$$W(t) = W_m \cdot (1 - \alpha \cdot e^{-k_f \cdot t} - (1 - \alpha) \cdot e^{-k_L \cdot t}) \tag{3}$$

where: W(t) is the cumulative weight loss at given time t (%), W_m is the maximum weight loss potential (%), t is the time (days), k_f is the rate constant for the rapidly degradable substrate (1/days), k_L is the rate constant for slowly degradable substrate (1/days), α is the ratio between the rapidly degradable substrate and the slowly degradable substrate [18]. Figure 3 displays the simulated values according to expression (2) versus the experimentally determined weight loss of the sample. Table 1 comparatively shows the two models' parameters and the calculated correlation coefficients using both models discussed herein.

The chosen mathematical models describe adequately the biodegradation process, the correlation coefficient and determination coefficient being very close to 1 (more than 0.992). For practical applications, mathematical models which predict and evaluate the parameters of the process can provide data for the optimal design of the biodegradation process at larger scale [19]. Cone and Dual pooled model are suitable candidates for such a task.

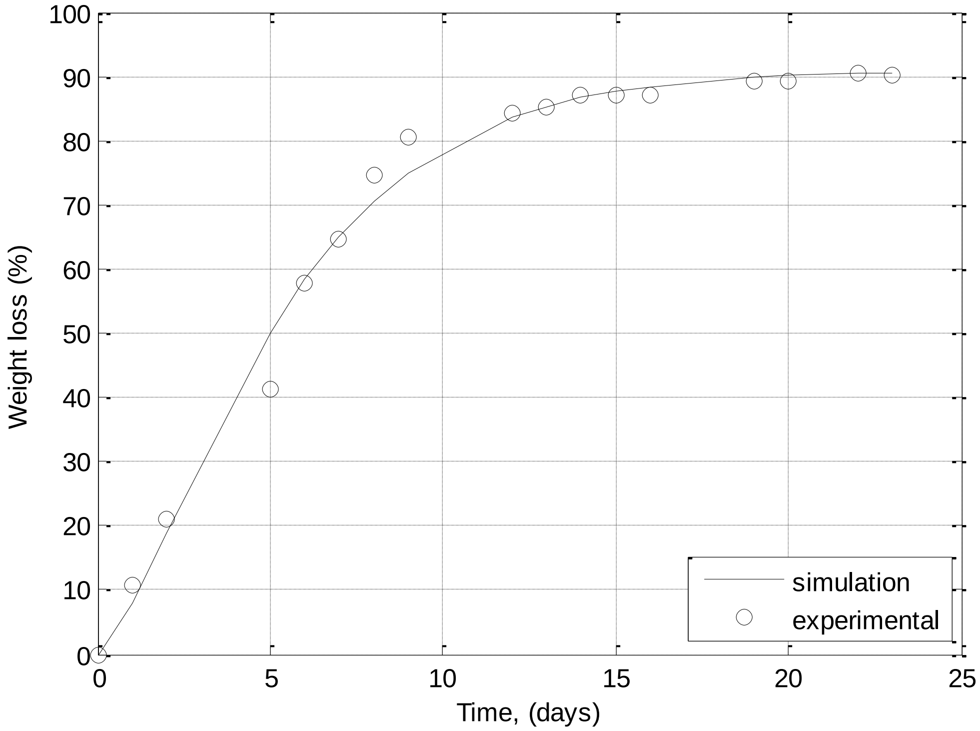

Figure 3. The experimental data vs. simulation values using Dual pooled first-order kinetic model

Table 1. Correlation data for mathematical kinetics models

Model	Maximum Weight loss potential, W_m (%)	Shape factor, n*	Rate constant, k (1/days)**	Root-mean square error, RMSE	Mean square error SD	Determination coefficient R^2	Correlation coefficient R	Relative absolute error, rAE
Cone	97.7855	1.7822	0.2118	3.5965	12.9350	0.9976	0.9928	0.0016
Dual pooled first-order kinetics	90.8685	-	0.3493 0.3153	2.8883	8.3423	0.9984	0.9952	0.0011

* for Dual pooled first-order kinetics model, α;
** for Dual pooled first-order kinetics model, k_f the rate constant for the rapidly degradable substrate (1/days) and k_L, the rate constant for slowly degradable substrate (1/days), respectively were assessed

CONCLUSION

The biodegradation of sugar derived polymeric materials inside an aerobic bioreactor under continuous stirring and constant temperature was studied from kinetics point of view. The main parameter of the process was weight loss, which was determined almost daily for about 23 days. The total weight loss of the sample reached 90%. The mathematical modeling of the biodegradation process was performed against Cone and Dual pooled kinetics model. The calculated correlation data revealed good fit for both models, each of them describing accurately the biodegradation process. Further studies will be performed following a scale-up of the process to pilot scale.

AKNOWLEDGEMENT

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REFERENCES

[1] Yamano N., Kawasaki N., Ida S., Nakayama A., Biodegradation of polyamide 4 in seawater, Polymer Degradation and Stability, 166, pp. 230-236, 2019

[2] Zumstein M.T., Schintlmeister A., Nelson T.F., Baumgartner R., Woebken D., Wagner M., Kohler H.P.E., McNeil K., Sender M., Biodegradation of synthetic polymers in soils: Tracking carbon into CO_2 and microbial biomass, Science Advances, 4(7), eaas 9024, pp. 1-8, 2018

[3] Ahmed T., Shahid M., Azzem F., Rasul I., Shah A.A., Noman M., Hameed A., Manzoor N., Manzoor I., Muhammad S., Biodegradation of plastics: current scenario and future prospects for environmental safety, Environmental science and Pollution Research, 25, pp. 7287-7298, 2018

[4] Pitt C.G., Schindler A., Biodegradation of Polymers in Controlled Drug Delivery: vol. 2, Clinical Applications, Eds. Bruck S.D., CRC Press, 2019

[5] Sander M., Biodegradation of Polymeric Mulch Films in Agricultural Soils: Concepts, Knowledge Gaps, and Future Research Directions, Environmental Science and Technology, 53(5), pp. 2304-2315, 2019

[6] Karimi M., Biria D., The promiscuous activity of alpha-amylase in biodegradation of low-density polyethylene in a polymer-starch blend, Nature Scientific Reports, 9, art. No.: 2612, pp. 1-10, 2019

[7] Da Silva D., Kaduri M., Poley M., Adir O., Krinsky N., Shainsky-Roitman J., Schroeder A., Biocompatibility, biodegradation and excretion of polylactic acid (PLA) in medical implants and theranostic systems, Chemical Engineering Journal, 340, pp. 9-14, 2018

[8] Malhotra M., Surnar B., Jayakannan M., Polymer Topology Driven Enzymatic Biodegradation in Polycaprolactone Block and Random Copolymer Architectures for Drug Delivery to Cancer Cells, Macromolecules, 49(21), pp. 8098-8112, 2016

[9] Takagi H., Review of Functional Properties of natural Fiber-Reinforced Polymer Composites: Thermal Insulation, Biodegradation and Vibration Damping Properties, Advanced Composite Materials, pp. 1-19, 2019

[10] Pană A.M., Rusnac L.M, Bandur G., Şişu E., Badea V. and Silion M, Synthesis and characterization of new glycopolymers based on monosaccharides and maleic anhydride. I. Glucose derivatives, Mat. Plastice (Bucharest), 47(1), pp. 28-34, 2010

[11] Pană A.M., Rusnac L.M., Bandur G., Deleanu C., Bălan M., Silion M., Synthesis and characterization of new glycopolymers based on monosaccharides and maleic anhydride. II. Mannose derivatives, Mat. Plastice (Bucharest), 47(3), pp. 299-305, 2010

[12] Pană A.M., Rusnac L.M., Bandur G., Silion M., Deleanu C., and Bălan M., Novel D-glucose and D-mannose based oligomers. Synthesis and characterization, e-Polymers, no.004, pp. 1-13, 2011

[13] Pană A.M., Gherman V., Sfîrloagă P., Bandur G., Ştefan L.M., Popa M., Rusnac L.M. Thermal stability and biodegradation of novel D-mannose based glycopolymers, Polymer Testing, 31, pp. 384-392, 2012

[14] Ştefan L.M., Pană A.M., Bandur G., Martin P., Popa M., Rusnac L.M., Thermal analysis of new glycopolymers derived from monosaccharides, Journal of Thermal Analysis and Calorimetry, 111, pp. 789-797, 2013

[15] Pană A.M., Popa M., Silion M., Sfîrloagă P., Duchatel L., Bandur G., Rusnac L.M., Novel semi-interpenetrating network hydrogels based on monnosaccharide oligomers with itaconic moiety: synthesis and properties, Iran. Polym J., 26, pp. 743-751, 2017

[16] Pană A.M., Ştefan L.M., Bandur G., Sfîrloagă P., Gherman V., Silion M., Popa M., Rusnac L.M., Novel glycopolymers based on D-mannose and methacrylates. Synthesis, thermal stability and biodegradability testing, Journal of Polymers and the Environment, 21, pp. 981–994, 2013

[17] Pană A.M., Gherman V., Sfîrloagă P., Rusu G., Bandur G., Popa M., Rusnac L.M., Dumitrel G.A., Biodegradation studies on new glycopolymers derived from oligomeric D-mannose itaconates and 2-hydroxypropyl acrylate, Polymer Degradation and Stability, 167, pp. 210-216, 2019

[18] Nquyen D.D., Jeon B.H., Jeung J.H., Rene E.R., Banu J.R., Ravindran B., Vu C.M., Ngo H.H., Guo W., Chang S.W., Thermophilic anaerobic digestion model organic wastes: Evaluation of biomethane production and multiple kinetic models analysis, Bioresource Technology, 280, pp. 269-276, 2019

[19] Mata-Alvarez, J., Macé, S., Llabrés, P., Anaerobic digestion of organic solid wastes. An overview of research achievements and perspectives, Bioresource Technology 74 (1), pp. 3–16, 2000

[20] Zhen, G., Lu, X., Kobayashi, T., Li, Y.-Y., Xu, K., Zhao, Y., Mesophilic anaerobic codigestion of waste activated sludge and *Egeria densa*: performance assessment and kinetic analysis, Applied Energy 148, pp. 78–86, 2015.

AMMONIA WITHIN NITROGEN CYCLE PROCESS AND ITS PRESENCE IN DRINKING WATER

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Abstract: To be used for drinking, water must be health safe. That implies certain physical, physico-chemical, chemical, microbiological, biological and radiological characteristics of water. Nitrogen compounds, and ammonia among them as well, are integral parts of nitrogen cycle in nature. During the last century nitrogen cycle was severely disrupted due to the development and the use of new agrotechnical practices. Ammonia in drinking water can be an idicator of chemical water pollution. As it is very toxic, it is very important to check drinking water quality in order to save the health of people.
Key words: ammonia, drinking water, nitrogen cycle, spectrophotometry, health safety

INTRODUCTION

The largest quantity of nitrogen on the planet is found in gaseous state (N_2). The most plentiful form in elementary state is in atmosphere (78%). Nevertheless, most organisms cannot use nitrogen in molecular form (atmospheric nitrogen). In order to use it, plants must have mediators who convert the nitrogen in atmosphere into ammonia or nitrates. Microorganisms have their basic role in all these processes. All green plants need nitrogen in its "fixated" form, i.e. in the form of compounds such as nitrate ions (NO^{3-}), ammonia (NH_3) and urea $(NH_2)_2Co$. Animals and people provide the need for nitrogen compounds (and everything else) by eating plants and animals who feed on plants.
The transformation of atmospheric nitrogen into a compound that takes part in biochemical processes is called nitrogen fixation. It is the reduction of N_2 to NH_3 or NH_4^+ ion or organic nitrogen. Nitrogen molecules are very stable. Energy is required for breaking the bonds between atoms and forming the bonds with other atoms.
Three processes are required for nitrogen fixation in biosphere: atmospheric fixation (in the presence of light), industrial fixation and biological fixation (independently helped by certain microorganisms or in symbiosis with plants). Atmospheric fixation takes place during electric discharge (occuring with lightning and thunder). Then, a large quantity of light energy, in the form of photons disintegrate nitrogen atoms and enable making the bonds with atmosferic oxygen and forming nitrogen oxides. These oxides are dossolved by rain, forming nitrates that reach the soil in the form of "acid rains". During industrial fixation – using Haber-Bosch process – ammonia is produced (NH_3) and the reaction of nitrogen gases and hydrogen takes place under extreme processing conditions with the help of catalysts: $N_2 + 3H_2 \rightarrow 2NH_3$. Ammonia can be directly used as fertilizer, but a large part of it is used in the production of urea $(NH_2)_2CO$ and ammonium nitrate (NH_4NO_3). Biological fixation takes place in nature helped by certain bacteria who have the ability to fix nitrogen. Biological fixation is the result of a complex activity of a number of enzymes and the use of a large quantity of ATP. Although ammonia is the first stable product, it quickly integrates into proteins and other organic nitrogen compounds. Bilogical nitrogen fixation is a reduction process in which nitrogen gas (N_2) from the air is converted in the form of ammonium (NH_3). This is very important ecological process because all plants need nitrogen in the form of ammonium or nitrates needed for the synthesis of amino acids of their own proteins, and plant–based proteins are the only sources of protein for animals. The only organisms able to perform this reduction reaction on our planet are certain types of bacteria, particularly *Cyanobacteria*, and it can be said that the whole life on our planet depends on their activity. The forms of procaryote organism that can fix nitrogen provide the link between the enormous abundance of nitrogen as a gas in atmosphere and the rest of living world on our planet. Nitrogen which fixes in the form of ammonium or ammonium-ion makes the basic material for chemoautotrophic and nutritional types of bacteria.

For a long time it has been known that leguminous plants (beans, lucerne, pea, clover, common vetch) are important crops because they improve soil fertility. The reason for this lies in the fact that bacteria from the genus *Rhizobium* leguminous plants live on the root nodi of these plants. These bacteria use sugar produced by these plants in the process of photosyntesis, and in return provide them with ammonia, [1, 2].
The process of the removal of an amino group is called deamination. In the process of deamination, organic molecules containing nitrogen are decomposed, creating ammonia. The proteins synthetized by the plants and hydrocarbons, taken with food, are transformed during metabolic process into by-products, organic compounds of nitrogen returned to nature as fertilizers. End users of these substances are microorganisms of deamination, who decompose the molecules in the fertilizer and died out organisms, turning them into ammonia, [2].
In the process of nitrification, nitrifying bacteria, who are chemoautotrophic forms, oxidize ammonia (NH_3) or ammonium ion (NH_4^+) into nitrate (NO_2^-), namely nitrites into nitrates (NO_3^-). These bacteria have vital role in the cycle of nitrogen on our planet, [3, 4].

$NH_4^+ + 3/2\ O_2 \rightarrow NO_2^- + H_2O + 2H^+$ (bacterium *Nitrosomonas*) (1)

$NO_2^- + ½\ O_2 \rightarrow NO_3^-$ (bacterium *Nitrobacter*) (2)

It is possible to find a number of reactions leading to the creation of ammonia again, and beginning with nitrates. That process is known as nitrate ammonification.

$NO_3^- \rightarrow NO_2^- \rightarrow NH_3$ (3)

Ammonification (mineralization) is the process of organic nitrogen decomposition into NH_3 ili NH_4^+. Heterotrophic bacteria or mushrooms turn the organic nitrogen found in excrement or perished plants or animals into inorganic form, ammonia, [1, 2].
Ammonia is a gas with a characteristic pungent and unpleasant smell. The term ammonia refers also to nonionized (NH_3) and ionized (NH_4^+) form. In free state, it is not found in water but forms a bond with carbonic acid. Both ammonia and carbonic acid are extremely poisonous. Ammonia is the result of organic material decomposition containing nitrogen, namely organic nitrogen compounds in the process of mineralization and the hydrolysis of urea to form ammonia and carbon dioxide. In organic compounds it is created under the influence of enzymes and in aerobic conditions turns to nitrites and nitrates. Because of that, the quantity of ammonia in natural waters is relatively small. Intensive rearing of animals on the farms can raise the level of ammonia in the surface waters. Ammonia in the water is an indication of a possible bacterial activity, and the presence of sewage system waste or perished animals waste. A larger quantity of ammonia in the given water points to the presence of waste or fecal water. However, ammonia can sometimes be created in the process of the reduction of mineral nitrogen. In well buffered waters, namely those that contain sufficient quantity of carbon acid, ammonia cannot be found, [1, 5, 6].
Nitrogen compunds can derive from atmosphere, become as a product of decomposition of organic materials (proteins, urea, etc., as a result of bacterial action or under the influence of chemical reactions), from nitrogen fertlizers, and so on.

MATERIAL AND METHODS

The method most often used to determine the presence of ammonium in drinking water is spectrophotometric method [6-10]. According to the Book of Rules that defines the way for taking samples and methods for laboratory analysis of drinking water, the methods of determining nitrogen compounds are as follows: spectrophotometric with Nessler's reagent (after destilation), spectrophotometric reagent (without destilation) and spectrophotometric with phenol-hypochlorite, [11].
Drinking water checking methods according to the Book of Rules on Disinfection and Inspection of Drinking Water, [12] reads that the sample for physico-chemical check-up (extensive analysis) is taken at least in the quantity of 5 dm^3, in a clean bottle. While taking the sample of water, the

temperature is measured at the spot with determining organoleptic characteristics, gaseous and unstable compounds. According to this Book of Rules ammonia is determined using colorometric (spectrophotometric) method with Nessler’s reagent.

Chromogen chemicals are those which, after the needed reaction, form a coloured product. Every chromogen reacts with the corresponding mineral as to form a soluble coloured product which can be quantified by the absorption of light in a certain wave length on the spectrophotometer. The link between the concentration and absorption is expressed by **Beer'sLaw. Generally speaking, the concentration of a mineral in the given sample iz determined by the standard curve obtained during the analysis, though, in some cases the concentration can be directly calculated on the basis of absorbing capacity of chromogen-mineral complex. The samples must usually be turned to ashes or treated in some other ways as to be isolated and/or to let free the minerals from organic complexes which can otherwise inhibit their reactivity with the chromogen. The minerals, dry ashes, we are interested in must be dissolved as to prevent their sedimentation. The minerals which can be dissolved possibly have to be treated (e.g. reduced or oxidized) as to make sure that the minerals are in the form that can react with the given chromogen. It would be perfect to have a quick reaction of the chromogen and to have a stable product. This is not a usual case in practice** [13].

Figure 1. UV-Vis Spectrophotometer

Standard reagent for ammonia is Nessler's reagent and, during the reaction, the solution becomes deeper yellow and at higher concentrations a brown precipitate may form. This reagent is specific ammonia reagent (reacts only with ammonia) and sensitive (reacts on very low concentrations of ammonia). Nessler's reagent contains mercury(II) iodide. Nessler's reagent is very toxic and corrosive, and has to be handled with exceptional care. In case that the hardness of water exceeds the value of 500 mg/dm^3 $CaCO_3$ i 500 mg/dm^3 Mg kao $CaCO_3$ a mineral stabilizer is added.

Polyvinyl alcohol (PVA), a dispersing agent, is added as to speed up the reaction after Nessler's reagent and ammonia. The yellow colour that appears is proportional to the intensity of concentration of ammonia ion. The determination of the values is done on the spectrophotometer (Figure 1.) on the wave length of 425 nm, [6].

RESULTS AND DISCUSSION

According the Book of Rules on Hygienically Safe Drinking Water [14], hygienically safe water is the one that meets certain requirements in view of microbiological characteristics, chemical substances (inorganic, organic and chemical substances and pesticides in drinking water), residuums of coagulation and flocculation waste, disinfectants and their by-products, physical, phsical-chemical and chemical characteristics, radiological characteristcs (allowed lovel of total alpha-activity and total beta-activity), as well as chemical warfare (in a state of war). The frequency of elementary and periodical check-ups of hygienically safe drinking water is performed according to the Book of Rules. According to The Book of Rules [14], maximum allowed concentration for ammonia in drinking water in ordinary situations is 0,5 mg/l, for water-supply system up to 5.000 ES do 1 mg/l.

In normal circumstances, drinking water does not contain ammonia. Spectrophotometric metod was used for the determination of ammonia contents at six sites of the river Rama in the period of maximun and minimum water levels. The results of the chemical analysis of the samples during the period of maximum and minimum levels showed that there were no signs of amonia at these sites [6].
The results of spectrophotometric analysis of raw water and the treated drinking water, from the same sites, in Water Supply Company Ruma showed that the concentration of ammonia in the given samples of raw water were twice as big than allowed. However, the treatment reduced this amount, and the concentration of ammonia in the given samples was lower than maximun allowed concentration, [15].

CONCLUSION

The largest amount of nitrogen on the planet is found in gaseous state (N_2).During fixation, nitrogen is turned to ammonia, and after that, in the process of nitrification to nitrites and nitrates, which become material for making biomass. The most important influence on nitrogen cycle is the synthesis of ammonia using Haber-Bosch process. Chemical industry made a substantial influence in the management of natural resources. The largest part of this nitrogen, turned to ammonia, is used in the production of fertilizers. These nitrogen compounds are very toxic. From the soil they reach surface and underground water streams, which are used as the sources of water supply. They are dangerous for the health of people if they are found in concentrations larger than allowed. To avoid these risks caused by the presence of these compounds in drinking water check-ups to determine the quality of water must be done frequently and according to the Book of Rules.

REFERENCES

[1] Shrimali, M., Singh K.P., New methods of nitrate removal from water, Environmental Pollution, 112, pp. 351-359, 2001.
[2] Cvetkovska, M., Vuković, M., Cvetkovski, V., The nitrification bacteria and nitrogen cycle, Proceedings of the EkoIst '06, ECOLOGICAL TRUTH, Sokobanja, Srbija i Crna Gora, pp. 251-255, 2006.
[3] Ciudad, G., Rubilar, O., Muñoz, P., Ruiz, G., Chamy, R., Vergara, C., Jeison, D., Partial nitrification of high ammonia concentration wastewater as a part of a shortcut biological nitrogen removal process, Process Biochemistry, Vol.40 (5), pp. 1715–1719, 2005.
[4] Ruiza, G., Jeisonb, D., Rubilarb, O., Ciudadb, G., Chamy, R., Nitrification–denitrification via nitrite accumulation for nitrogen removal from wastewaters,Bioresource Technology,Vol. 97 (2), pp. 330–335, 2006.
[5] Dalmacija, B., Agbaba J., Quality control of drinking water, Faculty of Sciences, Novi Sad, 2006. [In Serbian]
[6] Bobar, S., Konjarić, S., Quantity and correlation of nitrogen compounds with the Rama river water level, Educa, VI, br. 6., pp. 13-19, 2013. [In Serbian]
[7] Burakhama, R., Oshima, M., Grudpan, K., Motomizu, S., Simple flow-injection system for the simultaneous determination of nitrite and nitrate in water samples, Talanta 64, pp. 1259–1265, 2004.
[8] Birke, M., Reimann, C., Demetriades, A., Rauch, U., Lorenz, H., Harazim, B., Glatte W., Determination of main and trace elements in European bottled mineral water-analytical methods, Journal of Geochemical Exploration, 107, pp. 217–226, 2010.
[9] Peh, Z., Šorša, A., Halamić, J., Composition and variation of major and trace elements in Croatian bottled waters, Journal of Geochemical Exploration, Vol. 107(3), pp. 227–237, 2010.
[10] Petrović, T., Zlokolica-Mandić, M., VeljVidojević, N., Hydrogeological conditions for the forming and quality of mineral waters in Serbia, Journal of Geochemical Exploration, Vol. 107, pp. 373-381, 2010.
[11] Regulations of sampling and methods of laboratory analysis of drinking water, Official Gazette of SFRY 33/87, Belgrade, Serbia. [In Serbian]
[12] Regulations of drinking water disinfection and inspection, Official Gazette of the Republic of Serbia, No 60/81, Belgrade, Serbia. [In Serbian]

[13] Nielsen, S. S., Food Analysis, Purdue University, USA, 2010.
[14] Regulations of water potability, Official Gazette of SFRY, Nos 42/98 and 44/99 and Official Gazette of the Republic of Serbia, No 28/2019, Belgrade, Serbia. [In Serbian]
[15] Cibulić, V., Veljković, N., Stamenković, L., Staletović, N. (2015): Procena i upravljanje rizikom u sistemima za snabdevanje vodom za piće, Vodoprivreda 0350-0519, Vol. 47 No. 273-275, pp. 119-130.

THE ORIGIN OF NITRITES AND NITRATES IN NATURE AND DETERMINATION OF THEIR CONTENT IN DRINKING WATER

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Abstract: The entire life on planet Earth is dependent on nitrogen compounds, i.e. proteins and nucleic acid. Nitrogen compounds – nitrates (NO^{3-}) and nitrites (NO^{2-}) can get into water from the atmosphere, leguminous plants, plant waste, animal feces, sewage, industrial wastewater, artificial fertilizers, etc. In classical ''hygiene-chemical'' analyses these compounds are used as indicators of the chemical contamination of water. These nutrients stimulate the development of plant flora in water, and therefore the Regulations set maximum allowed concentrations in drinking water. Spectrophotometry is a rapid and simple method to quantify their content and thus to control water potability.
Key words: nitrates, nitrites, drinking water, nitrogen cycle, spectrophotometry, water safety.

INTRODUCTION

Nitrous acid salts - nitrites occur naturally as a part of the nitrogen cycle. They develop as a reaction intermediate from ammonium oxidation (nitrification) and in nitrite reduction (denitrification). Nitrites are a good indicator of unfinished redox reactions. Nitrite ion is very unstable and in the aerobic zone it oxidizes into the nitrates under the influence of oxygen, with the help of *Nitrobacter*. So, nitrites are not found in significant amounts in surface waters, due to oxidation into nitrates. The elevated content of this ion can occur during oxidation of ammonium compounds, which is often caused by the action of nitrifying bacteria, as well as during reduction of nitrates into nitrites. Nitrate reduction is the product of bacterial activity. Large amounts of nitrites in water indicate partial decomposition or newly caused contamination by organic compounds, wastewaters and bacteria, and inadequate disinfection. Nitrites are often used as corrosion inhibitors in industrial or cooling waters, and as preservatives in food industry. They perform oxidation of myoglobine into metmyoglobine. Also, they are used as fertilizers. The presence of nitrites in water can be also an evidence of fresh fecal contamination. They can be found in wastewaters and dump wastewaters, agricultural areas and atmospheric urban sewage. The amount of nitrites is limited by Regulations due to their potential carcinogenic effects [1, 2].
Nitric acid salts – nitrates also occur naturally as a part of nitrogen cycle. Nitrates are an end-product of organic matter mineralization, so that the presence of this ion indicates total oxidation of nitrogen compounds in groundwaters. The sources of nitrates are mineral deposits (sodium and potassium nitrate), soil, sea water, and atmosphere. From the soil, nitrates spread to the environment starting from food to the atmosphere and water. Higher nitrate concentrations are expected in the areas where fertilizers are applied, in decaying animal and plant residues, dump wastewaters, as well as in industrial waste. Also, the presence of nitrates in water indicates old water contamination or old source of contamination. Nitrates are always found in higher concentrations than nitrites. Much higher amounts were found in shallow waters, contaminated settlements (wastewaters) and/or due to excessive use of fertilizers than in groundwaters. In surface waters, utilization of nitrates as fertilizers by the plants tends to reduce significantly the concentration of nitrates. Nitrates are essential mineral substances for photosynthetic autotrophic organisms, and in some cases they can be also a limiting factor of growth, [1, 3].
Nitrates formed by nitrifying bacteria (*Nitrosomonas, Nitrobacter)* can be also used by the plants. Nitrogen-fixing bacteria have been studied extensively, especially for their value in agriculture. Legumes, being very important crops, improve soil fertility due to the presence of bacteria from the genus *Rhizobium* in the nodules within the legume roots, because in the process of photosynthesis they produce ammonium from sugars and provide nitrogen compounds for the plant, [3, 4]. Nitrogen fixation is an important ecolocical process, because all plants need ammonium and nitrates to produce biomass with their help. In this way, by NH_3 assimilation – fixed NH_3 or NH_4^+ ions are converted into

organic form. Nitrogen assimilation refers to the part of the cycle where there is ammonium built-in in organic molecules of the general formula R-NH_2 such as nucleic acids, amino acids, i.e. proteins, thus becoming a part of the biomass, [3, 4].

Nitrates are reduced to elementary nitrogen by the process of denitrification, sending nitrogen back to the atmosphere, because previous processes that are taking place in nature, are based on nitrogen transfer from the atmosphere to ecosystems. Also, this process is catalyzed by microorganisms, which live deep in the soil and water sediments with anaerobic conditions. Microorganisms use nitrates in the role of oxygen acceptors in their respiration. Denitrification can be considered a special case of the general process known as nitrate reduction, [5]. Namely, the reactions of nitrate reduction into the end-product, nitrogen, proceed in a sequence as follows, [6]:

$$NO_3^- \rightarrow NO_2^- \rightarrow NO \rightarrow N_2O \rightarrow N_2 \qquad (1)$$

Nitrates are found in moderate concentrations in the majority of natural waters, but they often contaminate groundwaters mainly due to excessive application of fertilizers and uncontrolled wastewater discharge and treatment. This causes more serious problems, direct use of groundwater sources for human diet is limited in several parts of the world, including Saudi Arabia, India, China, Japan, USA and Great Britain. Similar problems are encountered in certain parts of Europe, [3].

MATERIAL AND METHODS

The most commonly used method for determination of nitrites and nitrates in drinking water is spectrophotometry, [1, 7, 8]. According to the Regulations of sampling and methods for laboratory analysis of drinking water, [9], the methods for determinig nitrogen compounds, for nitrites, are: spectrophotometry with alpha-naphthylamine and sulfonic acid and spectrophotometry with indol, and for nitrates: spectrophotometry with sodium salicylate and colorimetric with Brucine Ultraviolet method.

Methods for water inspection are applied according to the Regulations of drinking water disinfection and inspection, [10]. Based on the Regulations, nitrites are determined colorimetrically (spectrophotometrically) with alpha-naphthylamine. Nitrates are determined colorimetrically (spectrophotometrically) with brucine or 1N-(1-naphthyl)-ethylenediamine using the reduction with cadmium, ultraviolet, electrophotometry, or ion-selective electrode.

Nitrites are determined spectrophotometrically in such way that nitrite-ion in water sample reacts with sulfonic acid, from the NitraVer reagent and a transient compound, the diazonium salt, is formed. Diazonium salt yields the solution of pink (red-violet) color with the chromotropic acid in a reagent. The intensity of color is proportionate to the concentration of nitrite-ion. Determination is performed on a spectrophotometer at wavelength of 525 nm, [1].

Spectrophotometric determination of nitrates is conducted in two ways. The first method is applied to determine nitrates in the samples of drinking water that contains small amounts of organic matter, such as unpolluted natural waters and drinking waters. Determination is done by measuring sample absorbance at 220 nm. Since some organic matter can absorb at 220 nm, and nitrites absorb at 275 nm, the second measurement is performed at 275 nm to correct the value for nitrates, [1]. In the second method, cadmium, a metal present in the NitraVer reagent, reduces nitrates in the sample into nitrites. Nitrite-ion reacts in an acid medium with sulfonic acid from NitraVer and a transient compound - the diazonium salt is formed. Diazonium salt yields yellow solution with acid in the reagent. The intensity of yellow color is proportionate to the nitrate-ion concentration. Determination is done spectrophotometrically at the wavelength of 400 nm, [11].

A simple system with a flow injection was constructed for simultaneous determination of nitrites and nitrates in water samples. A spectrophotometric system of flow injecting was operating with a Cu/Cd reduction column. The basis of detection was the reaction between nitrite-ion and phloroglucinol (1,3,5-trihydroxybenzene), commercially available phenolic compound. The sample injected in the supporting stream is divided into two currents in the Y-shape connector. One of the streams reacts directly with the stream reagent, and thus nitrite-ion is detected in the sample. The second stream is brought through the reduction column, where the reduction of nitrites into nitrites is performed, and then the sample zone is mixed with the stream reagent and they pass through a detector, where nitrates

and nitrites are detected. The procedure is rather simple, rapid and does not require careful pH and temperature control, [7].
Also, the application of chemiluminiscence in direct nitrite determination was studied. Peroxynitric acid (ONOOH) was produced by mixing acidic hydrogen peroxide and nitrites in the flow system. Strong chemiluminiscent (CL) emission was recorded when ONOOH reacts with carbonate without special CL reagents, [12].
A rapid, simple, selective and sensitive method was developed for spectrophotometric determination of nitrites in the water. Nitrites react with barbituric acid in acidic solution yielding nitroso derivative, violuric acid $C_4H_3N_3O_4$. Completeness of the reaction depends on pH solution. Forming of voluric acid was followed by absorbance measurement at 310 nm. The method does not require costly equipment and reagents are health safe, [8].

RESULTS AND DISCUSSION

According to the Regulations of water potability, [13], maximum allowed concentrations of inorganic matter in potable water under regular conditions amount to 50.0 mg/l for nitrates and 0.03 mg/l for nitrites. It is considered that water is potable if in 20% of measurements, which are not consecutive, the concentration value reaches 0.1 mg/l throughout the year; the measurement frequency is according to the Regulations in effect.
The content of nitrites and nitrates was determined by spectrophotometric method at six locations in the Rama river in the period of low and high water level, [1].
The results indicated that in the low- and high-water level period the nitrates content ranged from 0.002 mg/dm^3 to 0.006 mg/dm^3. Tests showed that nitrates are present in the Rama river in the 0.0 mg/dm^3 – 0.4 mg/dm^3 range. All obtained values were within the limits of maximum allowed concentrations. Results of the chemical analysis of the Rama water samples from the low-water-level period indicated that measured concentrations of nitrites and nitrates changed along the river stream. The highest concentrations were measured below the settlements located on the river banks. In the high-water-level period the concentrations of nitrites and nitrates were rather uniform along the river stream. Also, it proved that measured values for nitrates are considerably higher in the period of low water level (small amount of water in the watercourse, presence of plants and algae in water, high water temperatures, and other factors).
The results of spectrophotometric analysis of the raw and purified water, from the same sources, showed that in the Ruma waterworks the concentration of nitrates and nitrites in both raw and drinking water was within allowed limits, [14].
Studies of the chemiluminiscence application in direct determination of nitrites implied that when cotton was present in CL cell, Cl emission was significantly improved. This CL system proved to be sensitive and selective for determining nitrites in natural water samples, without any special pretreatment. This approach and standard spectrophotometric method demonstrated good agreement in obtained results in determining nitrites in tap water and deep waters, [12].
The system with flow injection was developed for simultaneous determination of nitrites and nitrates in water samples, where it is possible to analyze 20 samples per hour with relative standard deviation lower than 1.5%, [7].
Optimum conditions of the reaction were established along with other analytical parameters for spectrophotometric determination of nitrites in water. It proved that proposed method can be used for determination of low-level nitrites in natural waters, as well as in contaminated river waters, [8].

CONCLUSION

The nitrogen cycle has been greatly disrupted over the last century by the increasing development and implementation of agrotechnical measures to meet the growing global demands for food. Fertilizers, which are drained into the water during periods of rain, are rich in phosphates and nitrates that are otherwise a limiting factor of life abundance in the water. Such water cannot be potable. This is the cause of large-scale eutrofication of freshwater and riverside zones (leading to water blooming) and increase of the nitrogen oxide gas N_2O deposits, resulting in greenhouse effect.

In the majority of natural waters, nitrogen compounds (nitrites and nitrates) are found in moderate concentrations, but groundwaters are frequently contaminated mainly due to excessive fertilizer application and uncontrolled wastewater discharge and treatment. All this leads to more serious problems. Groundwater resources are limited in direct use for human diet in several parts of the world, including Saudi Arabia, India, China, Japan, USA, Great Britain and some parts of Europe. Ecological awareness, regular inspection of drinking water and timely responses can prevent the consequences that can endanger human health.

REFERENCES

[1] Aydın, A., Ercan, O., Taşcıoğlu, S., A novel method for the spectrophotometric determination of nitrite in water, Talanta, 66, pp. 1181–1186, 2005.
[2] Bobar, S., Konjarić, S., Quantity and correlation of nitrogen compounds with the Rama river water level, Educa, VI, br. 6., pp. 13-19, 2013. [In Serbian]
[3] Burakhama, R., Oshima, M., Grudpan, K., Motomizu, S., Simple flow-injection system for the simultaneous determination of nitrite and nitrate in water samples, Talanta 64, pp. 1259–1265, 2004.
[4] Cibulić, V., Veljković, N., Stamenković, L., Staletović, N., Evaluation and risk management of drinking water supply systems, Water Management, 0350-0519, Vol. 47 No. 273-275, pp. 119-130, 2015. [In Serbian]
[5] Ciudad, G., Rubilar, O., Muñoz, P., Ruiz, G., Chamy, R., Vergara, C., Jeison, D., Partial nitrification of high ammonia concentration wastewater as a part of a shortcut biological nitrogen removal process, Process Biochemistry, Vol.40 (5), pp. 1715–1719, 2005.
[6] Cvetkovska, M., Vuković, M., Cvetkovski, V., The nitrification bacteria and nitrogen cycle, Proceedings of the EkoIst '06, ECOLOGICAL TRUTH, Sokobanja, Srbija i Crna Gora, pp. 251-255, 2006.
[7] Dalmacija, B., Agbaba J., Quality control of drinking water, Faculty of Sciences, Novi Sad, 2006. [In Serbian]
[8] Faculty of Civil Engineering (2015), Quality of waters, laboratory manual, Belgrade, Serbia. [In Serbian]
[9] Lu, C., Lin, J.-M. Huie, C. W., Yamada, M., Chemiluminescence study of carbonate and peroxynitrous acid and its application to the direct determination of nitrite based on solid surface enhancement, Analytica Chimica Acta, 510, pp. 29–34, 2004.
[10] Ruiza, G., Jeisonb, D., Rubilarb, O., Ciudadb, G., Chamy, R., Nitrification–denitrification via nitrite accumulation for nitrogen removal from wastewaters,Bioresource Technology,Vol. 97 (2), pp. 330–335, 2006.
[11] Shrimali, M., Singh K.P., New methods of nitrate removal from water, Environmental Pollution, 112, pp. 351-359, 2001.
[12] Regulations of drinking water disinfection and inspection, Official Gazette of the Republic of Serbia, No 60/81, Belgrade, Serbia. [In Serbian]
[13] Regulations of water potability, Official Gazette of SFRY, Nos 42/98 and 44/99 and Official Gazette of the Republic of Serbia, No 28/2019, Belgrade, Serbia. [In Serbian]
[14] Regulations of sampling and methods of laboratory analysis of drinking water, Official Gazette of SFRY 33/87, Belgrade, Serbia. [In Serbian]

ECOLOGICAL MONITORING OF MICROBIOLOGICAL, BIOCHEMICAL CHARACTERIZATION AND GROWTH OF *SECALE CEREALE* L. PLANT IN SOILS AMENDED WITH SEWAGE SLUDGE

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Abstract: The objectives of the model pot experiment were to determine the effects of sewage sludge application on biological (Different microbial and activities of enzymatic properties, carbon dioxide production) and physicochemical (pH, soil moisture) properties as well as rye plant productivity for 9 weeks were studied. Two soil types [kovárvány brown forest soil (Nyíregyháza), and meadow chernozem soil (Szeged)] were used and treated with various rates of sewage sludge [Control soil (0), 20, 40, 60, 100 (sludge) %)] originated from Nyíregyháza sewage water purification.. Results indicated that the soil retained its moisture content for a longer period than the free wastewater sludge control soil. Also, soil pH was maintained to be favourable for plant growth more than the control soil. In addition to exhibiting healthy growth and development, the plants also produced the greatest dry matter mass on soils with the largest proportion of sewage sludge (60–100%). Also, enzyme activities in the soil samples treated with sewage sludge were increased in soil with higher sludge doses. There was an increase in the density of the microbial population in the rye rhizosphere as the sludge dose increased. Results demonstrated that Gram negative bacteria were dominant in the rye plant rhizosphere and the ratio between Gram-negative and Gram-positive bacteria in the Kovárvány brown forest soil and meadow chernozem soil treated with Nyíregyháza sludges were 2.367 and 2.35, respectively. Finally, soil treatment with the sludge stimulated rye plant growth, the biochemical and microbial properties of the rye plant rhizosphere. For maintaining the soil quality, the authors recommend to treat the acidic soil with a ratio of 40–60% of this sludge to improve the fertility of the soil.
Key words: monitoring, rhizosphere properties, microbiological, biochemical, rye plant growth, sewage sludge

INTRODUCTION

Monitoring of soil properties, microbiological and biochemical parameters is one of the most essential characterizations to qualify soil health when amended with sewage sludge. The biological activities of the soils are determined by several microbiological and soil enzyme activities together. Demographic growth and western economic model seriously menace these vital resources: soil scarcity, soil losses through erosion, natural disasters and contamination; water scarcity and contamination; and limitation and exhaustion of mineral resources and fossil energies.

Today, one of the most pressing environmental and environmental problems of is the increasing volume of waste, including wastewater amendment, sewage sludge application, utilization and disposal.

Sewage sludge is used as possible way of organic fertilization and importance because it is not only nutrient input into the soil, but it improves soil structure and induces useful microbiological processes. Sewage sludge is environmentally polluting if the concentrations of heavy metals level is high. And, on the other hand, is suitable for farming as organic fertilizer. From an environmental and soil protection point of view, it is important that the sewage sludge used does not restrict the production of safe food raw materials.

The organic matter of sewage sludge is decomposed by heterotrophic nutrition prokaryotes and fungi. Biodegradation of organic matter in soil is basically the result of microbial and biochemical processes, therefore all factors that have an effect on the structure, function and enzymatic activity of microorganisms impact the rate of degradation. In the case of agricultural and forestry utilization it contributes to increasing the content of organic matter of the soil and has a favorable influence on the physical and chemical properties of the soils. Sewage sludge increases the water absorbing ability of soils, promote aggregation of the medium on sandy soils and increase the cation exchange ability. As a result of sewage sludge application, the amount of microbiotas in the soil usually increases. The nutrient flow for the soil is determined by the activity of enzymes, in addition to the physical, chemical parameters, plant cover and microbial activity.

Generally, most growth parameters, as well as the biomass of treated wheat, were significantly increased with the amendment of SS, up to the addition rate of 40 g kg^{-1}. The content of all heavy metals (except Cr in grains and Pb in spikes) significantly increased in different tissues of treated wheat with the increasing rate of SS application [1]. Reutilization of putrescible municipal solid wastes in agriculture can provide valuable plant nutrients. However, it may pose serious non-carcinogenic health risks for a human when contaminants, especially the heavy metals in MSW, end up in plants through the waste-soil-plant continuum [2]. Results indicated that for the most oxidative processes, the released organic matter was probably mineralized by the hydroxyl radicals produced during the treatments. It is interesting to remark that even if the biochemical methane potential was barely enhanced by the different methods applied, all the methods demonstrated to enhance the overall kinetics of the biomethanation processes, increasing the rapidly biodegradable fraction of the sludge.
During the present work, author investigated the effects of sewage sludge on the some soil properties such as soil pH, moisture content, CO_2-production, FDA activity and the rye plant growth at different levels of sewage sludge treated in two soil types [3]. Results showed that MSWC doses over 10 t ha^{-1} may create a heavy metal risk in long term for soils with pH $\geq$ 7. Therefore, in MSWC use over agricultural lands, heavy metal contents should always be taken into consideration and excessive uses should be avoided [4]. From the literature covered it can be concluded that sludge deposition induces two detrimental effects on the environment: 1) raising of the levels of persistent toxins in soil, vegetation and wild life and 2) slow and long-termed biodiversity-reduction through the fertilizing nutrient pollution operating on the vegetation. Since recent studies show that eutrophication of the environment is a major threat to global biodiversity supplying additional nutrients through sludge-based fertilization seems imprudent. Toxins that accumulate in the vegetation are transferred to feeding herbivores and their predators, resulting in a reduced long-term survival chance of exposed species. We briefly review current legislation for sludge deposition and suggest alternative routes to handling this difficult class of waste [5]. Although guidelines limit the addition of toxic elements in sludges and soils, thus reducing the quantities of these elements accumulated by plants, total concentrations of toxic elements in soil provide no indication of their availability to plants. The procedures applied to the determination of the forms of elements in sludges and soils and attempts to relate forms extractable in a variety of reagents to their availability to plants have been discussed. The factors which influence the forms of nutrient and toxic elements, their long term availability and hence their accumulation by crops are also reviewed [6]. It appeared that improving the structure to enhance the contact efficiency between the wastewater and the soil in soil mixture blocks was important for enhancing treatment performances. The combined use of existing wastewater treatment systems with the MSL system was effective for preventing environmental pollution over a long period [7].

MATERIAL AND METHODS

The origin of soil samples were: Meadow chernozem soil (RCST) of the Szeged and Kovárvány brown forest soil (KBET) was from the Center for Agricultural and Technical Sciences at the Nyíregyháza Research Institute of the University of Debrecen. Soil samples were collected from the upper layer of 0-25 cm. Some chemical properties of communal sewage sludge from the municipal wastewater treatment plants (Nyíregyháza) and soil samples are presented in Table 1.
The air dry soil was thoroughly mixed with sewage sludge so that the final mixture contained sewage sludge in the soil sample was as following percentages: 0% (sewage-free control soil), 20, 40, 60 and 100% (sewage sludge only, without soil). Rye (*Secale cereale* L.) seeds were sterilized [8] and planted in plastic containers of 3 kg of tested soil as prepared above. After ten days of germinating, young plants were reduced for 10 plant densities/pot.
Soils pH was measured by Pérez De Mora et al. [9] at various sewage sludge doses (after 63 days of incubation). The pH of the untreated and treated soil was tested in a 1: 2.5 (soil: 1 mole KCl) g ml^{-1} ratio after shaking for 60 minutes. The moisture content of the treated and untreated soil samples was modified by the method of Brzezinska et al. [10] (measured at 48 hours at 28°C, incubation). Initial soil moisture was of the soil samples was 60%. The relative dry weight of the rye plants samples was determined after 9 weeks of cultivation (with a constant moisture content of about 60%) (at 75°C, drying cabinet, to constant weight).

Table 1. Properties of the soils and sludge used in the model experiment

Parameters	Soil types		Wastewater sludge: NySzv
	KBET	RCST	
$pH_{(KCl)}$	5.78	6.02	6.71
Dry matter content, %	na	na	53
Organic matter, %	na	na	21.7
Humus content, %	2.54	3.55	na
Total-N, $mg \cdot kg^{-1}$	na	na	7470
NO_3-N, $mg \cdot kg^{-1}$	23	39	na
NH_4-N, $mg \cdot kg^{-1}$	5.6	4.5	na
Mg, $mg \cdot kg^{-1}$	214	257	2507
Na, $mg \cdot kg^{-1}$	64	53	994
P_2O_5, $mg \cdot kg^{-1}$	318	378	28720
K_2O, $mg \cdot kg^{-1}$	412	428	3171
Zn, $mg \cdot kg^{-1}$	1.7	1.1	537
Cu, $mg \cdot kg^{-1}$	1.4	2.4	110.4
Mn, $mg \cdot kg^{-1}$	55	61	421
Fe, $mg \cdot kg^{-1}$	945	1094	11308
Cd, $mg \cdot kg^{-1}$	1.7	1.02	2.3
Pb, $mg \cdot kg^{-1}$	1.3	0.96	66.9

na: no data available

Determination of CO_2 production: For the measurement of CO_2 emissions, 0.5 kg of sewage sludge treated soil was poured into 2 l glass containers and in the middle of the soil were placed a plastic tube containing 50 mL of 1.0 mol of NaOH solution to bind the developing CO_2, then the containers are tightly closed. The NaOH solution was titrated with 1 mol of HCl solution and calculated the volume of CO_2 released during the soil respiration [11, 12].

Characterization of soil microorganisms: The total plate count of aerobic bacteria, aerobic endospore-forming bacteria, filamentous fungi, yeasts, cellulose decomposers and phosphate-solubiliers in the rye rhizosphere was determined by means of a soil suspension. The roots separated from the plants were washed in sterile tap water to remove sticky soil particles followed by washing with a sterile 0.85% NaCl solution again. 10 g of the washed roots were cut and placed in 90 ml of sterile saline. A suspension of sterile tap water was prepared from the suspension. The total numbers of colony forming units (CFU) of culturable microorganisms were determined by serial dilution and plating on selective media. Plate counts of culturally viable bacteria and endospore-forming bacteria were made on Tryptone Soya Agar (TSA; Oxoid, Basingstone, Hampshire, England) amended with 0.1 g/l cyclohexamide. For fungi the Martin’s medium for fungi [13] was Rose Bengal Agar (RB; Oxoid) amended with 30 mg/l streptomycin sulphate. Yeasts were cultivated on Malt Extract Agar, actinobacteria were counted on Glycerol Casein Agar [14, 15] amended with 0.05 g/l cyclohexamide. Examination of phosphate solubilisation was done in the medium described by Goldstein [16] for the selection of phosphate solvents. Dicalcium phosphate agar plates were inoculated, so that pure ring-producing strains around their cells are phosphate-free. Cellulose agar plates were seeded using two types of media (PDA: fungi and Nutrient agar: bacteria), which included the carboxymethylcellulose Congo red (CMC-Congo red) substrate as determined by Hendricks et al. [17].

All plates were inoculated with 0.1 ml of soil suspension and cultured at 25°C for 4 to 7 days for fungi, 30°C for 2 days for heterotrophic and endospore-forming bacteria and for 10 days for actinobacteria. Isolation and classification of microorganisms were done according to their morphological characteristics (colour, shape, appearance, cell size). Cultivable aerobic heterotrophic bacterial isolates belonging to different genes were studied by colony and cell morphology, Gram staining, spore staining, oxidase and catalase reactions, oxidation and fermentation of glucose, and motion and pigmentation.

Enzymatic Activity: Dehydrogenase activity (µg INTF/g^{-1} dry soil) was measured according to García et al. [18]. The catalase activity (µmol O_2/min^{-1}/g^{-1} dry soil) was measured by potassium permanganate O_2 consumption following the addition of H_2O_2 [19]. Urease and protease activity (µmol NH_4^+-N/g^{-1} dry soil/h^{-1}) according to Nannipieri et al. [20]; phosphatase activity (µmol p-nitrophenol (PNP)/g^{-1} dry soil/h^{-1}) regard to the method of Tabatabai and Bremner [21]; β-glucosidase activity (µmol p-nitrophenol/g^{-1} dry soil/h^{-1}) was determined by the method described by Masciandaro et al. [22]. Invertase activity was measured by Siegenthaler [23] using p-nitrophenyl α-D-glucopyranoside (Fluka, Buchs, Switzerland). After adding a solution containing p-nitrophenol, tris buffer (pH 9.5), it is converted to nitrophenolate anion which can be measured by a spectrophotometer due to the pH effect. The extinction value at 400 nm is multiplied by 21.64 in an invertase number. The aryl sulfatase activity (µmol nitrophenol g^{-1} dry soil/h^{-1}) was determined according to Tabatabai and Bremner [21] (absorption of p-phenol at 400 nm after incubation with PNP sulphate).

RESULTS AND DISCUSSION

The results of the present studies showed an increase in the observed parameters (pH and moisture content) after treatment of soil samples with sewage sludge. For acid soils, the pH value (Figure 1) was increased in sewage treated samples and the moisture content remained longer than in the control (Figure 2).

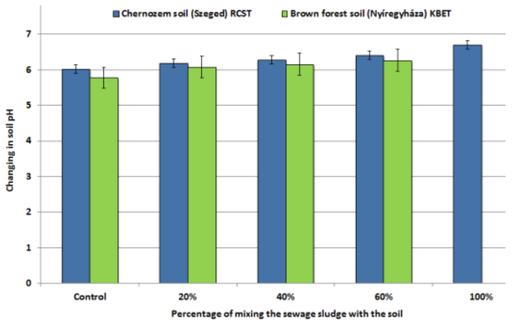

Figure 1. Impacts of sewage sludge on pH of the two soil samples

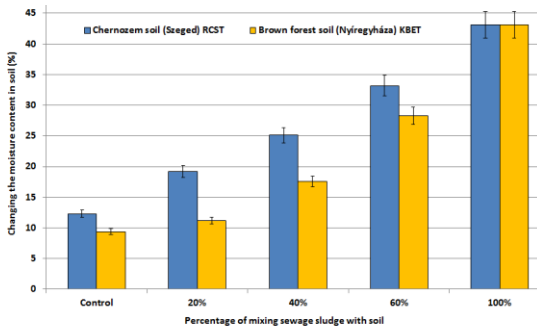

Figure 2. Impacts of sewage sludge on moisture content of the two soil samples

The addition of sewage sludge to soil significantly increased rye plant dry matter content (Figure 3) for each soil sample. Growth and development of plants were faster and healthier, in particular the clay abrasion of 60% sewage sludge in the case of brown forest soil and chernozem soil treated with sewage sludge from Nyíregyháza.

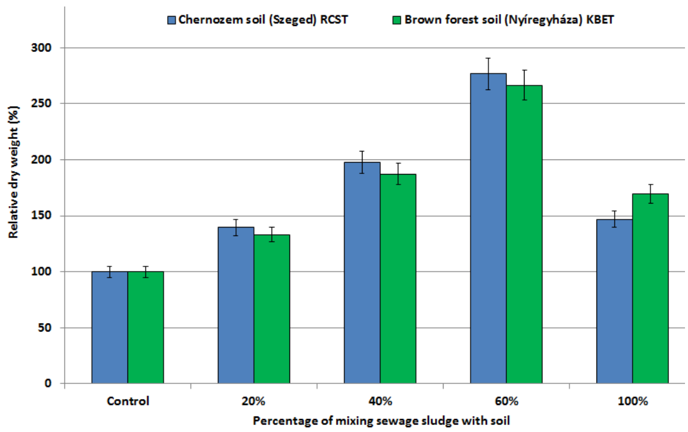

Figure 3. Effect of sewage sludge on rye plant dry weight in two soil samples

The total biomass mass of the plants increased proportionally with the increase in the amount of sewage sludge added to soil. Growth and nutritional needs were uniform on the basis of morphological characteristics during the vegetation period. Adverse symptoms were not observed on either control

plants or plants derived from sewage sludge treated soil. The morphological characters of all plants (leaves, shape, colour and size) were normal and healthy. The maximum rye plants dry matter mass was observed with a mixture of sewage sludge 60: 40%. No significant statistical difference was observed in the relative dry weight of the rye in the brown forest soil treated with the sewage sludge from Nyíregyháza. According to the results, alkaline pH sewage sludge increases the pH of acidic soils, which favours the growth of rye plants and reduces or inhibits the harmful effects of heavy metals.
The degree of microbial activity can be determined by the amount of CO_2 released from the two soil samples. In this study, the value of soil respiration compared with the control increased significantly by increasing the sewage sludge dose. Figure 4 shows that the amount of CO_2 released from the metabolism of microorganisms, root respiration in the soil of the meadow chernozem and in the brown forest soil from Nyíregyháza.

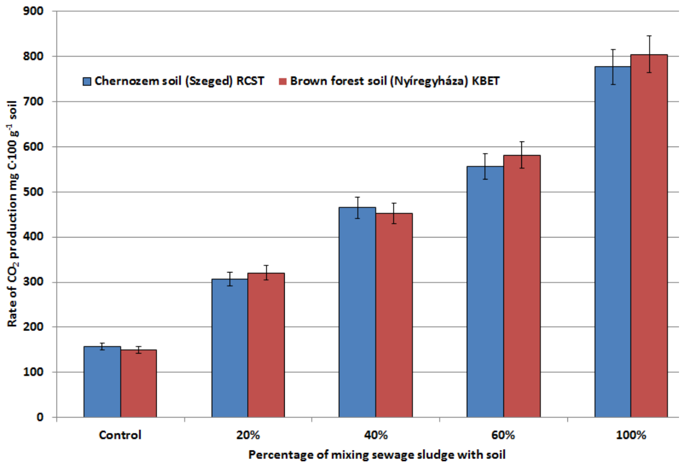

Figure 4. Effect of sewage sludge on the amount of CO_2 released in soil samples

Such rate of respiration can provide valuable information on the increased metabolism activity of the soil microorganisms. The highest CO_2 emissions were observed in the soil of the brown forest soil from Nyíregyháza.

Enzymatic activities: The results of measuring dehydrogenase activity also confirm the microbial population. In our experiments, the enzymatic activity measured in sewage sludge treated soils exceeded double the values of the control samples. The enzyme activity of FDA hydrolysis was determined by spectrophotometric measurement, and the results of which are shown in Figure 5. The largest FDA activity was registered in RCST soil. In samples of sewage sludge: soil mixture 60: 40% to 100: 0% FDA activities showed positive significance for each treatment. The results show that the amount of fluorescein produced by FDA hydrolysis (spectrophotometric measurement) is in direct proportion with microbial growth, and the hydrolytic activity of FDA shows a close correlation with soil respiration.
Accordingly, the organic material turnover of the examined model experiment is influenced and determined by the overall microbial activity. There was also a growing tendency for FDA activity after increasing the amount of sewage sludge mixed with soil. The equilibrium effects of sewage sludge did not only significantly increase the soil microbial population, but also the activity of the soil enzymes investigated, soil respiration and FDA activity.
Soil dehydrogenase activity refers to the total oxidative activity of the soil microbial and can therefore be a good indicator of the degree of microbial activity. Sewage sludge addition increased dehydrogenase activity and catalase activity for each treatment (Figures 6 and 8).

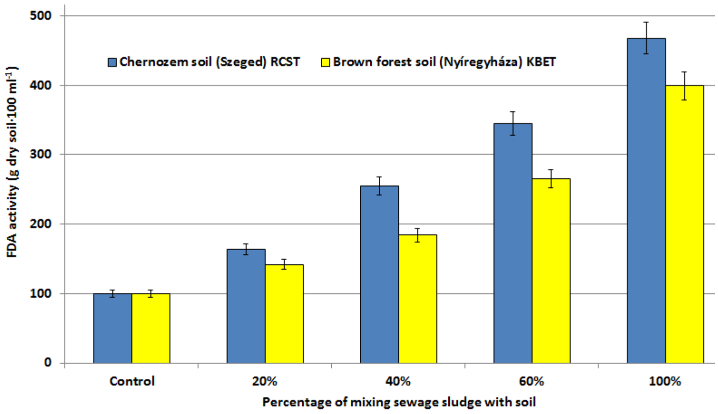

Figure 5. Effect of sewage sludge application on the activity of FDA enzyme in two soil samples

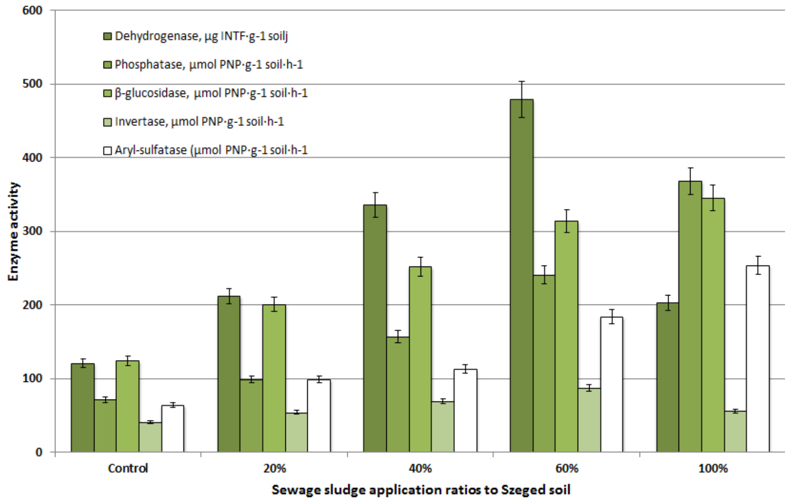

Figure 6. Effect of sewage sludge on the activities of some enzymes in soil of Szeged

The highest enzyme activities of urease, protease (Figures 7 and 9), phosphatase, β-glucosidase and aryl sulfatase (Figures 6 and 8) were found in the presence of sewage sludge only. The higher enzyme activity can be explained by the increased microbial activity that is caused by the high nutrient and organic content of sewage sludge. Protease activity increased significantly after 9 weeks of growth time. The more organic matter the sewage sludge in question is, the more enzyme activity is due to its complexity with the resistance to organic matter. The enzyme activity was also higher in the rhizosphere of brown forest soil mixed with the sewage sludge in Nyíregyháza.

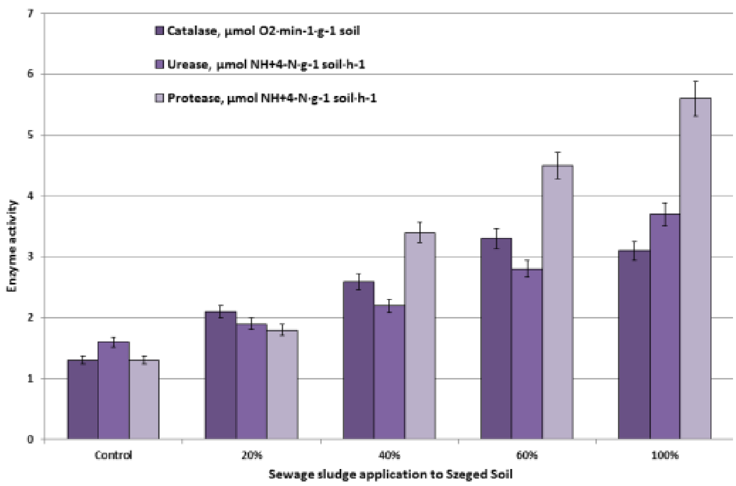

Figure 7. Effect of sewage sludge application on the activities of catalase, urease and protease enzymes in soil of Szeged

During the experiment, the plant grown on sewage sludge treated soil had a positive effect on the synthesis of the β-glucosidase enzyme. The highest values were measured in soil treated with sewage sludge, apparently due to the degradation of organic matter. The values of aryl sulfatase activity in the rhizosphere of rye treated in different soil types are similar to that of protease and urease activity.

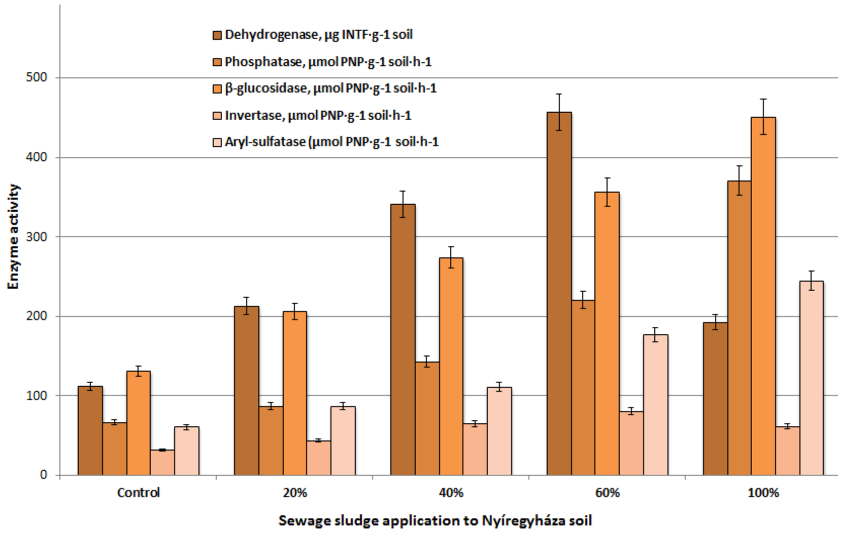

Figure 8. Effect of sewage sludge on the activities of some enzymes in soil of Nyíregyháza

Composition of microbe population: the number of aerobic heterotrophic bacteria, aerobic spore-forming bacteria, actinobacteria and fungi was determined after 9 weeks of plant growth in the two soils mixed with different doses of sewage sludge are presented in the Figures 10 to 12.

It was found that population of the different microbial groups significantly increased with the addition of 20% sludge to soil. This suggests that the increased microbial populations are able to utilize large quantities of organic matter and use sewage sludge as energy sources. Consequently, sewage sludge has a beneficial effect on the general microbial activity of the soil and on some specific microbial portions.

A 1254 bacterial strain was isolated from the rye-soil sewage sludge model experiment. It can be concluded that the bacterial populations increased significantly with sewage sludge treated soils by increasing the amount of sewage sludge used (Figures 10 and 12). The bacterial number of bacteria was 4 to 14 times greater than the control depending on the sewage sludge-soil-plant system. The largest bacterial number was found in brown forest soil mixed with the sewage sludge in Nyíregyháza.

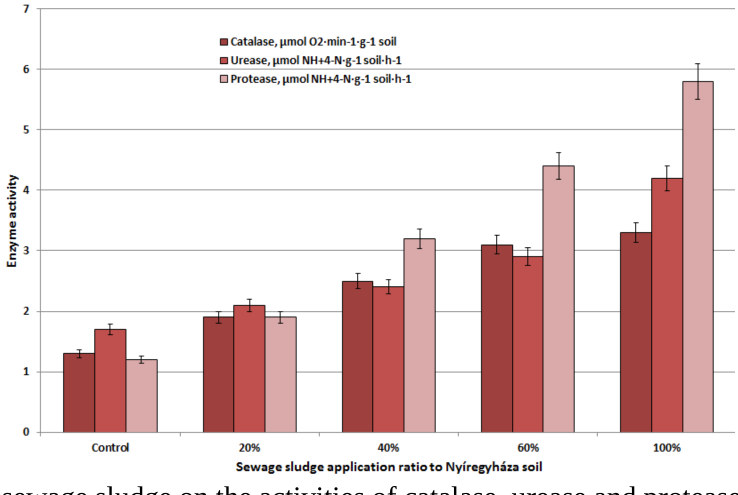

Figure 9. Effect of sewage sludge on the activities of catalase, urease and protease enzymes in soil of Nyíregyháza

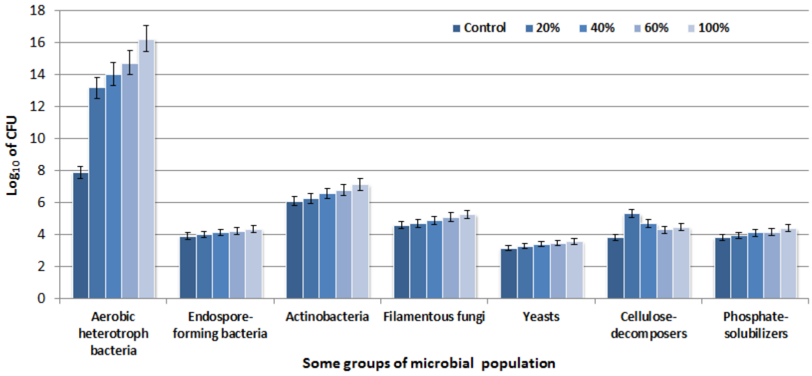

Figure 10. Effect of sewage sludge application on microbial structure in soil of Nyíregyháza

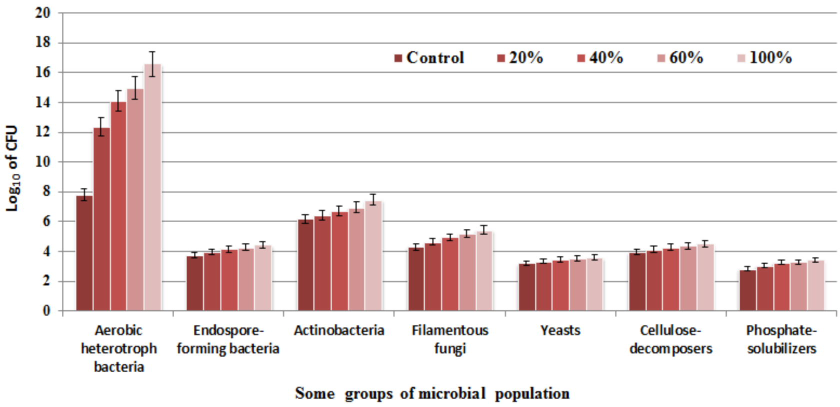

Figure 11. Effect of sewage sludge application on microbial structure in soil of Szeged

The most common isolates were the following genera: *Achromobacter, Acinetobacter, Aeromonas, Alcaligenes, Arthrobacter, Azotobacter, Bacillus, Brevundimonas, Burkholderia, Cellulomonas, Chromobacterium, Chryseobacterium, Corynebacterium, Enterobacter, Escherichia, Flavobacterium, Klebsiella, Microbacterium, Micrococcus, Pseudomonas, Rhodococcus, Serratia, Stenotrophomonas, Staphyllococcus, Streptococcus, Streptomyces* and *Zooglea*. We have not found representatives of *Aeromonas*, *Citrobacter*, *Listeria*, *Salmonella*, *Shigella*, *Vibrio* and *Yersinia*. The bacterial number of aerobic spore-forming bacteria in sewage sludge-soil-plant model experiment was 3 to 7 times greater than control. Sewage sludge treatments increased the population of actinobacteria compared to untreated soils. The number of actinobacteria in the sewage sludge-soil-plant model experiment was 2-22 times higher than the control. The highest number of actinobacteria was observed in brown forest soil of Nyíregyháza. Domestic isolates in different sewage sludge/soil mixtures belonged to the *Streptomyces* genus. The fungal populations in each sewage sludge/soil mixture were largely different from the control. The number of filamentous fungi according to the sludge-soil-soil ecosystem was 2-13 times greater than that of the control.

In a model experiment composed of various sewage sludge/soil mixtures, more than 350 representative fungal strains were isolated. These isolates belong to the following genera: *Alternaria, Aspergillus, Cephalosporium, Cladosporium, Fusarium, Geotrichum, Mucor, Penicillium, Rhizopus and Trichoderma*. In addition, there are many strains belonging to the *Saccharomyces* genus, which were only isolated from soil of Nyíregyháza. Most of the filamentous fungi were found in brown forest soil, especially when the soil was treated with the sewage sludge in Nyíregyháza (Figures 10 and 11).

Bacterial communities: In our experiments gram negative bacteria dominated the rhizosphere of the rye. The proportion of gram-negative and gram-positive bacteria (Figure 12) is proportional to the brown forest soil and the Chernozem soil in the meadow mixed with Nyíregyháza sewage sludge 2,367; and 3.24 respectively. These data suggest that there is no statistical difference between the bacterial communities of rye rhizosphere in the brown forest soil treated with the sewage sludge in

Nyíregyháza, while in the other soil there was a significant difference. The soil treated with the sewage sludge in Nyíregyháza was higher in gram-negative bacteria than in soil from Szeged.

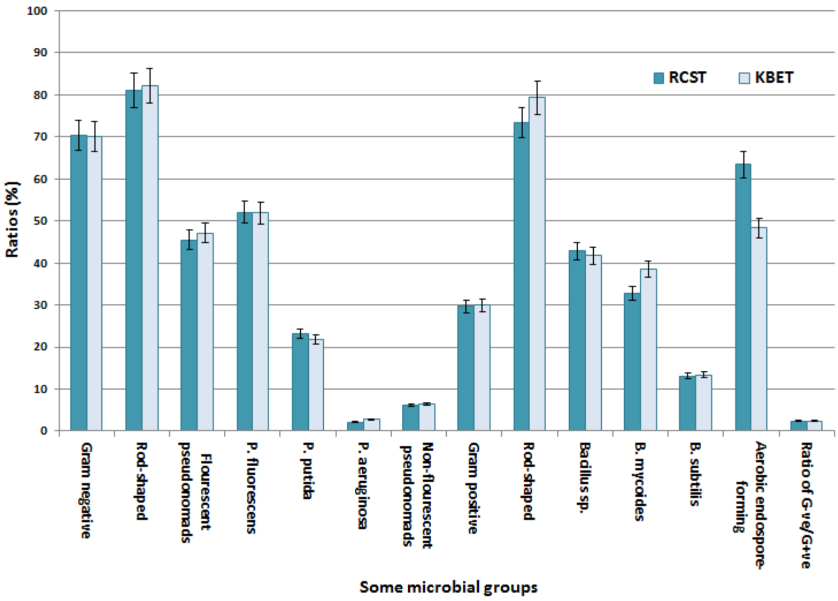

Figure 12. Effect of sewage sludge application on microbial communities in soil samples of Nyíregyháza and Szeged

Sustainable agriculture will pay attention primarily to water and soil protection and conservation, avoiding soil erosion and degradation, and also care for the use of resources (water, energy, machinery, fertilizers and amendments and soil labours) in a frame of environmental respect. Sludge and sustainability, when proper sludge products quality attained and recycling is feasible many objectives connected with sustainability are accomplished: Soil economy and recovery eliminating landfill disposal and contributing to rangelands restoration; The use of resources through promotion of soft technologies; Mineral nutrients savings through recycling and mineral fertilizers replacement; Fossil fuel energy savings through mineral fertilizers replacement; Nature's protection through reduction of fertilizers production; and Erosion control and increase of soil fertility and productivity.

Investigation of the data showed that there is more evidence that such parameters are sensitive indicators of the composition and function of the stressed soil caused by the use of sewage sludge because microbiological activity directly affects the stability of agro-ecological systems and fertility. There is a growing interest in the use of soil enzymes as indicators of soil fertility, because the activity of soil enzymes is sensitive to many factors. Since the enzyme activity is substrate-specific, it is difficult to predict the nutrient supply of the soil from the activity of an enzyme, and the parallel measurement of several properties can better describe the microbiological activity of the soil.

The number of heterotrophic microorganisms in the soil usually increases following the addition of sewage sludge. In fact, microorganisms capable of utilizing the organic material of sludge are rapidly propagating.

In the pot experiment of two soil samples and one sample of sewage sludge to form plant-soil systems, whose application possibilities can favourably contribute to plant nutrition. We found that besides rye growth, the plant health was better than control. So the plant utilized the micro and macro nutrients necessary and easy to apply from the immediate environment.

According to Stadelmann and Furrer [20], the number of aerobic bacteria and beetles increased due to sewage sludge addition.

In summary, the treatment of soil samples with sewage sludge stimulates the plants development, improves the physical, biochemical and microbial properties of the rhizosphere, helps to maintain soil moisture and increases soil pH, which is also favourable for plant growth. To improve soil fertility, the authors propose an alkaline sewage sludge treatment for acidic soils.

The sewage sludge application causes an increase in the microbial populations. Environmental factors also affect microbial activity and mineralization of sewage sludge. Sewage sludge and its management

affect the quality of the organic material, its degradation speed, the time required for it, and the amount of nutrient released. Our results confirm the statement by Garcia et al. [18] that microbial and dehydrogenase activity is directly related to each other and depends on the metabolic state of microbial populations in soil. Crecchio et al. [25] observed that with increasing use of communal waste compost the organic C, N, dehydrogenase, β-glucosidase, urease, nitrate reductase and phosphatase activity of the soil increased with the composition of the bacterial communities living in soil did not change significantly. However, in our case, the activity of soil enzymes and the density of microbial populations increased with the addition of sewage sludge.
Sewage sludges, as products obtained by wastewater treatment, contain organic matter, micro and macronutrients and are potentially useful for any agriculture use. They may contain undesirable harmful materials. For these reasons, the use of sewage sludges in agriculture, at European Union (EU) level, is regulated by the EU Sludge Directive 86/278/EEC. One of the current Council Directive of 12 June 1986 aims on the protection of soil environment, when sewage sludge is applied in agriculture is to avoid toxicity effects on soil, plants and man [26, 27]. Considerable improvement in dehydrogenase activity and aggregate associated organic matter was observed particularly when higher amount of sludge was applied our results are confirmed with the observation of Mondal et al. [28]. The greater soil urease and invertase activities in spring soil amended with sewage sludge provided evidence of increased soil microbial population [29]. Soil microorganisms excrete a variety of enzymes such as ureases, invertases, dehydrogenases, cellulases, amylases and phosphatases that have long been recognized as a primary means of degrading xenobiotics in soil and water ecosystems [29]. According to Pierzynski et al. [30], soil quality is determined mainly by physical (structure, water retaining capacity, etc.), chemical (organic and inorganic substances concentration) properties which can strongly affect fertility, biological activity, or other important soil factor. Our results are in agreement with the Pierzynski et al. [30] in regards to the issues of plant growth and soil quality. The degradation of the organic material of the sewage sludge can be monitored well in the soil based on the measured amounts of the releasing of CO_2. Previous studies [31] have shown that soil respiration has increased due to addition of sewage sludge.

CONCLUSION

The presence and activity of soil microorganisms is essential for the fertility of agricultural soils. The beneficial effect of fertilization on soils' productivity has long been known. The results of our experiments support the above mentioned works that the density of microbial populations is related to the amount of sewage sludge mixed with soil. Our results are in accordance with the above mentioned work, which increases the fertility rate and the density of microbial populations as well as soil enzyme activity by increasing the proportion of sewage sludge mixed with soil. Sewage sludge extraction can be partially replaced by organic fertilization and fertilization, as well as the treatment of soil physico-chemical properties. At the same time, due to the aspects of food safety, the use of continuous state monitoring methods is recommended.

REFERENCES

[1] Eid M.E., Alrumman Sulaiman A., El-Bebany A.F., Fawy .K., Taher A. M., Hesham Abd El-Latif, El-Shaboury A.G., Ahmed T.M., Evaluation of the potential of sewage sludge as a valuable fertilizer for wheat (Triticum aestivum L.) crops. Environmental Science and Pollution Research, 26(1): 392–401. 2019.

[2] Shah G.M., Tufail N., Bakhat F.H., Ahmad I., Shahid M., Hammad M.H., Nasim W., Waqar A., Rizwan M., Dong Renjie, Composting of municipal solid waste by different methods improved the growth of vegetables and reduced the health risks of cadmium and lead. Environmental Science and Pollution Research, 26(6): 5463–5474. 2019.

[3] Segura Y., Puyol D., Ballesteros L., Martínez F., Melero J.A., Wastewater sludges pretreated by different oxidation systems at mild conditions to promote the biogas formation in anaerobic processes. Environmental Science and Pollution Research, 23(23): 24393–24401. 2016,

[4] Yuksel, O., Influence of municipal solid waste compost application on heavy metal content in soil. Environmental Monitoring and Assessment, 187: 313. 2015.

[5] Manzetti, S., van der Spoel, D., Impact of sludge deposition on biodiversity. Ecotoxicology, 24(9): 1799–1814. 2015.

[6] Sterritt M.R., Lester N.J., The value of sewage sludge to agriculture and effects of the agricultural use of sludges contaminated with toxic elements: A review. Science of The Total Environment, 16(1): 55-90. 1980.

[7] Sato K., Wakatsuki T., Iwashima N., Masunaga T., Evaluation of long-term wastewater treatment őerformances in multi-soil-layering systems in small rural communities. Applied and Environmental Soil Science Volume 2019, Article ID 1214368, 11 pages

[8] Vincent M. J., The Prokaryotes. In: P. M. Syars, et al., A handbook on habitats, isolation and identification of bacteria. Springer Verlag, Berlin, pp. 818–841, 1981.

[9] de Mora Perez, Burgos P., Madejón E., Cabrera F., Jaeckel P., Schloter M., Microbial community structure and function in a soil contaminated by heavy metals: effects of plant growth and different amendments". Soil Biol. Biochem., vol. 38, pp. 327–341, 2006.

[10] BrzezinskaM., TiwariC. S., StepniewskaZ., NosalewiczM., BennicelliP. R., Samborska A. Variation of enzyme activities, CO2 evolution and redox potential in an Eutric Histosol irrigated with wastewater and tap water. Biol. Fertil. Soils, vol. 43, pp. 131–135, 2006.

[11] Wardle D., Parkinson D., 1991. Analysis of co-occurrence in a fungal community. Mycol. Res., vol. 95: pp. 504–507, 1991.

[12] Fernandes P. A. S., Bettiol W., Cerri C. C., Effect of sewage sludge on microbial biomass, basal respiration, metabolic quotient and soil enzymatic activity. Appl. Soil Ecol., vol. 30, pp. 65–77, 2005.

[13] Martin P. J., Use of acid, rose bengal, and streptomycin in the plate method for estimating soil fungi. Soil Sci., vol. 69, pp. 215-232, 1950.

[14] Williams T. S., Davies L. F., Use of antibiotics for selective isolation and enumeration of actinomycetes in soil. J. Gen. Microbiol., vol. 38, pp. 251-261, 1975.

[15] Williams T. S., Wellington H. M. E., Actinomycetes, pp. 969–987. In Methods of soil analysis, part 2: chemical and microbiological properties, 2nd ed. American Society of Agronomy, Madison, WI, 1982.

[16] Goldstein H. A., Bacterial solubilization of mineral phosphates: historical perspective and future prospects. Am. J. Altern. Agric., vol. 1, pp. 51–57, 1986.

[17] Hendricks W. C., D. J. Doyle, Hugley B., A new solid medium for enumerating cellulose-utilizing bacteria in soil. Appl. Environ. Microbiol., vol. 61, pp. 2016–2019, 1995.

[18] García C., Hernanddez T. M., Costa F., Potential use of dehydrogenase as an index of microbial activity in degraded soils. Commun. Soil Sci. Plant Anal., vol. 28, pp. 123–134, 1997.

[19] Tabatabai M., Bremner M. J., Factors affecting soil aryl-sulphate activity. Soil Sci. Soc. Amer. Proc., vol. 34, pp. 427–429, 1970.

[20] Nannipieri P., Ceccanti B., Cervel S. H., Matarese E., Extraction of phosphatase, urease, protease, organic carbon and nitrogen from soil. Soil Sci. Soc. Am. J., vol. 44, pp. 1011–1016, 1980.

[21] Tabatabai M., Bremner M. J., Use of p-nitrophenil phosphate for assay of soil phosphatase activity. Soil Biol. Biochem., vol. 1, pp. 301–307, 1969.

[22] Masciandaro G., Ceccanti B., Garacía C., Anaerobic digestion of straw and piggery wastewater. II. Optimalization of the process. Agrochimica, vol. 38, pp. 195–203, 1994.

[23] Siegenthaler U., Eine einfache und rasche Methode zur Bestimmung der alpha-Glucosidase (Saccharase) im Homig. Mitt. Gebiete Lebensm. Hyg., vol. 68, pp. 251–258, 1977.

[24] Stadelmann X., Furrer J. O., Influence of sewage sludge application on organic matter content, microorganisms and microbial activities of a sandy loam soil. In: Catroux G., L'hermite P., Suess E., The influence of sewage sludge application on physical and biological properties of soils. D. Reidel Publ. Co. Dordrecht, pp. 141–166, 1983.

[25] Crecchio C., Curci M., Pizzigallo M. R. D., Ricciuti P., Ruggiero P., Effects of municipal solid waste compost amendments on soil enzyme activities and bacterial genetic diversity. Soil Biol. Biochem., vol. 36, pp. 1595–1605, 2004.

[26] Commission of the European Communities, Council Directive of 12 June 1986 on the protection of the environment, and in particular of the soil, when sewage sludge is used in

agriculture. Official Journal of the European Communities L181 (86/278/EEC), 6-12 OJ L181, 4.7.86, 1986.

[27] Commission of the European Communities, Report from the Commission to the Council and the European Parliament on the implementation of Community waste legislation for the period 1995-1997. COM(1999) 752 final, 1-92, 2000.

[28] Mondala S., Singhb R. D., Patrab A. K., B. Dwivedi S., Changes in soil quality in response to short-term application of municipal sewage sludge in a typic haplustept under cowpea-wheatcropping system. Environ. Nanotechnol. Monit. Manag., vol. 4, pp. 37–41, 2015.

[29] Antonious G. F., Enzyme activities and heavy metals concentration in soil amended with sewage sludge. J. Environ. Sci. Health, Part A vol. 44, pp. 1019–1024, 2009.

[30] M. G. Pierzynski, T. J. Sims, and F. G. Vance, “Soils and Environmental Quality”. CRC Press, Inc., 1990

[31] X. Stadelmann, and J. O. Furrer, Influence of sewage sludge application on organic matter content, microorganisms and microbial activities of a sandy loam soil. In: G. Catroux, P. L’hermite, and E. Suess, The influence of sewage sludge application on physical and biological properties of soils. D. Reidel Publ. Co. Dordrecht, pp. 141–166, 1983.

RADIATION OF HIGH FREQUENCY ELECTROMAGNETIC FIELDS BIOLOGICAL EFFECTS AND HEALTH CONSEQUENCES

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Abstract: The sources of radio frequency radiation (radio and TV transmitters, radars, microwave ovens, portable radio transciever equipment) are presented first. The absorption factors of radio frequency and microwave emissions by human body are also presented. The basic structure and operating principles of GSM equipment (mobile stations, system of basic stations, network and communication systems) are given. The interaction between mobile phone and human tissue, i.e. absorption of radio frequency energy emitted by mobile phone is described. Advices for safer usage of mobile phones are given.
Key words: electromagnetic fields, radio frequency, mobile phone

INTRODUCTION

Electromagnetic radiation consists of waves of electric and magnetic energy moving together (that is, radiating) through space at the speed of light. Taken together, all forms of electromagnetic energy are referred to as the electromagnetic spectrum (Fig. 1). Radio waves and microwaves emitted by transmitting antennas are one form of electromagnetic energy. Often the term electromagnetic field or radiofrequency (RF) field may be used to indicate the presence of electromagnetic or RF energy. An RF field has both an electric and a magnetic component (electric field and magnetic field), and it is often convenient to express the intensity of the RF environment at a given location in terms of units specific for each component [1].
For example, the unit "volts per meter" (V/m) is used to measure the strength of the electric field and the unit "amperes per meter" (A/m) is used to express the strength of the magnetic field.
RF waves can be characterized by a wavelength and a frequency. The number of cycles per second is known as the frequency, which is measured in Hertz (Hz).
There are different kinds of radiation with different wavelengths all around us, inside us, everywhere, they flow continuously, changing each other, coinciding and colliding. We have just started to realize their variety, understand that our ideas about the surrounding and penetrating into us radiation are fragmentary and insufficient, about its key role in the processes encircling us.

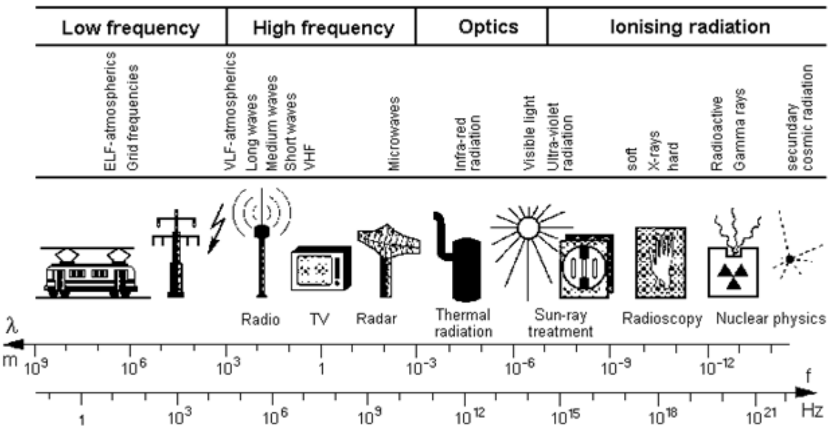

Figure 1. Electromagnetic Spectrum

Nowadays, this idea became even more relevant since the purposeful use of electromagnetic energy in various areas of human activity has resulted in the fact that existing electric and magnetic fields of the Earth, atmospheric electricity, solar and galaxy radio radiation were added by an artificial

electromagnetic field. Its level considerably exceeds the level of natural electromagnetic background. Every ten years world energy resources are doubled and within this period specific gravity of electromagnetic field variables in power industry has thrice increased.
Electromagnetic radiation sources, which include overhead high voltage and extra high voltage transmission lines, radio broadcasting, TV, radio relay and satellite communication equipment, radar and navigation systems, laser beacons and etc. have significantly influenced the natural electromagnetic background.

The effect of mobile phone radiation on human health is the subject of recent interest and study, as a result of the enormous increase in mobile phone usage throughout the world. Mobile phones use electromagnetic radiation in the microwave range. Other digital wireless systems, such as data communication networks, produce similar radiation. Many scientific studies have investigated possible health symptoms of mobile phone radiation. These studies are occasionally reviewed by some scientific committees to assess overall risks [2].

THE SOURCES OF RADIOFREQUENCY RADIATION

Radiofrequency (or RF) Radiation refers to electromagnetic fields with frequencies between300 kHz and 300 MHz, while - Microwave (or MW) Radiation ‖ (Fig. 2) covers fields from 300 MHz to 300 GHz. Since they have similar characteristics, RF and MW radiation are usually treated together. As well, the lower-frequency boundary of RF radiation is often extended to 10 kHz, or even to 3 kHz, in order to include emissions from commonly used devices. The sources of radio frequency radiation are: radio and TV transmitters, radars, microwave ovens, microwave radio systems, transceivers, handheld radio transceivers, amateur radio transceivers, mobile phones.

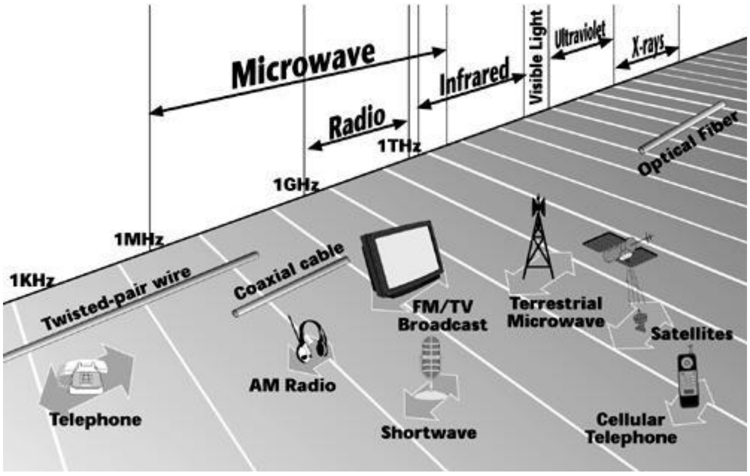

Figure 2. Microwave devices, radio frequency and microwave spectrum

In electronics and telecommunications a transmitter or radio transmitter is an electronic device which, with the aid of an antenna, produces radio waves. Microwave radio networks are systems used for digital transmission of TV images and tones, wireless internet, data transmission between computer networks at various locations, as well as systems for wireless transmission of other electrical information in digital form. Fig. 3 shows a typical architecture of Wi -Fi systems as well as broadband microwave radio systems.

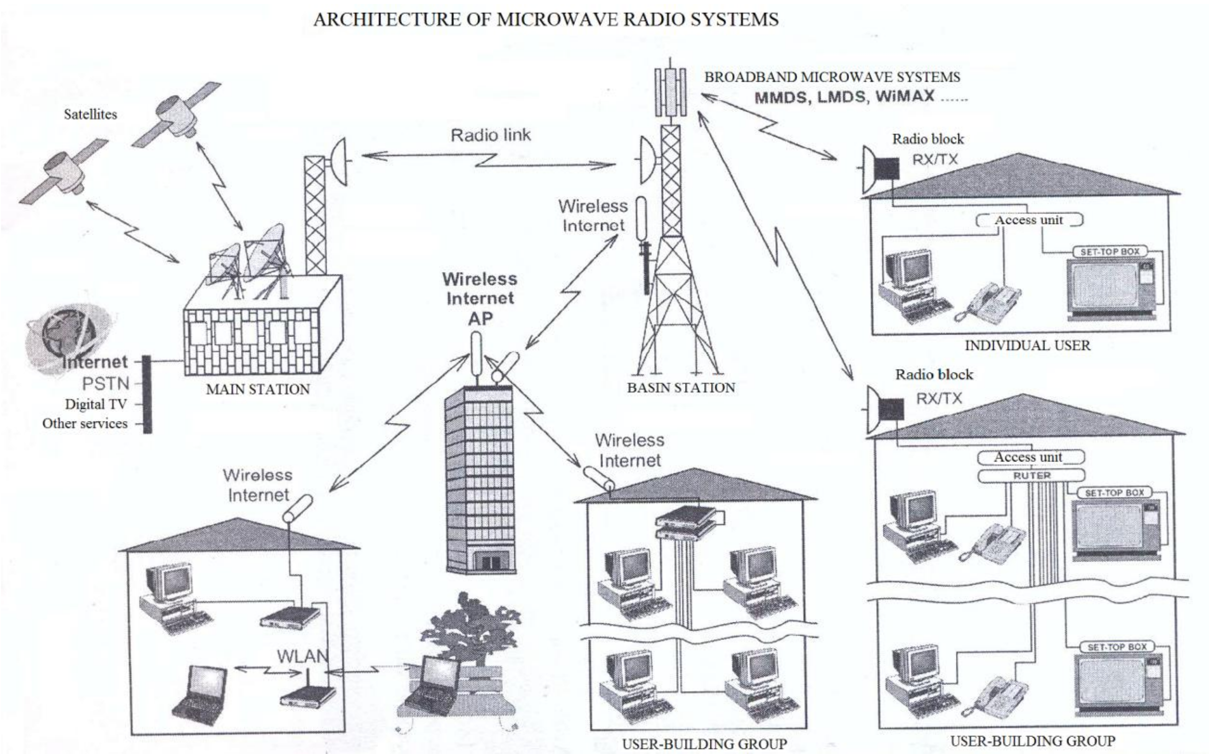

Figure 3. Architecture of microwave radio systems

GSM NETVORK ARCHITECTURE ELEMENTS

GSM (Global System for Mobile Communications) architecture can be divided into three broad functional areas: the Base Station Subsystem (**BSS**), the Network and Switching Subsystems (**NSS**), and the Operations Support Subsystem (**OSS**). Each of the subsystems is comprised of functional entities that communicate through various interfaces using specified protocols [2].

Figure 4 shows a general **GSM** architecture to illustrate the scope and the entities that comprise the three subsystems.

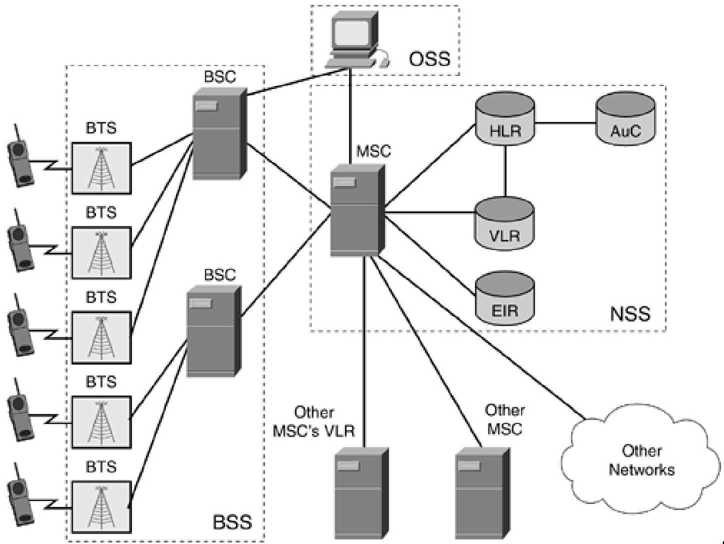

Figure 4. General GSM Architecture, Including the Three Main Separations in the Network

The **GSM** network architecture as defined in the **GSM** specifications can be grouped into four main areas:

- Mobile station (**MS**)
- Base-station subsystem (**BSS**)
- Network and Switching Subsystem (**NSS**)
- Operation and Support Subsystem (**OSS**)

Mobile station

There are a number of elements to the cell phone, although the two main elements are the main hardware Mobile Equipment (**ME**) and the Subscriber Identity Module (**SIM)** (Figure 5).The hardware (**ME**) itself contains the main elements of the mobile phone including the display, case, battery, and the electronics used to generate the signal, and process the data receiver and to be transmitted.

The **SIM** or Subscriber Identity Module contains the information that provides the identity of the user to the network. It contains are variety of information including a number known as the International Mobile Subscriber Identity (**IMSI**).

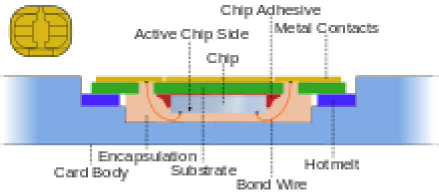

Figure 5. SIM chip structure and packaging

The block diagram in Fig. 6 provides a simplified description of the mobile station. A microphone captures the sound, which is sampled in a numerical format, compressed, coded, and modulated. A high-frequency oscillator translates the modulated signal to a valid transmission frequency. The received signal (less than 1mV) is amplified before down-conversion to a low-frequency, demodulation, decoding, and sound reconstruction [2].

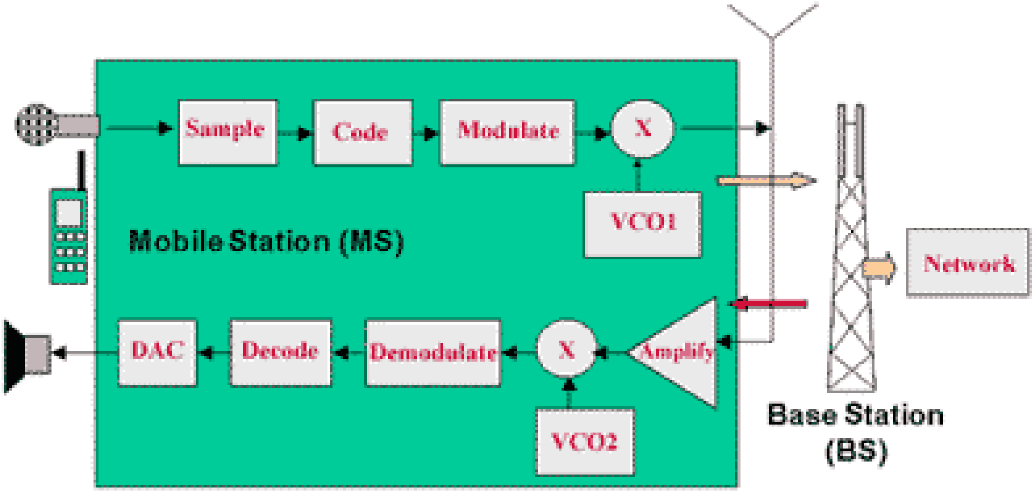

Figure 6. Block diagram of a mobile station

Base Station Subsystem (BSS)

The Base Station Subsystem (**BSS**) section of the **GSM** network architecture that is fundamentally associated with communicating with the mobiles on the network. It consists of two elements:

Base Transceiver Station (**BTS**): The **BTS** used in a **GSM** network comprises the radio transmitter receivers, and their associated antennas that transmit and receive to directly communicate with the

mobiles. The **BTS** is the defining element for each cell. The BTS communicates with the mobiles and the interface between the two is known as the Um interface with its associated protocols.
Base Station Controller (**BSC**): The **BSC** forms the next stage back into the **GSM** network. It controls a group of **BTS**s, and is often co-located with one of the BTSs in its group. It manages the radio resources and controls items such as handover within the group of BTSs, allocates channels and the like [2].

Network Switching Subsystem (NSS)

Its main role is to manage the communications between the mobile users and other users, such as mobile users, ISDN users, fixed telephony users, etc. It also includes data bases needed in order to store information about the subscribers and to manage their mobility.

Mobile Switching services Centre (**MSC**): the central component of the **NSS**. The **MSC** performs the switching functions of the network. It also provides connection to other networks.

Home Location Register (**HLR**): The **HLR** stores information of the subscribers belonging to the coverage area of a **MSC**; it also stores the current location of these subscribers and the services to which they have access.

Visitor Location Register **(VLR**): contains information from a subscriber's **HLR** necessary to provide the subscribed services to visiting users.

Authentication Center (**AUC**): It serves security purposes; it provides the parameters needed for authentication and encryption functions. These parameters allow verification of the subscriber's identity.

Operation and Support Subsystem (OSS)

The **OSS** or operation support subsystem is an element within the overall **GSM** network architecture that is connected to components of the **NSS** and the **BSC**. It is used to control and monitor the overall GSM network and it is also used to control the traffic load of the BSS. It must be noted that as the number of BS increases with the scaling of the subscriber population some of the maintenance tasks are transferred to the BTS, allowing savings in the cost of ownership of the system (http://www.radio-electronics.com).
The **OSS** consists of Operation and Maintenance Centers (**OMC**s) that are used for remote and centralized operation, administration, and maintenance (**OAM**) tasks. The **OSS** provides means for a service provider to control and manage the network [2].

HEALTH EFFECTS FROM RADIOFREQUENCY ELECTROMAGNETIC FIELD

The basics of EM interaction with materials were elucidated over a century ago and stated as the well-known Maxwell‘s equations. The application of these basics to biological systems, however, is very difficult because of the extreme complexity and multiple levels of organization in living organisms, in addition to the wide range of electrical properties of biological tissues.
There are many factors to be taken in determining how the RF / MT energy absorbed in the body, such as:
- Dielectric compositions
- The size of the body,
- The shape and orientation of the body and polarization fields,
- The complexity (similar to zones) RF / MT field

Interaction of electromagnetic field (EMF) with environment and with tissue of human beings is still under discussion and many research teams are investigating it. Biological tissues are modeled by their permittivity and conductivity. The complex permittivity of a biological tissue is given by:

$$\underline{\varepsilon} = \varepsilon_r \cdot \varepsilon_0 + j\frac{\sigma}{2\pi f} \quad (1)$$

where, σ (S/m) is the conductivity of tissue in siemens per meter and $\varepsilon_0 = 8{:}854 x 10^{-12}$ F/m.

Electrical conductivity and permittivity vary with the type of body tissue and also depend on the frequency of the applied field [1].

Table 1. Electrical conductivity of body tissue

	Conductivity (S/m)			
Tissue type	150 MHz	450 MHz	900 MHz	1,800 MHz
Muscle	0.73	0.81	0.94	1.3
Skin (wet)	0.56	0.69	0.85	1.2
Blood	1.2	1.4	1.5	2.0
Grey brain matter	0.60	0.76	0.94	1.4
White brain matter	0.35	0.46	0.59	0.92
Fat	0.07	0.083	0.11	0.19
Bone	0.070	0.096	0.14	0.28
Liver	0.53	0.68	0.86	1.3

Each object, whether it is a case or a living being, when found in the RF / MW field, can under certain conditions, to enter into resonance with the source of such a field. If the object is a person, its resonant frequency is primarily dependent on the height of the body.

Three different cases:

- when the body is less than the size of the wavelength,
- when they are approximately equal in their size and
- when the body is much larger than the size of the wavelength.

In cases where a body size smaller than the wavelength (Fig. 7-a), there is little absorption. When the wavelength is approximately equal to the size of the body (Fig. 7-b), it appears the greatest absorption of the unequal distribution of power. Therefore, it may appear " hot spots" in certain parts of the body. When the wavelength is smaller than the size of the body (Fig. 7-b), the absorption is smaller, while the heating is limited to the irradiated surface.

At RF and microwave frequencies, electromagnetic fields penetrate into human body. These fields interact with biological tissue in several ways. The most important interaction can be explained in terms of energy transfer from the electromagnetic field to the tissue material. One measure of this macroscopic effect is the time-averaged absorbed power.

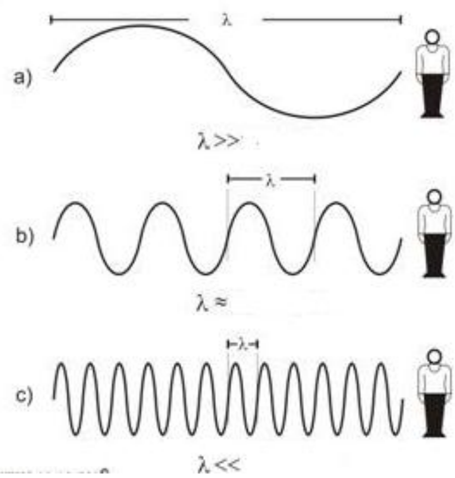

Figure 7. Size of the human body in relation to the wavelength of the electromagnetic wave [1].

Specific absorption rate (SAR) is a measure of the rate at which energy is absorbed by the human body when exposed to a radio frequency (RF) electromagnetic field; although, it can also refer to absorption of other forms of energy by tissue.
A quantity usually used is known as SAR and has dimension W/kg. SAR can be defined as:

$$SAR = \frac{1}{2} \cdot \frac{\omega \varepsilon_0 \varepsilon_r}{\rho} |E|^2 \tag{2}$$

with ω the angular frequency, ε_0 the permittivity of free space, ε_r the imaginary part of the relative complex permittivity, ρ the tissue density in kg/m3 and E is the peak value of the total field inside the tissue material.

We can see that the SAR depends on dielectric parameters therefore the materials of phantoms have to have similar dielectric parameters as human tissues. The human head consists of several tissues, which have different electrical characteristics and form complex-shaped boundaries. The electrical characteristics of human tissues are very different from the normal propagation medium (air), but not so different between each other. For values of SAR are recommended maximum values by committee INCRIP, this value is 2 W/kg in EU (SSI'S Independent Expert Group on Electromagnetic Fields) [1].

In the past few years, very rapid development in mobile cellular communication has drawn attention to possible health risks of the electromagnetic energy (EM) emitted from the transmitters of hand-held phones [3]. The interaction between a human head and a hand-held phone under various conditions should be quantitatively evaluated in order to establish the safety in cellular mobile communication systems [4].

Beside public biological concerns in cellular mobile communication system, there is also a great demand to know the deterioration of the antenna performance because of the existence of human head. This is an important feedback for antenna designers to develop better structures. Analyzing possible range of variations of the induced field strengths in various tissues requires an extensive effort, since local field strengths strongly depend on various parameters [3]. Among the others : operational frequency and antenna power, mutual positions of the between device and head, design of the device, size and the shape of human head, distribution of tissues within the head and electrical properties of the tissues can be listed as important parameters which strongly affect the SAR distribution. Since some of the listed parameters are different for various individuals and can even change with time, analytical formulations (even the approximate ones) in SAR distribution calculations are extremely difficult.

The SAR distributions in a human head exposed to EM fields from hand-held cellular phones have been estimated through experimental [5], and numerical calculations [6]. The models used in these studies are quite different where from simple to enhanced geometries and from a few to many different tissue types are taken into account with different electrical properties. Moreover, quite different values have been used in some of these studies [7], parallel to more accurate measurements of human tissues [6]. For example, there are more than hundred percent differences in some of the tissue parameters in [7].

CONCLUSION

High frequency radiation exists in free space around us from an increasing number of sources and cover a wide range of the electromagnetic spectrum. The most important use for RF energy is in providing telecommunications services. Radio and television broadcasting, cellular telephones, radio communications for police and fire departments, amateur radio, microwave point-to-point links, and satellite communications are just a few of the many telecommunications applications. By for the most important and rapidly expanding source is the mobile phone base stations. Fortunately, the radiated power densities around these base stations are below the standard limits set by the different world organizations. It is important to take care in the design of new base stations to meet the guidelines set for the antennas and their mounting so that the minimum required distance can be observed for the public access. New trends in the design of such antennas such as the smart antenna concept, can be applied in order to further reduce the radiation power levels.

REFERENCES

[1] Kemal Dervić, Vladimir Šinik, Željko Despotović, Momčilo Bjelica, Vojin Kerleta, RADIATION OF ELECTROMAGNETIC FIELDS AT RADIO FREQUENCIES, III International Conference „Ecology of Urban Areas 2013, 11th October 2013, Zrenjanin, Serbia, Pg 649-656,

[2] Vladimir Šinik, Željko Despotović, Slobodan Janković, Momčilo Bjelica, Vojin Kerleta , RADIOFREQUENCY RADIATION OF GSM NETWORKS , III International Conference „ Ecology of Urban Areas 2013, 11th October 2013, Zrenjanin, Serbia, Pg 662 667

[3] Selcuk Paker, Levent Sevgi, FDTD Evaluation of the SAR Distribution in a Human Head Near a Mobile Cellular Phone

[4] L. Sevgi and S. Paker, Fdtd based rcs calculations and antenna simulations.AEU, International J. of electronics and Communication, Vol.52, NO:2, pp.65-75. March 1998.

[5] Q. Balzano O. Garay, F. R. Steel. Heating of biological tissue in the induction _eld of VHF portable radio transmitters. *IEEE Trans. Veh. Technol.*, VT-27, pp. 51-56, 1978.

[6] Y. Rahmat-Samii M. A. Jensen. Performance analysis of antennas for hend-held transsreceivers using FDTD. *IEEE Trans. Antennas and Propagat.*, V 42, No 8, pp.1106-1112, 1994.

[7] O.P. Gandhi G. Lazzi, C.M. Furse. Electromagnetic absorbtion in the human head and neck for mobile telephones at 835 and 1900 MHz. *IEEE Trans. Microwave Theory Tech.*, MTT-44, No 10, pp.1884-1897, 1996.

REVIEW OF TECHNIQUES FOR LANDFILL LEACHATE TREATMENT

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Abstract: One of the basic problems of waste management, which is in practice encountered in landfills, is the collection and treatment of wastewater. Their production, and therefore quantity, depends on the age of the landfill, types of waste, climatic conditions, etc. These wastewater must not be discharged directly into the environment without prior collection and adequate treating. Water from solid waste, as well as water infiltrated into the landfill, forms a medium in which all soluble matter is dissolved and which causes the movement of unreacted material towards the bottom of the landfill. These waters are known as leachate water. The paper presents the production and composition of leachate landfills, and reviewed the technologies that are most often applied for their treatment. It can be concluded that leachate water due to its complex composition poses environmental risks and must be managed in an environmentally friendly manner.
Key words: landfill, wastewater, treatment

INTRODUCTION

Disposal to landfills is one of the most common ways to manage waste materials safely in the human life and work environment. Well-designed landfills have systems for collecting and managing wastewaters and gases. By discharging untreated leachate from the landfill, surface and groundwater may be contaminated.
According to the chemical composition of the leachate, they belong to the group of the most polluted wastewater and therefore can have a detrimental effect on human health and the environment if they are not managed in an adequate manner. Therefore, their collection and treating is necessary in order to remove the present harmful compounds and reduce their concentrations to levels acceptable to the environment. For treating leachate landfill waters physico-chemical, biological and membrane processes are used.
In this work is comprehensively considered the way of formation, composition and possibilities of treating leachate landfill waters.

FORMATION OF THE WASTEWATER AT THE LANDFILL

Leachate waters are generated by the flow of water from atmospheric precipitation through the body of the landfill, in which extraction of soluble, colloidal and suspended matter from the waste occurs. In addition to the type of waste that is deposited, the compactness of the layers and processes taking place at the landfill, the quantity of leachate waters is influenced by other factors. The quantities of leachate water depend to a considerable extent on the location of the landfill, on the method of waste disposal, the collection and disposal system of leachate (filtrate) from the landfill.
The amount of leachate is affected by the outer waters that penetrate to the body of the landfill. The outer waters that penetrate to the body of the landfill are:

- groundwater,
- landfill surface water
- water caused by atmospheric precipitation.

The latest research in order to examine the problem of leachate from municipal solid waste landfills shows that these waters are one of the most complex sources of pollution in the environment. The landfill leachate is a medium whose composition and quantity are significantly changing during the life of the landfill. From the point of view of toxicity, they are among the most polluted wastewater and are therefore extremely demanding for treating. Each landfill is a separate system where the composition and quantity of leachate water depends exclusively on the characteristics of the landfill. The main source of landfill leachate waters is the atmospheric precipitation coming to the surface of the landfill and flowing through the body of the landfill. A part of that water is running as precipitation water, the part is returned to the atmosphere by evaporation from the upper surface of the landfill or vegetation, and the remain is retained in the upper layer of the landfill, where moisture increases in the waste. When the waste is saturated with this moisture, the excess water flows through the layers of waste. Movement of water through waste depends on the permeability, porosity, humidity and thickness of the waste, the chemical reactions of the internal overhangs that form impermeable barriers and accumulation zones in the waste. Figure 1 shows the layout of the landfill with the collection system for leachate waters.

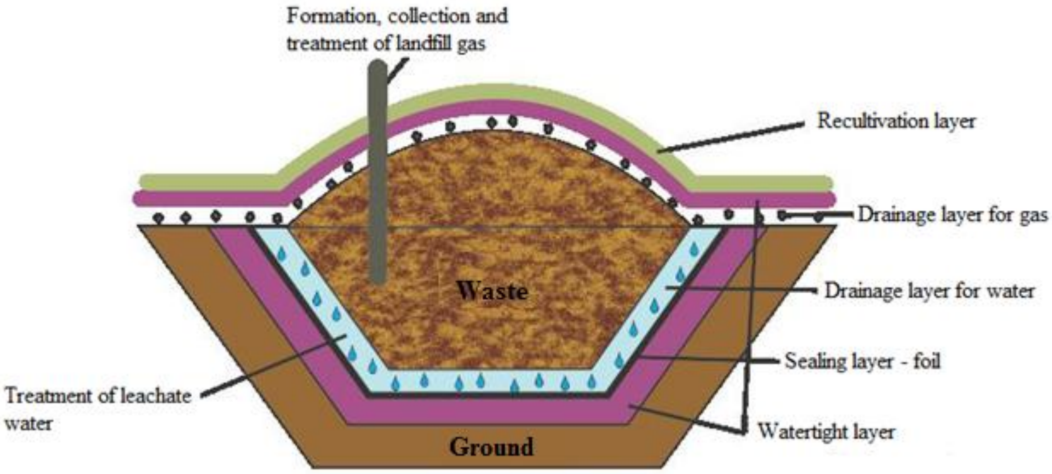

Figure1. Layout of the landfill with the collection system for leachate waters [1]

The amount of collected water in the layers of waste up to the moment of achieving the degree of saturation of moisture represents the capacity of retaining moisture in the waste. At that stage, the moisture from the waste begins to form the leachate water at the landfill. The amount of water that occurs as a product of the biological and chemical processes of decomposition of waste is practically insignificant compared to other sources, except in areas with dry climate.

The quantity of leachate landfills can be calculated using various experimental methods and patterns, as well as using mathematical models and computer programs.

For the purpose of long-term control of the production of leachate water and reduction of purification costs, reducing the infiltration of atmospheric precipitation into the landfill body is one of the priority tasks. With the implementation of certain operational measures, the production of landfill leachate can be reduced to 0,02 to 0,2 mm / day. However, the reduction in the production of leachate has negative effects on the degradation of organic waste components in the landfill body. The lack of moisture in the landfill body leads to a decrease in the intensity of microbiological processes by which the organic components are broken down into waste, which causes an undesirable process of "dry stabilization" or "mummification" of organic waste components.

According to individual technical solutions and technical equipment of the landfill, controlled recirculation of leachate waters can be achieved in the body of the landfill. Recirculation of leachate water into the body of the landfill provides regulated dosing and their retention at the site of formation, and accelerates the degradation of deposited organic waste components.

COMPOSITION OF LANDFILL WASTEWATER

The quality of wastewater is conditioned by the physical, chemical and biological processes in the landfill body. The composition of wastewaters depends on a number of factors: the composition of waste, its pre-treatment, the stabilization and decontamination process at the landfill, the height and age of deposited waste, the charging technique and the degree of compression of waste, weather and hydrological conditions at the location. Landfill wastewaters are significantly different in composition. The real composition of these waters is very difficult to predict because it depends on a number of variables such as:

- waste composition,
- temperature and moisture content,
- the pathway of the fluid,
- thickness of the landfill,
- stages of waste decomposition,
- the ability of interlayers to absorb and remove pollution, and
- the quality of water infiltrating into the landfill.

So far the research carried out on the landfill leachate waters shows the following:

- the quality of the effluent is extremely variable, but partial or complete purification must be carried out before discharge into the recipient;
- assessment of the quality of the effluent water of the existing or future landfill, for the forthcoming period, can be orientated and bound to the experiential indicators from the literature;
- mathematical modeling, based on models and empirical relations, can be applied to the treating and application of specific conditions and characteristics of a specific landfill;
- the quality of the treated waters changes depending on the age of the landfill, and therefore the processing plant must be flexible and adaptable to monitor the changes in the quality of the treated water;
- the quality parameters of the effluent, in the treatment of leachate waste waters, should meet the legal regulations for industrial wastewater, and the obligatory quality indicators are the content of the suspended matter, the temperature, the pH value, chemical oxygen demand (COD), biologycal oxygen demand (BOD5), nitrogen content and total phosphorus.

Landfill wastewaters mainly contain dissolved organic matter, ammonium nitrate, sulfides, chlorides and other harmful substances. Their concentrations depend on the age of the landfill and the type of waste that is being disposed of, as well as the decomposition phase of the waste. The change in the composition of the effluent landfill depends on the phase of the decomposition of waste. The stages of decomposition of the waste at the landfill are the following: aerobic (phase I), acidic (phase II), the start of methane production (intermediate phase III), anaerobic intense methane production (Phase IV) and aerobic phase (phase V).
Based on the literature data, it is possible to illustrate the average composition of landfill leachate water depending on the age of the landfill (Table 1).

Table 1. Characteristics of landfill leachate water, depending on the age of the landfill [2]

Parameter	Unit	The age of the landfill		
		up to 1 year	from 1 to 10 years	from 10 to 20 years
pH value	-	5,4 ÷ 7,7	7,1 ÷ 8,7	7,3 ÷ 9,3
Suspended substances	mg/L	1875	386 ÷ 1950	159 ÷ 1150
Total suspended substances	mg/L	4,6 ÷ 6,8	848 ÷ 6786	767 ÷ 6786
Biologycal oxygen demand (BOD5)	mg/L	5000 ÷ 15000	280 ÷ 15000	207 ÷ 1800
Chemical oxygen demand (COD)	mg/L	-	640 ÷ 13040	5500 ÷ 17600
Chlorides	mg/L	-	420 ÷ 2875	119 ÷ 5860
Ammonium nitrogen (NH3-N)	mg/L	-	150 ÷ 2700	2 ÷ 47
Nickel (Ni)	mg/L	-	0,02 ÷ 1,56	0 ÷ 1,56
Cadmium (Cd)	mg/L	-	0 ÷ 0,13	0 ÷ 0,05
Lead (Pb)	mg/L	-	0 ÷ 3,25	0 ÷ 3,45
Chromium (Cr)	mg/L	-	0,05 ÷ 16,9	0,04 ÷ 1,16
Mercury (Hg)	mg/L	-	0,4 ÷ 1,70	-

Organic contaminants are organic compounds that are harmful to the ecosystem. They can be carcinogenic, toxic and mutagenic to living organisms. Organic pollutants are determined using mass spectrometry methods. Gas chromatography in combination with mass spectrometry (GS-MS) is the most commonly used method.

Heavy metals are present in leachate if heavy metal waste is deposited at the landfill. If the leachate contains colloids, then the greater risk is that heavy metals, such as cadmium, copper, lead and chromium, are transported outside the landfill.

Ammonia nitrogen (NH_3-N) represents the amount of ammonia, toxic pollutants in waste landfills, sewerage, liquid fertilizer and other liquid organic products. Ammonia nitrogen can directly disturb the balance of water systems. High concentrations of untreated ammonia nitrogen boost algae growth, reduce the performance of biological systems for water treatment, accelerate eutrophication, increase the consumption of dissolved oxygen in the water and increase the toxicity of surface waters.

PROCESSES FOR THE LANDFILL LEACHATE TREATMENT

All waters generated at landfills, according to the Waste Disposal Directive 1999/31 / EC, should be collected and refined before discharge into the recipient. Leachate water is collected by the drainage system and can be treated together with wastewater from the recycling waste separation plant, municipal waste water from the auxiliary objects of the landfill, as well as the waste water from the washing of vehicles that bring the waste to the landfill. The quantity of leachate water during the year varies considerably depending on meteorological conditions, and therefore their quality, or concentrations of pollutants.

Selection and design of the treatment process of leachate waters are not simple. Important factors that significantly influence the selection and design of the treatment systems for the landfill leachate water are:

- defining the characteristics of leachate water (quantity and quality);
- analysis of the possibility of final discharge of leachate waters, and determining the appropriate level of treatment;
- the selection of a purification process or process that will ensure that the quality of the effluent meets the legal regulations and uninterrupted release into the recipient;
- cost analysis of different treatment processes depending on the choice of the final disposition;
- selection of the best treatment and disposition process from the aspect of cost, reliability, flexibility and other specific requirements.

Transfer of leachate waters includes processes such as recycling / recirculation and combined treatment with water from the public drainage system, i.e. public sewers. In the last few years, the solution has often been the treatment of leachate waters along with water from public sewerage systems in municipal wastewater treatment plants. This solution was popular due to low cost and relatively simple processing. One of the arguments in favor of the application of this treatment is the fact that nutrients for the growth of microorganisms in municipal wastewater treatment plants do not need to be added; nitrogen is fed to the leachate while phosphorus is introduced with sewage water. In addition to the nutrients of leachate water, organic compounds with low biodegradability are brought with them, as well as heavy metals, which can reduce the quality of the treatment and result in an increase in the concentration of metals in the effluent, which bring into questions process of treatment of leachate water using this procedure. There are different types of technologies for the treatment of leachate water and some of them are shown in Table 2. It is not appropriate to specify in advance what technologies are the best, and a general solution can not be proposed. It is necessary to design a treatment plant for effluent water that can efficiently and economically respond to variations in the quality and quantity of wastewater, as well as the necessary degree of purification based on the required water quality in the recipient.

Table 2. Technologies for the treatment of wastewaters [3, 4]

Technology and processes	Advantages	Disadventages
Physical-chemical processes: flotation, coagulation / flocculation, precipitation, chemical oxidation, adsorption, aeration and evaporation	Low investment	Low level of purification efficiency
Biological processes: aerial lagoons, suspended activated sludge, sand irrigation filters, anaerobic (anaerobic lagoons and anaerobic digestion), rotating biological reactor	Efficient and economical removal BOD and ammonia	Complex system maintenance
Membrane technologies: microfiltration, ultrafiltration, nanofiltration and reverse osmosis	High level of purification efficiency	High investment, wastewater initial treatment, waste sludge problems

Physical and chemical processes for the treatment of leachate waters include the removal of suspended particles, colloids, floating materials, dye and toxic compounds by flotation, coagulation / flocculation, adsorption or stripping processes. Physico-chemical processing is used as an additional treatment in the line of treatment of leachate water, most often as a previous treatment or last treatment, i.e. post-purification.

Methods of biological treatment are carried out using microorganisms capable of converting unwanted products to biomass and gas. However, the main reason for the use of biological treatment is not just the removal of organic pollutants, because biological treatment in the removal of organic matter can remove parts of organic pollutants. Biological methods of treatment can be divided into: aerobic and anaerobic processes. Aerobic processes are more commonly used primarily because of their efficiency and ease of use. Biological anaerobic treatment methods involve the degradation of organic content by the action of microorganisms in the absence of oxygen and the formation of biogas. In contrast to aerobic, anaerobic processes produce small amounts of sludge, while the process, as well as in the case of aerobic degradation, can be carried out with suspended or immobilized microorganisms on the biofilm.

By increasing the demand for quality of treated water before discharge it into natural recipes, conventional methods of treatment are not sufficient to achieve a high level of treatment especially of leachate waters of older landfills, because the pollutant components in them are more stable and hardly biodegradable. In the past twenty years, methods of treatment based on membrane technologies have been developed which can meet the new more stringent regulations regarding the quality of treated leachate landfill water.

The purification system using membrane technologies can be divided into two groups:

- nanofiltration and reverse osmosis: In these systems are used pressure membrane modules with a high degree of purification and recirculation of the concentrate,
- ultrafiltration and microfiltration: Such plants are based on modules and cassettes completely submerged in biological reactors called membrane bioreactors.

The difference in these processes is in the nature of the matter and the size of the particles that can be extracted. In general, an indicator of the efficiency of membrane processes is the size of the particles separated from the water being processed. The size of the separated particles by individual processes is as follows: by reverse osmosis is extracted from 0.01 to 0.00015 μm, and by nanofiltration from 0.001 to 0.01 μm. Ultrafiltration extract particles in the range of 0.1 to 0.003 μm, and microfiltration of 3 to 0.05 μm

CONCLUSION

When designing facilities for treating leachate water it is difficult to accurately determine the quantity and composition of the water to be processed. Their quantity and composition depend on the age of the landfill, types of waste, disposal technology, microclimate parameters, etc. Due to all of this, it is very important to choose a technology that is flexible for treatment these types of wastewater to achieve the required quality of purified water.

Conditions for purification of leachate waters are prescribed by law, and the application of treatment technology depends on the quantity, composition and conditions of discharging the treated water into the recipient. The paper gives a brief overview of the production and composition of leachate landfill waters. The technologies that are most often applied for their purification are presented. The presence of organic, inorganic and microbiological loads, as well as the low biodegradability of leachate water requires a combination of different treatment processes to meet the criteria to environmental discharge. Due to the complex composition in comparison with other types of industrial wastewater, the landfill leachate is the most demanding for treating. Therefore, it is necessary to combine treating methods in order to achieve the prescribed quality of treated landfill water.

REFERENCES

[1] Serdarević, A.: Application of MBR Wastewater Treatment Devices, Doctoral thesis, Faculty of Civil Engineering, University in Sarajevo, Sarajevo, 2011

[2] Karanac, M., Jovanović, M., Mihajlović, M., Dajić, A., Stevanović, d., Jovanović, J.: Contribution to technological design of landfills in Serbia, recycling and sustainable development 8, page. 27-37, 2015.

[3] Renou, S., Givaudan, J-G., Poulain, S., Dirassouyan, F., Moulin, P.: Landfill leachate treatment: review and opportunities, J. Hazard. Mater., 150 (3), pp. 468-493, 2008.

[4] Abood, A. R., Bao, J., Dua, J., Zheng, D., Luo, Y.: Non-biodegradable landfill leachate treatment by combined process of agitation, coagulation, SBR and filtration, Waste Manage., 34, pp. 439-447, 2014.

[5] Knežević, N., Cukut, S., Dunović, S.: Membrane processes in purification of leachate from municipal waste landfills, Journal of Engineering & Processing Management, Volume 4, No. 1, pp. 151-162, 2012.,

[6] Renou, S., Givaudan, J. G., Poulain, S., Dirassouyan, F., Moulin, P.: Landfill lechate treatment: Review and oppurtunity, 2008.

[7] Serdarević, A.: Selection of the process of purification of leachate waters of sanitary landfills, Faculty of Civil Engineering, University in Sarajevo, Sarajevo, 2017.

[8] *** ISWA: Leachatemanagement, Antwerp, Belgium, 2015.

[9] Walker, C. H.: Organic Pollutants: An Ecotoxicological Perspective,2nd Edition, London, 2009.

ANALYSIS OF PARTICULATE MATTER CONCENTRATION IN AMBIENT AIR IN EASTERN SARAJEVO AREA

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Abstract: Natural processes and human activity are the main sources of pollutant components in the atmosphere. Natural and artificial sources, in addition to hydrocarbons, nitric, sulphur and carbon oxides, emit particulate matter of various sizes (PM_1, $PM_{2,5}$ and PM_{10}) into the atmosphere. Particulate matter is harmful to the environment and human health, therefore it is necessary to monitor its concentration in the air in urban and industrial areas.
The paper presents the results of PM_1, $PM_{2.5}$ and PM_{10} concentrations measurements at several locations in the area of Eastern Sarajevo, from April to December 2017. Based on the results of the measurements, it can be concluded that an increase in the concentration of particulate matter in the air occurs in winters. The obtained results showed that for a number of measurements the average daily concentration of particulate matter was above the limit values defined by the legislation in the field of air protection.
Key words: concentration, particulate matter, air, Eastern Sarajevo.

INTRODUCTION

Air pollution is one of the basic forms of environmental pollution. The protection of air from pollution in order to ensure the quality of life in residential area and industrial centres, as well as preserving the ecological potential of the environment, is one of the priorities of modern humanity.
Nature has been adapting to the natural sources of air pollution for centuries, while artificial pollution has emerged over a short period of time and has relatively large environmental impacts. The most common sources of air pollution are: processes of combustion of liquid and solid fuels in thermal power plants, heating plants and small domestic furnaces, processes in industrial plants, exhausts of motor vehicles, processes at waste damps, etc.
The most common pollutants in the air are carbon dioxide, carbon monoxide, sulfur dioxide, nitric oxides, various organic compounds (hydrocarbons, benzenes, freons), particulate matter, etc. In addition to the concentration of pollutants, the quality of air in one area is strongly influenced by meteorological elements: air pressure, wind direction and velocity, eddy currents, absence of wind, humidity, presence of fog, rainfall, air temperature and temperature inversions.
Particulate matter emitted into the air from various sources is harmful to human health and the environment. This paper presents the results of particulate matter concentration measurements (PM_1, $PM_{2,5}$ and PM_{10}) at three locations in the area of Eastern Sarajevo, from April to December 2017.

THE CONCEPT AND COMPOSITION OF PARTICULATE MATTER

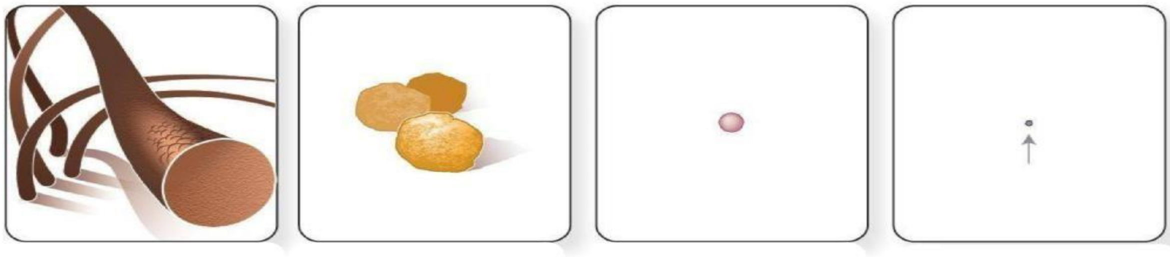
Substances that are mostly found in the lower parts of the troposphere, which are dispersed in the air in the form of dust or mist, are called particulate matter or aerosols. [1] Particulate matter emitted directly into the atmosphere from a source is referred to as a primary particulate matter, while secondary particulate matter are those particles formed in the atmosphere by the oxidation and transformation of a substance from primary emission by sunlight. Sulphur dioxide, nitric oxides, easily evaporative organic compounds are the most common gases from which secondary particulate matter is formed in the atmosphere. [2] Secondary particulate matter if often more harmful than the initial substance from which they are derived.
Particulate matter is usually not homogeneous, and they reach the environment in different sizes and shapes. Its chemical and physical composition depends on the location, season and weather conditions. Particulate matter is a mixture of organic and inorganic substances that is largely derived from energy plants, residential heating, industry and transport. The particles must be kept in a suspended state for long enough for the aerosol to be stable. Accordingly, all pollutants in the atmosphere, except water, in

liquid or solid state, are classified as particulate matter. Particulate matter includes dust, soot, smoke, fog and smog [3].

Various chemical compounds such as nitrates, organic compounds, metals, salts and water particles are found in particulate matter. Its composition depends on the season, meteorological conditions, the type and characteristics of the source, the size and age of the particles. The size of the particle is the most important matter because it is responsible for environmental behaviour (motion and duration of presence in the air).

According to the aerodynamic diameter, the particles are grouped as follows: PM_{10} (a diameter of 2.5 to 10 μm), $PM_{2.5}$ (a diameter less than or equal to 2.5 μm), and PM_1 (a diameter less than or 1 μm). The size of particle is the most important parameter because it is responsible for environmental behaviour.[2]

Figure 1 shows a comparison of PM_{10} and $PM_{2.5}$ particle size with sand particle size and human hair.



a) b) c) d)

Figure 1. Comparison of size of PM_{10} and $PM_{2.5}$ with sand and human hair: a – human hair of 70 μm, b – grain of sand 50 μm, c – PM_{10}, d – $PM_{2.5}$

Particulate matter adversely affects human health because it can reach deep inside human respiratory system by inhalation, and it can bind harmful substances such as polycyclic aromatic hydrocarbons that have a strong mutagenic or carcinogenic effect. The greatest danger to human health is particulate matter of aerodynamic diameter less than 2.5 μm. Particulate matter pollutes the air and by inhaling people are directly exposed to the risks of acute and chronic diseases. [3]

MATERIAL AND METHOD

Study domain

Eastern Sarajevo is located in the central part of Bosnia and Herzegovina, the eastern part of Republic of Srpska and it is the largest city in the Sarajevo-Romanija region. The total area of the city is 1,425.77 km^2. The city is surrounded by mountains whose highest peaks reach altitude of about 2,000 m. Bjelasnica extends in the south-west and Jahorina in east of the town. Igman is located southwest of the city, partly enclosing Bjelasnica. Treskavica is a mountain range located south of the city. Southeast of the town is Mount Trebevic. Romania is a mountain that extends to the northeast of the city. Based on the geographical position described, it is clear that Eastern Sarajevo is located in a valley surrounded by mountains. This geographical position of the city affects the quality of the air, especially in winter. Because of its location the city has a fog and smog problem. [4]

In winter, in addition to the fog which often lingers above the city and the emission of flue gases from industrial plants and motor vehicles, the largest air pollutants are urban boilers and small household furnaces. Most city boiler rooms use coal, fuel oil and wood waste as fuel. One part of the residential buildings is heated by natural gas. Small household furnaces mostly use coal and wood. [1]

PM monitoring

Particulate matter concentration was monitored at three locations in Eastern Sarajevo. Concentrations of particulate matter were measured at Spasovdanska Street in the centre of the city, at Vuk Karadzic Street at the location of the University Centre and in the Dobrinja settlement on the border between Republic of Srpska and the Federation of Bosnia and Herzegovina.

The concentration of airborne particles in three locations in East Sarajevo was measured from 1st April until 31st December 2017. Measurements were made using an ESP8266 device. Figure 2 shows the layout of the ESP8266. [4]

Figure 2. *Device ESP8266*

The PM_{10}, $PM_{2.5}$, and PM_1 particulate matter concentrations at the measured sites were obtained from ESP8266 device. Samples were collected throughout the day and 24-hour average concentrations were obtained. The obtained data is transmitted to the computer so that the values of the particulate matter in the air are constantly monitored. All data regarding PM_{10}, $PM_{2.5}$, and PM_1 particulate matter concentrations were processed in Microsoft Excel, and program Atom was used to analyse the data.
Table 1 shows the limit and tolerance values for PM_{10} and $PM_{2.5}$ particulate matter concentrations according to local air protection legislation.

Table 1. Limit and tolerance values for PM_{10} and $PM_{2.5}$ particulate matter in the air[4]

Particulate matter	Average time	Limit value	Frequency of allowed exceedence	Tolerated value of exceedence
PM_{10}	24 hours	50 μg/m^3	The limit value may not be exceeded more than 35 times during the calendar year	75 μg/m^3 (The limit value may not be exceeded more than 35 times during the calendar year)
	1 year	40 μg/m^3	-	60 μg/m^3
$PM_{2.5}$	1 year	25 μg/m^3	-	30 μg/m^3

Between April and the end of December, measurement of PM_{10}, $PM_{2.5}$, and PM_1 concentrations was performed on 254 days. Measurements were made at three defined locations.
Figure 3, Figure 4 and Figure 5 show the values of daily particulate matter concentration from April to December 2017 at one of the locations in Eastern Sarajevo.

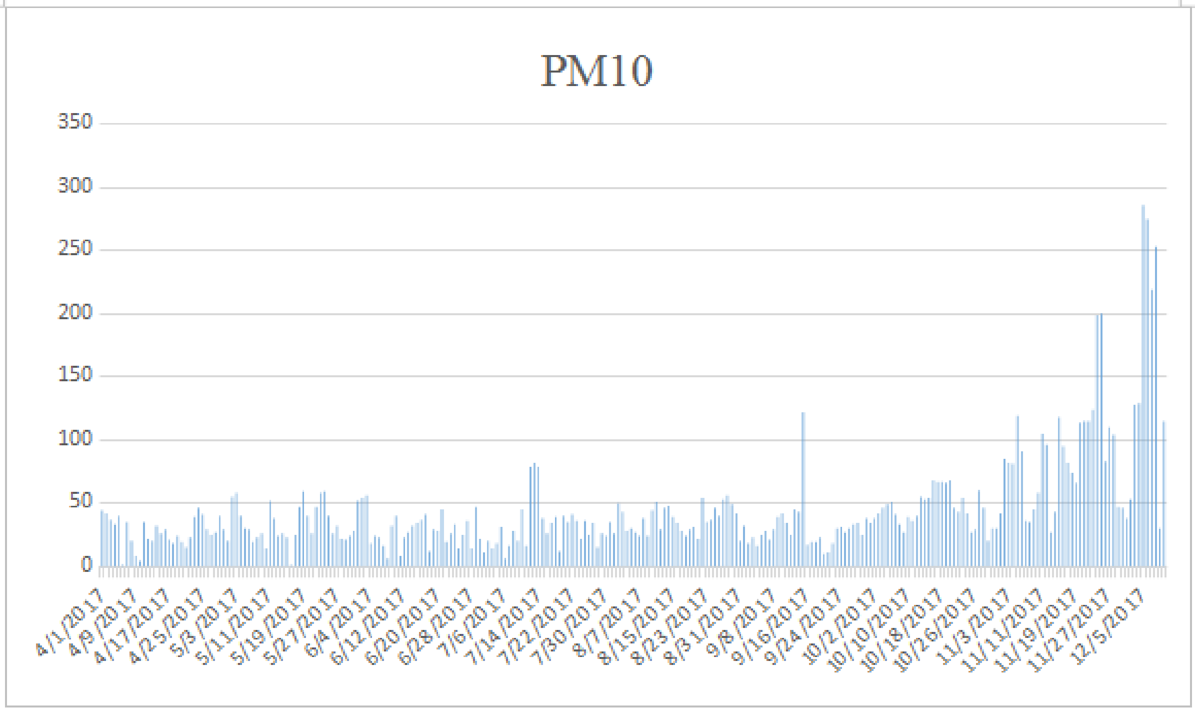


Figure 3. Daily concentration of particulate matter PM_{10} in the air

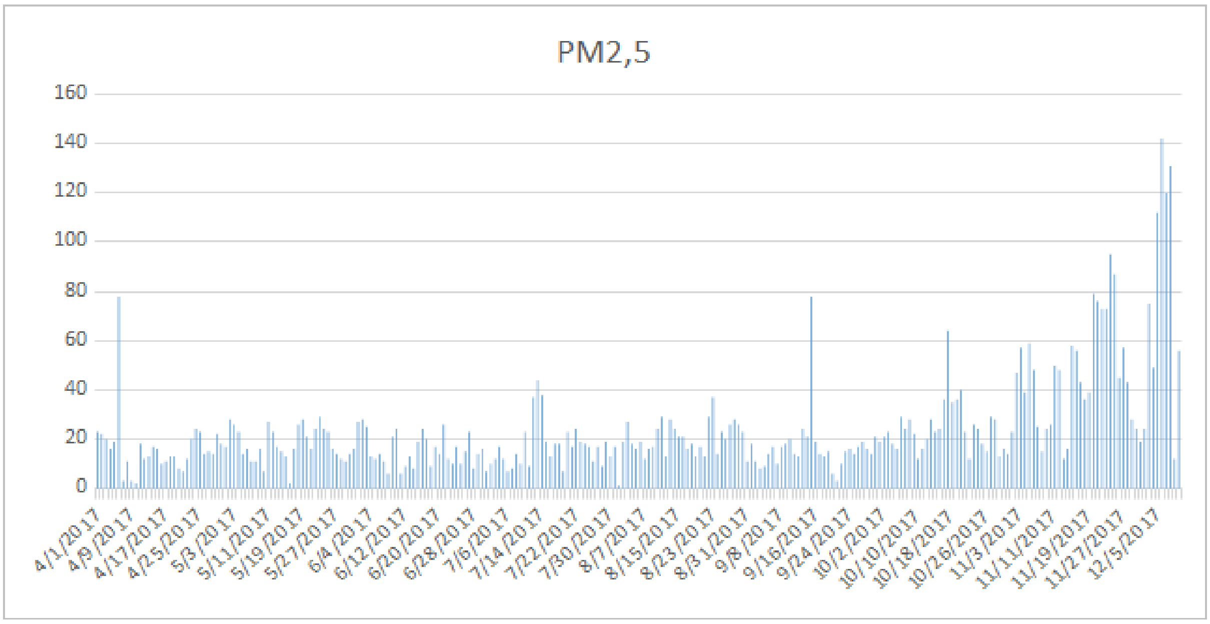


Figure 4. Daily concentration of particulate matter $PM_{2.5}$ in the air

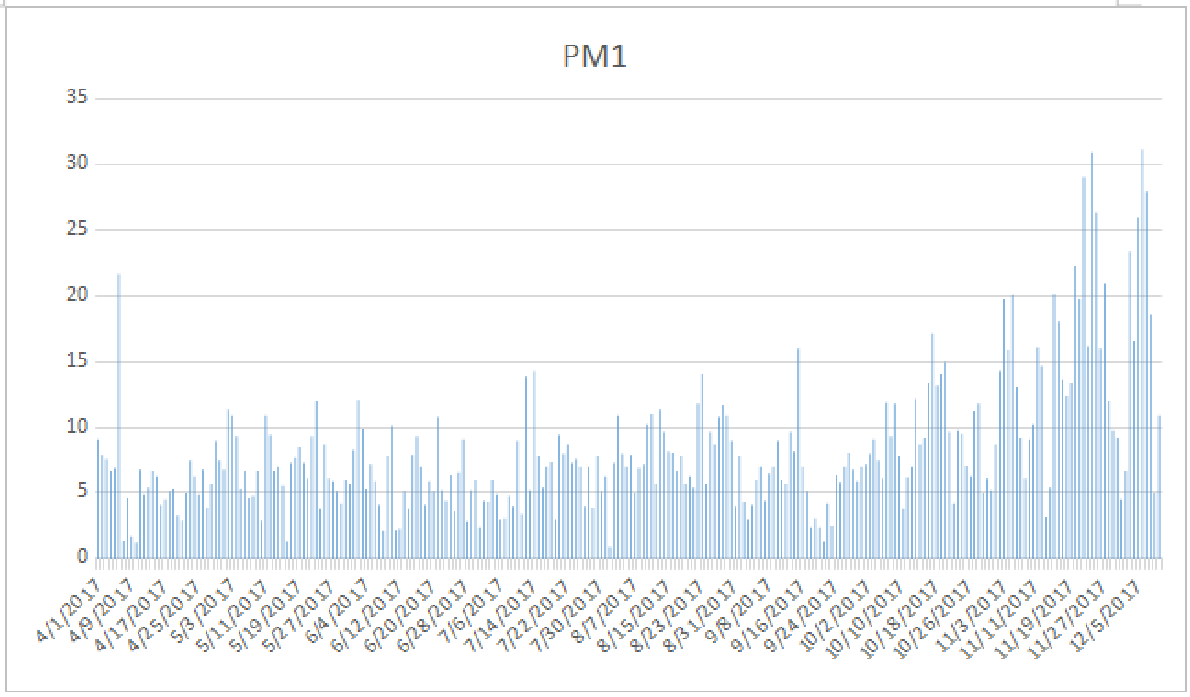


Figure 5. Daily concentration of particulate matter PM_1 in the air

Figure 6 shows the comparative daily concentrations of PM_{10}, $PM_{2.5}$ and PM_1 particulate matter for the time period for which measurements were made.

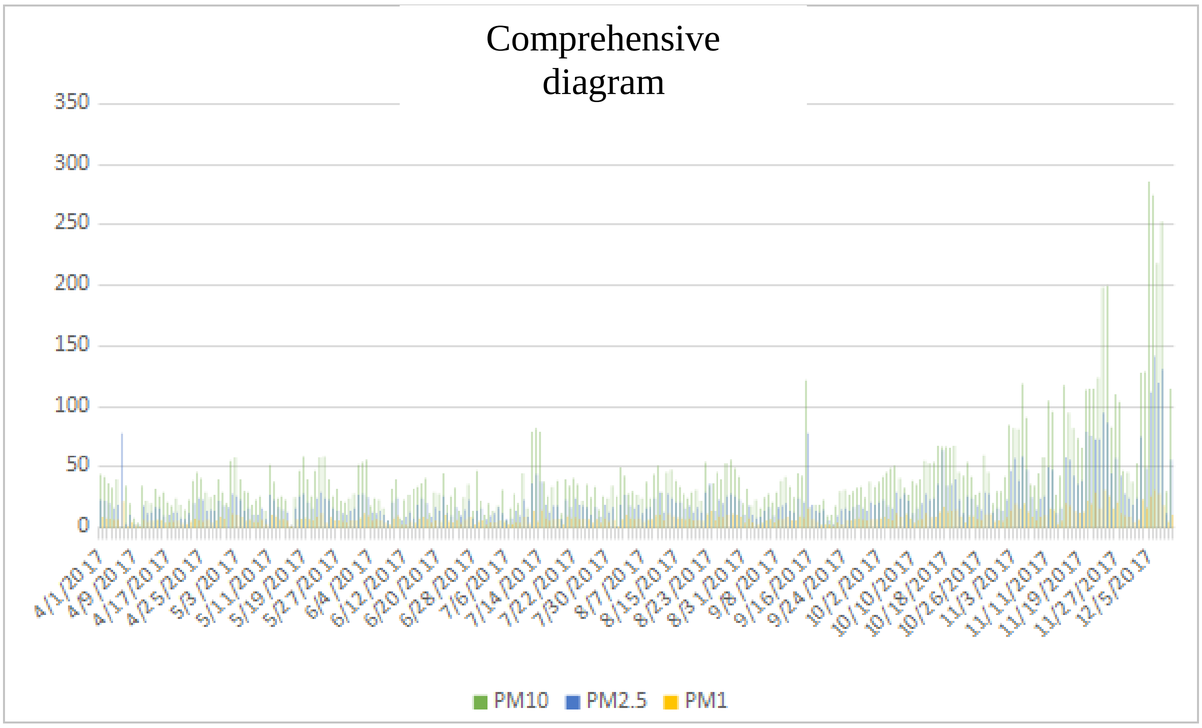


Figure 6. Comparative daily concentrations of particulate matter in the air

Table 2 shows the average monthly concentrations of PM_{10}, $PM_{2.5}$ and PM_1 particulate matter for the time period for which measurements were made.

Table 2. Average monthly concentrations of particulate matter

Month	Average concentrations of particulate matter, (µg/m^3)		
	Particulate matter PM_{10}	Particulate matter $PM_{2,5}$	Particulate matter PM_1
April	27,46	26,56	6,02
May	33,29	25,93	6,90
June	29,10	25,70	6,18
July	31,70	19,00	6,30
August	37,00	19,96	8,18
September	53,23	24,80	5,99
October	48,19	24,25	9,18
November	113,90	59,00	15,21
December	182,60	94,00	17,09

Based on the measurements, it can be concluded that the concentration of PM_{10}, $PM_{2,5}$ and PM_1 particulate matter in the area of Eastern Sarajevo is highest during the winter months. The highest PM_{10} concentration was measured in December at 286 µg / m^3, which is approximately six times higher than the maximum allowed concentration (50 µg / m^3). During the period of measurements, 58 exceedances of the emission values of these particles were recorded in relation to the maximum allowed concentration. The highest $PM_{2.5}$ concentration was measured in December and it was 142 µg / m^3, which is approximately six times higher than the maximum allowed concentration (25 µg / m^3). During the period of measurements, 56 exceedances of the emission values of these particles were recorded in relation to the maximum allowed concentration. Also in December, the highest PM_1 particulate matter concentration was recorded at 31.2 µg / m^3.

CONCLUSION

Monitoring the air quality in urban and industrial areas is one of the first steps to addressing air pollution. The paper presents the results of PM_1, $PM_{2.5}$ and PM_{10} concentrations at three locations in the area of Eastern Sarajevo, from April to December 2017. Based on the results of the measurements, it can be concluded that a significant increase in the concentration of the particulate matter in the air occurs in winter. The obtained results showed that a number of average daily concentration measurements of particulate matter was above the limit values prescribed by the legislation in the field of air protection. At all three measuring points, concentration values of particulate matter were similar.

Considering the geographical location of Eastern Sarajevo, the types of fuels used in urban boilers and small household furnaces, the situation in the field of industry and transport, it was realistic to expect that there would be exceedences of the particulate matter emission into the air during the year. [4]

REFERENCES

[1] Seinfeld, J. H., Pandis, S. N.: Atmospheric Chemistry and Physics: From Air Pollution to Climate Change, 2nd Edition, John Wiley & Sons, Inc., Hoboken, New York, 2006.

[2] . Trumbulovic-Bujic, Lj., Acimovic-Pavlovic, Z.: Impact of Air Pollutants on Air Quality in Industrial Area, METALURGIJA - JOURNAL OF METALLURGY, 14, (3) 2008, pg. 229-240.

[3] Durakovic, J., Duran, F.: Results of Air Pollution Measurement in Zenica in Period from 1st November to 31st March 2011, 7th Scientific Conference with International Participation, Quality 2011, Neum, B&H, 01-04.06.2011, pg. 749-75

POSSIBILITY OF USE OF RAW IRON MATERIALS FROM WASTEWATER FROM TECHNOLOGICAL PROCESSES OF FERRATE(VI) SYNTHESIS

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Abstract: Ferrate (VI) is a strong organic oxidizing, coagulating and flocculating agent. Due to its characteristics, it is suitable for treatment of waters of different origins. In these processes, resulting is an environmentally friendly and non-toxic product, $Fe(OH)_3$, which according to the results of this paper can be recycled and re-synthesized to ferrate(VI). This paper presents a method for the synthesis of ferrate salts by oxidation process from steel pickling wastewater containing $FeCl_2$ and $FeCl_3$ salts.
The method for synthesis involvesthe process of oxidation of ferrous and ferric ions by means of $Ca(ClO)_2$ in solid state and in the presence of KOH in solid state. The precipitate obtained from the wastewater of etching iron is mixed in a rotary ball mill with $Ca(ClO)_2$, and KOH, and then the resulting product is rinsed with organic solvents. After that it is dried in a vacuum dryer at room temperature. The recording ofthe x-ray diffractometer demonstrates a significant presence of K_2FeO_4, while analysis revealed a yield of 15%.
Keywords: potassium ferrate, ferrous chloride, ferric chloride, x-ray

INTRODUCTION

Ferrate(VI) salts have a wide range of potential applications due to their high efficient oxidation performance. In the area of environmental application ferrate has been considered for water and wastewater treatment because of its environmentally friendly properties without hazardous compounds forming, such as chlorine or bromine, carcinogenic organic pollutants [1-3]. Due to the fact that Fe(III), generated during oxidation by ferrate, exhibits valuable coagulating properties makes an additional contribution to water treatment processes.
Research works performed by Fremy [4, 5] are frequently cited in literature as the first to scientifically reveal the existence of iron in a hexavalent state and to effectively achieve ferrates synthesis. Since then, the preparation methods, developed mostly on a laboratory scale, have made little progress, and can be classified into three groups:

- The high temperature route consisting of heating and/or melting various iron oxides bearing materials under high concentration of alkali substances and oxygen flow [6]. These synthesis methods, performed at temperatures as high as 800°C, seem to be mostly ineffective since Fe(VI) is not stable at temperatures higher than 200°C. Most probably, Fe(VI) resulted from the dismutation of synthetized Fe(IV) and/or Fe(V) during manipulation of the synthesis product.
- The wet/humid oxidation of Fe(III) salts bearing solutions, under strong alkaline conditions, using hypochlorite or chlorine as an oxidant. This method is the most used since the 1950s [7, 8]. One of the drawbacks is that the wet method used pure chemicals and required many operations for Fe(VI) preparation and separation, making it very costly. Moreover, the water reacts with ferrate leading to its reduction into Fe(III).
- The electrochemical method [9, 10, 11], by anodic dissolution of iron or its alloys in a strong alkaline solution (pH > 10) in the transpassive region. Ferrate obtained by electrochemical synthesis has many advantages compared to chemically synthesized ferrate [10], such as: simplicity, lower consumption of chemicals, non-toxic products and exceptional purity of obtained ferrate. However, the decomposition of Fe(VI) by water, low current efficiency and anode passivation are some of the concerns for this route.

Ferrate(VI) salt is a potent oxidant. Under acidic and alkaline conditions, its respective reduction potentials are 2.20 and 0.700 V, being a potential for replacing traditional oxidants, such as ozone, hypochlorite, permanganate, and others [12]; their respective half-cell reduction potentials in acidic conditions are 2.08, 1.48, and 1.69 V, respectively [13], all less than Fe(VI). Potassium ferrate, other than acting as a powerful oxidant, can be an inorganic coagulant when chemically reduced to $Fe(OH)_3$; it can effectively remove suspended solids, heavy metals, and a variety of contaminants from water [14]. Further, using traditional oxidants to treat pollutants/contaminants usually can result in a noteworthy toxic byproduct problem, such as tri-halo-methane and bromates [15]. In contrast, potassium ferrate, as a water treatment agent, is reduced to environment friendly $Fe(OH)_3$ [3]. Prior to the chlorination process for drinking water, using Fe(VI) as a pre-treatment agent can effectively reduce the formation of hazardous by-products [16].

Despite the advantages Fe(VI) can provide, it is expensive for using it to treat pollutants and contaminants. There is also the problem of removing the resulting $Fe(OH)_3$ precipitate which also contains the removed pollutants. The paper presents the possibility of recycling $Fe(OH)_3$ from which Fe(VI) is recovered by a chemical process. For example, synthesizing Fe(VI) by using spent steel pickling liquid as an iron source can achieve a dual-win benefit by not only reducing the cost of Fe-raw chemicals source for Fe(VI) synthesis but also recycling spent steel pickling liquid for environmental sustainability.

Spent pickling liquid is unwantedly produced by the steel industry. Products like steel plates, pipes, and coils always require cleaning with acid to remove their surface impurities before being subjected to further processing. The impurities include black surfaces, iron oxides, and other contaminants. Hydrochloric acid is usually used as the pickling acid for carbon steel products due to its relatively lower price, lower acid consumption rate, and providing a faster pickling process, despite its shortcomings of a higher volatilization rate [17].

If spent pickling liquid is treated as waste water, toxic metal present in it is generally removed through different approaches, such as the precipitation method, ion exchange, and others. Among them, precipitation as hydroxide is the most often used technology. Although the technology is technically simple, its neutralization step requires a large amount of alkalineor alkaline earth-based chemicals, and it would be much more praised if spent steel pickling liquid could be recycled.

When hydrochloric acid is used as a pickling agent, most iron in spent steel pickling liquid would be present in the form of ferrous chloride through the following chemical reaction [17]

$$FeO + 2HCl \rightarrow FeCl_2 + H_2O \qquad (1)$$

MATERIALS AND METHODS

As a starting material for the synthesis of ferrate from scrap iron, wastewater from the plant for corrosion of carbon steel is used. Other chemicals used are as follows: a solution of $Ca(ClO)_2$, 99%, 85% KOH, 99% NaOH, n-C_5H_{12} 99%, 96% C_2H_5OH, $(C_2H_5)_2O$ 99.5%.

Due to the fact that the concentration of Fe in used wastewater was high, 133 g/L, a drying process at 85°C will produce a precipitate containing mostly hydrated $FeCl_2$ and a smaller proportion of hydrated $FeCl_3$.

K_2FeO_4 was synthesized by using the obtained residue as a raw material. After drying,grinding of the solid residue was performed to obtain a larger reactive surface area. A rotating ball mill was formed in the laboratory(Fig. 1), to which in addition to the resulting ground residue added was $Ca(ClO)_2$ 99% in solid form and KOH 85% in solid form in relation to: solid residue : $Ca(ClO)_2$: KOH, 1 : 2: 3. The mixing is carried out in aball mill, at a speed of 80 rotations per minute for 3 hours.

Since the reaction is exothermic, if necessary, cooling is performed from the outside of the mill. The resulting mixture was cooled in an ice bath, and then sequentially washed with 0.5 ml of n-pentane, methyl alcohol and ethyl ether for about 2 min. The solids on the filter paper were then dried in a vacuum furnace under pressure <30 mm Hg at room temperature for one hour to give a dry, K_2FeO_4. The resulting $K_2FeO_4$is of technical quality, and for a purer ferrateit needs recrystallization i.e. dissolving of NaOH and re-deposition using KOH. The obtained K_2FeO_4yield was determined by the chromite method [18].

RESULTS AND DISCUSSION

As reported in literature [19], iron sources for use in the process of dry and wet oxidation for Fe(VI) synthesis are mostly iron chloride and iron nitrate. Among them the iron nitrate is preferred because of the characteristics of fast dissolving and quick chemical reactions with hypochlorite to form Fe(VI). The rate of oxidation of iron chloride using hypochlorite is relatively low, since chloride ions which are released from the iron chloride will slow down the rate of dissociation of hypochlorite, which prolongs the time of Fe(VI) synthesis [20]. However, iron chloride will cost much less than iron nitrate.

Using the ratio of the reagent as an example, the ratio between the prices of these iron compounds (per unit of iron) was approximately (iron(III)chloride) : (iron(II)chloride): (iron(III) nitrate), 1.0: 1.25 : 2.5. However the goal of the study was to demonstrate the possibility of using wastewater from the steel pickling plant. According to data [19] wastewater from pickling steel contains many kinds of heavy metals and their concentrations are significantly higher than the legally permitted for wastewater. Heavy metals include Cr, Bi, Tl, Cd, Co, Cu, Ni, Pb and Zn. Fe and Cl are the most prevalent components, whereinMn and Ca (respectively 1.386 and 1.551 g/L) are the second most numerous elements.In general, when the Fe content in the solution for pickling steel reaches 70-100 g/L, the solution is not used further in the process of etching of steel [21].

It is obvious that the solution for pickling is used up to the Fe content of 133 g/L.

As the sum of Fe and Cl, 485 g/L is a third of the solutionmass of 1.0 L (i.e., 1.4 kg), only a small amount of heat is required for the evaporation of its liquid components, including water and HCl. The solution is evaporated at a temperature of 85°C. The resulting precipitate was refined by grinding in order to obtain a large reactive surface during the mixing with $Ca(ClO)_2$, and KOH. In the Figure 1is shown a ball mill with an electric motor in which the reactants were mixed and in which the reactions took place. Mixingwas performed at a speed of 80 rotations per minute for 3 h.

Figure 1. Appearance of the rotary ball mill, in which the reactions take place

The process that takes place during mixing in the ball mill can be represented by the following chemical reactions:

$$FeCl_2 x\ 4H_2O + Ca(ClO)_2 + 2KOH \rightarrow K_2FeO_4 + CaCl_2 + 2HCl + 4H_2O \quad (2)$$

$$2FeCl_3 x\ 6H_2O + 3Ca(ClO)_2 + 4KOH \rightarrow 2K_2FeO_4 + 3CaCl_2 + 3Cl_2 + 8H_2O \quad (3)$$

$$2FeCl_3 x 6H_2O + 3Cl_2 + 8KOH \rightarrow 2K_2FeO_4 + 4KCl + 8HCl + 6H_2O \quad (4)$$

The process is exothermic and cooling is needed from the outside althoughthe released water duringthe reaction lowers the temperature of the process. After the completion of mixing and cooling the resulting mixture in an ice bath, rinsing in organic solvents is conducted, and then drying in a vacuum dryer at room temperature. The obtained precipitate is dark purple in color proving the presence of Fe(VI), as confirmed by x-ray diffractometer. X-ray diffractogram of potassium ferrate (VI)(Fig. 2), is in good correlation with diffractograms presented in relevant literature [22], which has confirmed purity of this reactant.

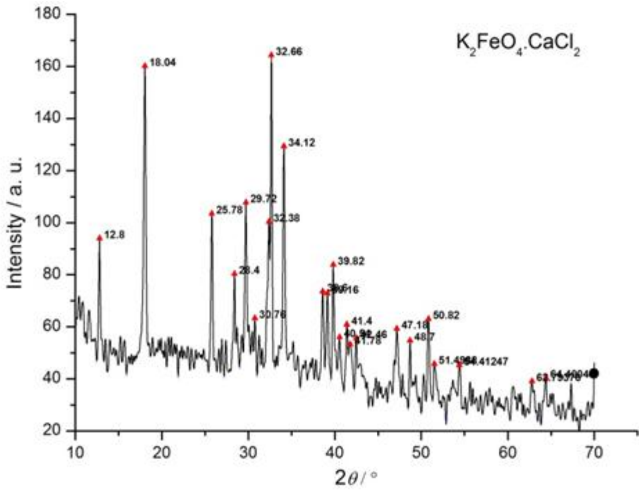

Figure 2. X-ray diffractogram of K_2FeO_4 admixture with $CaCl_2$

This method provides$K_2FeO_4$of sufficient purity for use in the treatment of wastewaters of different origin. The yield of ferrate salt is calculated from the following equation:

$$yield(mol\%) = \frac{(K_2FeO_4\ product\ weight) \times (product\ purity)\ \times\ (Fe\ atomic\ weight)}{(K_2FeO_4\ molecular\ weight) \times (Fe\ mass\ in\ the\ solid\ derived)}$$

The analysis of the obtained ferrate salt showed a purity of 82 wt. % while the yield was 15 Mol. %, which, given that waste Fe is used, it ismore cost-effective than any other method of synthesis of ferrate from iron or its alloys [19].
The basic idea of this study was the use of $Fe(OH)_3$ as raw material for the synthesis of ferrate. Ferrous hydroxide occurs asa product in the reduction of ferrate in the reaction with the pollutants as their coagulant in wastewater treatment. The formed precipitate could be used for the recovery of ferrate using the process described in this paper according to the given reactions 5 and 6.

$$Fe(OH)_2(s) + 2ClO^- + 2OH^- \rightarrow FeO_4^{2-} + 2Cl^- + 2H_2O, \quad (5)$$

$$2FeO(OH)(s) + 3ClO^- + 4OH^- \rightarrow \rightarrow 2\ FeO_4^{2-} + 3Cl^- + 3H_2O \quad (6)$$

The resulting $Fe(OH)_3$ needs to be annealed at 700°C to remove the pollutantswhich it precipitated as a coagulant, especially if they are organic compounds. Further procedure is in a ball mill,as previously described.

CONCLUSION

This paper presents the recycling of wastewater from the process of pickling steel which in itself besides iron contains a large percentage of other heavy metals. The core of this work was to use the present $FeCl_2$ and $FeCl_3$ as raw materials for gettingK_2FeO_4.
Using the rotary ball mill the synthesized K_2FeO_4has a purity of 82 wt. % with a yield of 15 Mol. %.
The resulting reaction product was a dark purple color which indicates the presence of ferrate, and x-ray diffraction confirmed it. Showed was that with this procedure it is possible to round off the process of synthesis and use of ferrate(VI) because the product formed in the process of wastewater treatment, $Fe(OH)_3$, can be recycled and from it derive ferrate(VI) again.

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REFERENCES

[1] Audette, R.J.; Quail, J.W.; Smith, P.J. Ferrate(VI) ion, a novel oxidizing agent. Tetrahedron Lett. 1971, 3, 279–282.
[2] Yoon, J.; Lee, Y.; Cho, M.; Kim, J.Y. Chemistry of ferrate (Fe(IV)) in aqueous solution and its application as a green chemistry. J. Ind. Eng. Chem. 2004, 10, 161–171.
[3] Jiang, J.Q.; Lloyd, B. Progress in the development and use of ferrate(VI) salt as an oxidant and coagulant for water and wastewater treatment. Water Res. 2002, 36, 1397–1408.
[4] Fremy, E. Recherches sur l'action des peroxides alcalins sur les oxides métalliques: Lettre de M. Ed. Fremy à M. Pelouze. ComptesRendus de l'Académie des Sci. Paris 1841, 12, 23–24.
[5] Fremy, E. Recherches sur les acidesmétalliques. ComptesRendus de l'Académie des Sci Paris 1842, 14, 442–446.
[6] Kiselev, N.S.; Kopelev, N.S.; Zavyalova, N.A.; Perfiliev, Y.D. The preparation of alkali metal ferrates(VI), Russ. J. Inorg. Chem. 1989, 34, 1250–1253
[7] Ockerman, L.T.; Schreyer, J.M. Preparation of sodium ferrate (VI). J. Am. Chem. Soc. 1951, 73, 5479.
[8] Schreyer, J.M.; Thompson, G.W.; Ockerman, L.T. Potassium ferrate (VI). Inorg.Synth.1953, 4, 164–167.
[9] Licht, S.; Tel-Vered, R.; Halperin, L. Direct electrochemical preparation of solid Fe(VI) ferrate, and super-iron battery compounds. Electrochem.Commun.2002, 4, 933–937.
[10] Mácová, Z.; Bouzek, K.; Híveš, J.; Sharma, V.K.; Terryn, R.J.; Baum, J.C. Research progress in the electrochemical synthesis of ferrate(VI). Electrochim.Acta2009, 54, 2673–2683.
[11] Nikolić-BujanovićLj., Čekerevac M., Vojinović-Miloradov M., Jokić A, Simičić M., *A comparative study of iron-containing anodes and their influence on electrochemical synthesis of ferrate(VI),* Journal of Industrial and Engineering Chemistry, 18 (2012) 1931–1936
[12] Audette, R.J.; Quail, J.W.; Smith, P.J. Ferrate(VI) ion, a novel oxidizing agent. *Tetrahedron Lett.*1971, *3,* 279–282.
[13] Yoon, J.; Lee, Y.; Cho, M.; Kim, J.Y. Chemistry of ferrate (Fe(IV)) in aqueous solution and its application as a green chemistry. *J. Ind. Eng. Chem.* 2004, *10*, 161–171.
[14] Jiang, J.Q.; Lloyd, B. Progress in the development and use of ferrate(VI) salt as an oxidant and coagulant for water and wastewater treatment. *Water Res.* 2002, *36*, 1397–1408.
[15] Gombos, E. Ferrate treatment for inactivation of bacterial community in municipal secondary effluent. *Bioresour. Technol*. 2012, *107*, 116–121.
[16] Yang, X.; Guo, W.; Zhang, X.; Chen, F.; Wei, T. Formation of disinfection by-products after pre-oxidation with chlorine dioxide or ferrate. *Water Res.* 2013, *47*, 5856–5864.
[17] Agrawal, A.; Sahu, K.K. An overview of the recovery of acid from spent acidic solutions from steel and electroplating industries. *J. Hazard. Mater*.2009, *171*, 61–75.
[18] Schreyer J.M., Thompson, G.W., Ockerman L.T., (1951) Potassium ferrate(VI). Inorg.Synth. IV: 164-168.
[19] Yu-Ling Wei, Yu-Shun Wang and Chia-Hung Liu, Preparation of Potassium Ferrate from Spent Steel Pickling Liquid, Metals 2015, 5 ,1770-1787
[20] Jiang, J.Q.; Lloyd, B. Preliminary study of ciprofloxacin (cip) removal by potassium ferrate(VI). *Sep. Purif. Technol.* 2013, *88*, 95–98.
[21] Agrawal, A.; Sahu, K.K. An overview of the recovery of acid from spent acidic solutions from steel and electroplating industries. *J. Hazard. Mater*.2009, *171*, 61–75.
[22] Z. Xu, J. Zhang, Z. Xu, J. Wang, H. Shao, Z. Tang, Preliminary investigation on the physicochemical properties of calcium ferrate(VI), Electrochemistry Communications 9 (2007) 371–377.

AN APPROACH TO INFRASTRUCTURE FOR ENVIRONMENT SENSOR NETWORK

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Abstract: The paper focuses on a systematic architectural approach for modular implementation of Infrastructure for environment sensor network. The requirements for devices to realization of infrastructure for the environment sensor network are defined. A model of sensor network is proposed. A model of computer system is synthesized on the basis of modern modules and devices for building a local infrastructure for the sensor network based on LoRaWAN technology. The end-node for sensor network is synthesized. The synthesized sensor end-node is based on a modern 32-bit microcontroller STM32 and LoRa transceiver SX1276. Proposed are variants of information services to the computer system on the basis of existing modern cloud technologies.
Key words: environment, sensor network, LoRaWAN, computer systems

INTRODUCTION

In recent years, sensor networks has evolved at a rapid pace, creating a separate direction of Internet of Things (IoT) [7]. Because the environment has separate objects with specific requirements, it is possible to define a separate connectivity based on their specific features. This new network connectivity of individual sensors, technological zones and ecosystems requires particular attention in the design of monitoring sensor systems. For this purpose is currently looking for different solutions to build sensor networks [3]. This new direction in computer systems and technologies will significantly change the way we can make data acquisition, transfer, store and process information about an ecosystem. The ability to track, identify and control an ecosystem in real time for individual regions and countries using the integration of sensor networks to existing network infrastructures is one of the most promising applications of the Internet of Things. As a basis for building sensor networks for the environment, the experience gained from the development of Internet of Things (IoT) technology can be used, taking into account the features of the distance of the observed objects from the existing network infrastructures.

MATERIAL AND METHODS

The end hosts of the environmental sensor networks consist of many sensor nodes located close to the observation object located in different territorial locations. These sensor nodes should be more functional, such as:

- to have wireless network capability greater than 1 km;
- to have the possibility of low consumption for the purpose of battery power;
- -to "capture" and discretize relevant technological signals describing the state of the ecosystem;
- to have the ability to locally buffer and store the received data in cloud structures;
- be able to measure the parameters for the environment of the sites and ecosystems;
- to have a low price;
- to have small dimensions for integration into typical environments and ecosystems.

These basic requirements automatically exclude wireless sensor nodes that support Bluetooth and Wi-Fi, due to the limited range of network connectivity, and wireless network nodes based on mobile 3G/4G, due to the high cost of hardware, monthly network support plan and high-energy efficiency. Alternatively, modules that support the LoRaWAN Low Consumption Network (LPWAN) standard may be used. The specifications of the LoRaWAN standard vary depending on the communication spectrum allowed. For Europe, the frequency range is 867 MHz to 869 MHz, divided into ten channels (eight for 5.5 kbps, one for 11 kbps and one for 50 kbps) and a maximum output power of +14 dBm

Terminal nodes of this standard allow two-way communication up to 5 km [10]. LoRaWAN has two security levels based on 802.15.4 Security. Network security guarantees the authenticity of the node in the network, while the application security layer ensures that the network operator does not have access to the end-user application data as shown in Figure 1.

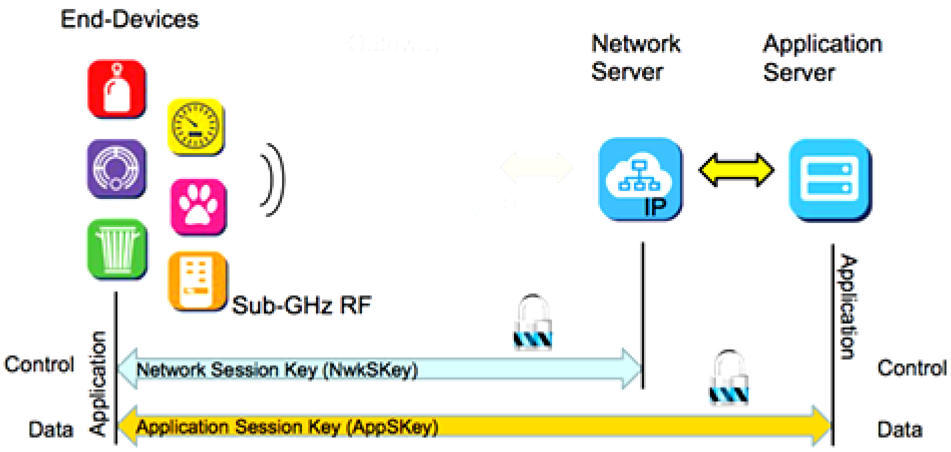

Figure 1. Flow diagram of data protection [4]

One possible variant of a functional structure for building separate branches of an environmental sensor network infrastructure based on existing Internet of Things systems is shown in Figure 2.

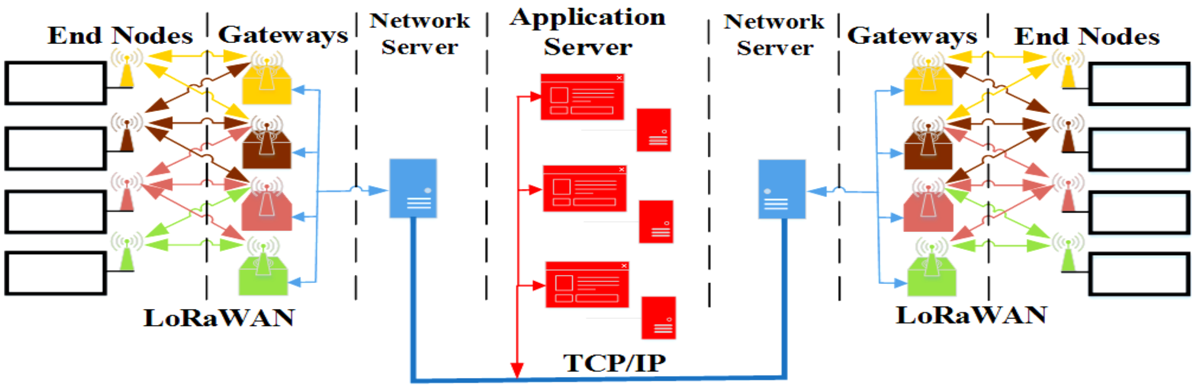

Figure 2. Functional diagram of the infrastructure for environment sensor network

RESULTS AND DISCUSSION

Based on the proposed network infrastructure for sensors, by integrating LoRa embedded microprocessor modules, a model of a computer system was developed to build infrastructure for traceability, identification, monitoring and remote environmental control (Figure 3).

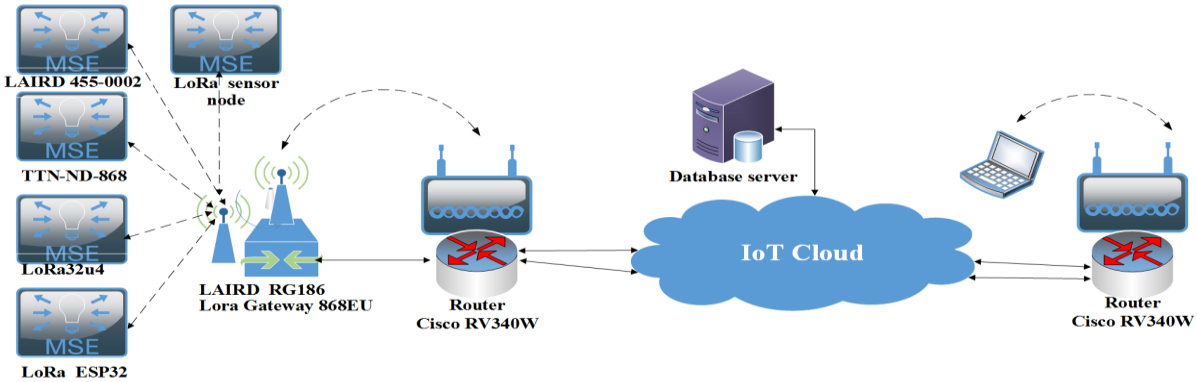

Figure 3. Model of computer monitoring system

Modern computer modules have been selected for the hardware implementation: LAIRD 455-0002 (for temperature and humidity), TTN-ND-868 (for temperature, acceleration, illumination), LoRa32u4 (for temperature, color, pressure, humidity), LoRa ESP32 with OLED display were used as specific devices at terminal units. (for temperature and pressure), LAIRD RG186 as gateway (supports Wi-Fi / Bluetooth/Ethernet), Cisco RV340W router with dual-port Wan for balancing and redundant load with combined connection (supports Wi-Fi) and wired Ethernet). Sensor modules for environment are of the integral type for given technological parameters. The input interface of the end nodes supports digital and analog sensor inputs, so that the sensors can have different interface signals. Sensor selection can be:

- for temperature LM75A, LM35D, TMP36, DS18B20 and others.
- for color TCS3200, TCS34725, TCS3414 and more.
- for pressure MS5540, MPX5500 and others.
- for humidity Si7021, HS1101, etc.
- combined for temperature, humidity and pressure BME280 and others.
- for gases MQ-2, MQ-3, MQ-4, MQ-5, MQ-6, MQ-7, MQ-8, MQ-9, MQ-135, etc.

The programming of the end nodes is done independently depending on the specific environmental sensor selected. In doing so, the end nodes allow bootloader programming modes and an external programmer. Linux-based open source software is used to implement the sensor programming utility.
In the attached structure, the main component for data collection is the end node. We offer our own version of the end sensor node. On the basis of the proposed structural diagram, the schematic-technical part of the computer system of the final node was developed, based on the general principles for implementation of embedded microprocessor systems and choice of modern architectural solutions. On Figure 4 is shown the schematic diagram of the realized end-to-end environmental traceability node.

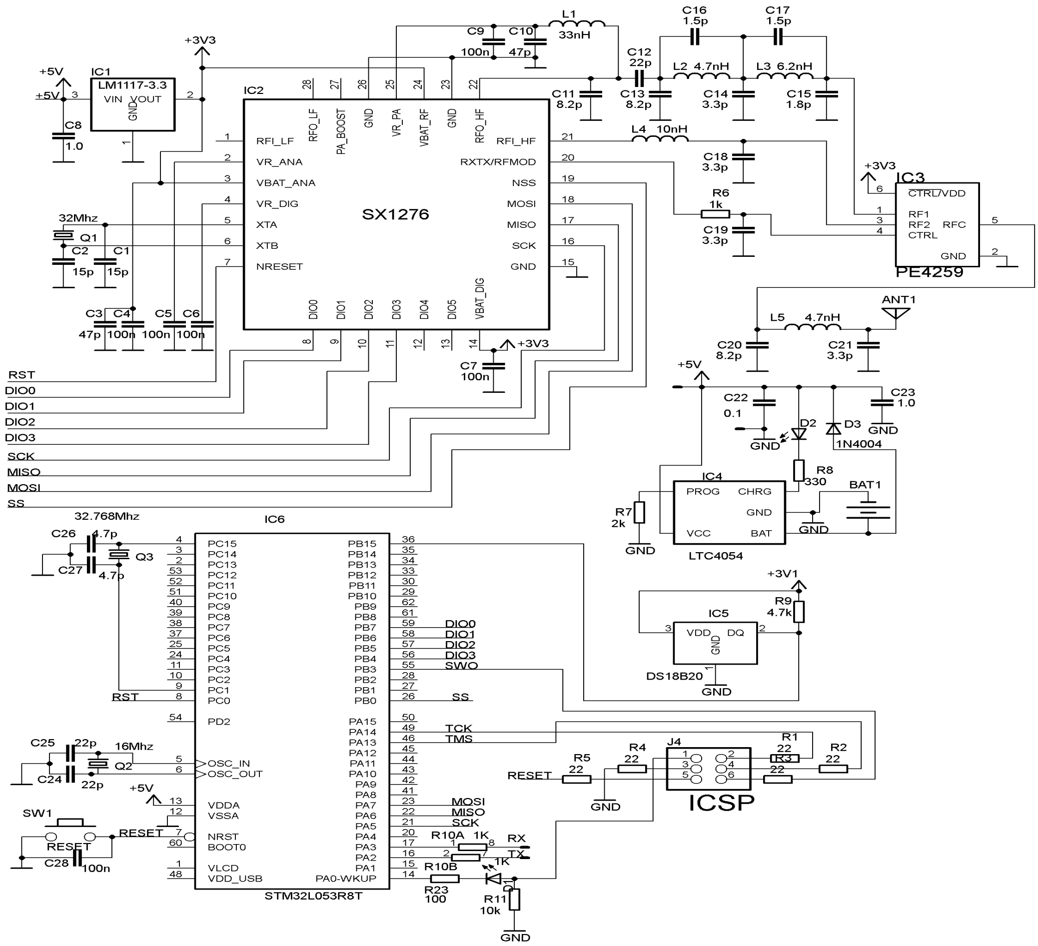

Figure 4. Schematic diagram of the end node

The synthesis of the microprocessor system is based on a built-in microcontroller in a single chip STM32L053R8 (IC6). The STM32L053R8 is a high-speed ultra-low consuming 32-bit Arm CortexM0 RISC based microcontroller with 64KB flash memory, 2KB EEPROM, 8KB SRAM, 51 input-output terminals, five timer modules / counters with comparison mode, internal and external interrupt sources microprocessors, two sequentially programmable USART universal synchronous and asynchronous transceivers, one RTC (real-time clock), two I^2C interfaces, four SPI interfaces, 16-channel 12-bit ADC, single-channel 12-bit DAC, programmable watchdog timer with internal clock generator as well selectable modes with reduced power consumption. The microcontroller operates with a voltage between 1.8 and 3.6 volts [9]. STM32L053R8 uses free software from the manufacturer and the free development environment of CoIDE and STM32Cube. The proposed end node is programmed via a ST-LINK / V2 debugger / programmer.

The RESET button is standard on this type of microcontroller and produces a signal for the initial establishment of the microprocessor system. The C24, C25, and Q2 element group is standard for the implementation of an external frequency group of the microprocessor clock generator, and C26, C27, and Q3 for the real-time clock. The power supply to the microprocessor system is realized by means of battery power, providing the possibility of charging via a specialized integrated circuit LTC4054 (IC4) for charging batteries to provide autonomous power supply to the designed sensor unit for the environment. The IC1 controller provides 3.3V DC for the transceiver and microcontroller. The Lora transceiver is based on Semtech's SX1276 (IC2) IC. The SX1276 has an acceptance sensitivity of about -148dBm. Power consumption of the transceiver in sleep mode is 0.2uA and standby 1.6 mA. The transmit power output is 13 dBm. The SX1276 has a built-in 256 byte RAM for data buffer available in LoRa mode **[8].** The C1, C2, and Q1 element groups are standard for the implementation of an external SX1276 clock frequency group. The transceiver uses a common antenna, therefore a dedicated analog high frequency switch type PE4259 (IC3) is used for multiplexing and demultiplexing the signals to / from the antenna. The antenna is interchangeable with the SMA / UFL connector for the use of different antenna systems depending on the gateway coverage. The IC4 temperature sensor is a DS18B20 type - Maxim digital single wire. It measures temperatures in the range of -55 ° C to 125 ° C with an accuracy of +/- 0.5 ° C, using a 12-bit digital data representation. The algorithmic diagram of the designed end node is shown in Figure 5.

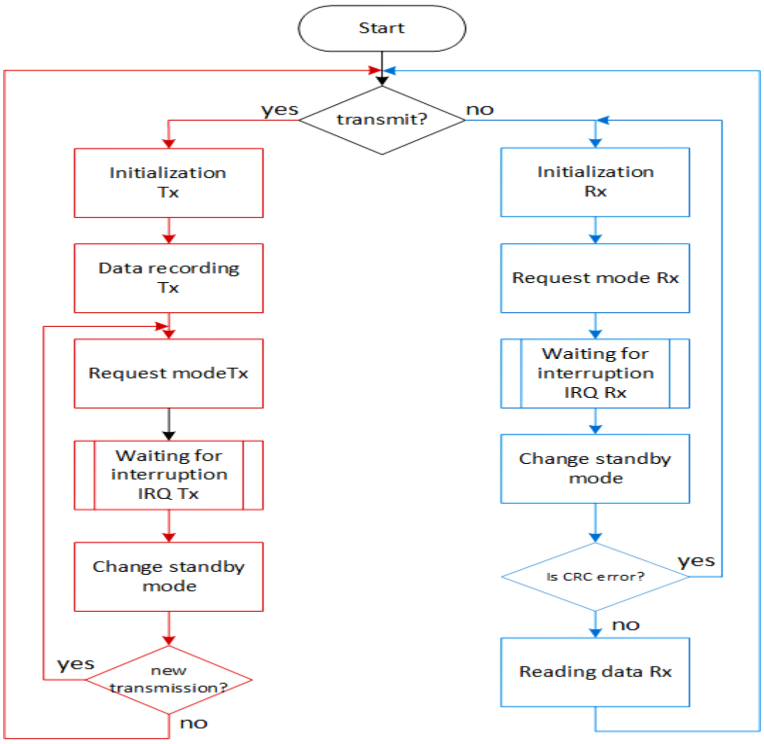

Figure 5. Algorithmic diagram of the sensor node

The end node firmware was developed based on the adaptation of the IBM LoRaWAN C-Libraries (LMiC) to control access to the transmission medium (MAC).
Different LoRaWAN based platforms can be used to implement the system software application such as:

- The Things Network, an open source free LoRaWAN network provider developed and maintained by a wide group of enthusiasts [6];
- LORIOT.io, a global public LoRaWAN operator for private and public networks [5];
- Everynet, a global public LoRaWAN operator [2];

The ResIOT remote monitoring platform [1] was used to develop the application software (Figure 6).

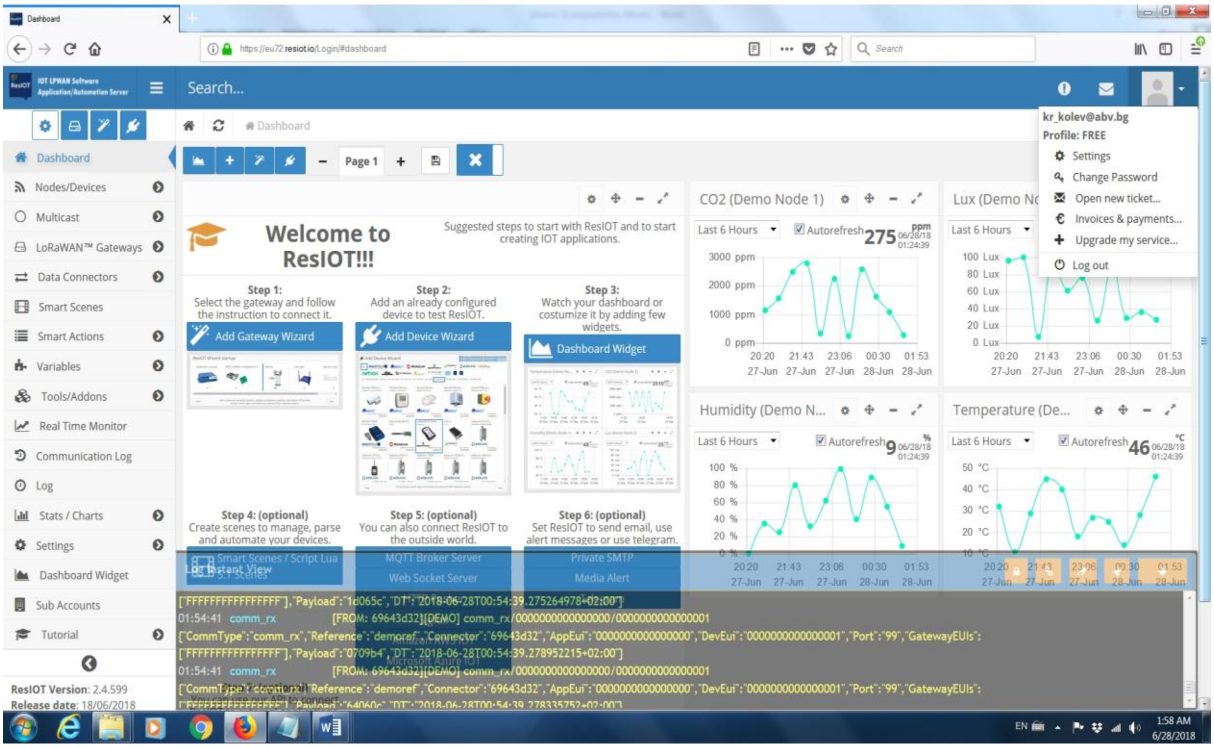

Figure 6. Remote monitoring platform for environment sensor network

The functionality of the environment sensor network is determined by the collaboration of all components - sensors, end nodes, gateways and system and application software. All components are configured remotely by collecting data in a central database with built-in hierarchical access rights to prevent data manipulation and traceability when triggered by environmental catastrophe alarms. Threats and prevention of environmental disasters are realized by triggered statistical functions of tracking unregulated deviation of environmental parameters and incommensurable activities. The functionality of the entire system depends on the correct selection of end nodes and the tuning of the cloud for monitoring and control.

CONCLUSION

The construction of the Infrastructure for environment sensor network requires special attention to the selection and design of the sensor end node. These devices work with different objects with different characteristics at different environmental parameters. The presented structure for the implementation of a system based on the microcontroller STM32L053R8 and the SX1276 transceiver allows basic environmental parameters to be controlled. The proposed system is hardware open and allows to expand with different types of sensors. The proposed structure adapts working models and technologies, which is why it will find application in the construction of expandable sensor networks. The proposed end node is reusable and as low cost as possible for mass battery powered use. Main application of developed system is to be used for monitoring and data acquisition with environmental sensors. The future design of the Infrastructure for environment sensor network also needs to take into account the development of emerging wireless technologies, as well as standards more closely focused on cloud technologies for data collection and processing.

REFERENCES

[1] Complete suite of software for LoRaWan networks, website: https://www.resiot.io , 2018.
[2] Helping the world make sense of everything, website: http://www.everynet.com , 2018.
[3] Khan S., A. Pathan, N.Alrajeh, Wireless Sensor Networks: Current Status and Future Trends, CRC Press, 2016.
[4] LoRa Alliance, LoRaWAN™ 1.1 Specification, LoRa Alliance Inc., 2017.

[5] LoRaWAN Services and Software, website: https://www.loriot.io , 2018
[6] Migrate from Staging to Production, website: https://www.thethingsnetwork.org , 2018.
[7] Pethuru, R., R. Anupama, The Internet of things : enabling technologies, platforms, and use Cases, Taylor & Francis, CRC Press, 2017.
[8] Semtech, DATASHEET: SX1276/77/78/79 - 137 MHz to 1020 MHz Low Power Long Range Transceiver, Semtech Corporation, 2016.
[9] STMicroelectronics, STM32L053R8 - Datasheet DocID025844, STMicroelectronics, 2017.
[10] Yang, S. H., Wireless Sensor Networks: Principles, Design and Applications, Springer, 2014.

FULFILLMENT OF THE EUROPEAN UNION QUANTITATIVE GOALS OF THE EU WASTE MANAGEMENT DIRECTIVES

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Abstract: As a Candidate European Union country, Republic of Serbia is in the process of integrating EU legislation that meets EU directives on waste management into national law. Material flow analysis and substance flow analysis methods can be used as a very effective method of supporting decision making for the development and improvement of waste management systems and they can enable noticing useful and harmful substances throughout the waste management systems. Material flow analysis (MFA) and substance flow analysis (SFA) are widely used engineering tools for modeling entire waste management systems. In this paper, MFA and SFA were used to evaluate scenarios that should meet EU goals by 2030. This scenario included combinations of mechanical separation, composting and landfills. As a result of modeled scenario, the amount of compost will be 530,000 tons per year. SFA was used to follow and evaluate flows of cadmium. Most of cadmium ends up in plastic while certain amount ends up in compost material.
Key words: material flow analysis, substance flow analysis, composting, Republic of Serbia, European Union

INTRODUCTION

The role of waste management systems as filters between the anthroposphere and the environment is becoming larger and more significant due to increased production and consumption in all spheres. The increasing pressure on them also requires an increasing willingness of the systems to cope with the increasing amounts of various materials and substances that end up in them. Materials and substances that need to be adequately disposed are increasingly complex nowadays, and a complementary approach that meets waste management goals is necessary. The focus on waste management should be multiple, qualitative and quantitative [1]. The primary goals of waste management are based on the protection of human health and the environment, the conservation of resources and aftercare-free waste treatment and landfilling without negative impacts on future generations [2].
Serbia is one of the countries with a transition economy and therefore the waste management system is not on the high level. Within the research mentioned in Stanisavljevic et al., 92% of the total amount of generated waste has been landfilled [3]. As a candidate country for European Union (EU) membership, Serbia is expected to implement solid waste management strategies that meet EU directives. The three directives that require improvement in waste management infrastructure are Landfill Directive, Waste Framework Directive and Packaging and Packaging Waste Directive. The year 2008 was taken as a reference year. Only 35% of biodegradable waste generated in the reference year will be able to be landfilled in 2030. The remained part (65%) should be treated using the adequate technology for biodegradable waste.
The aim of this paper is to model future waste management system in the territory of the Republic of Serbia with emphasizes on biodegradable waste, hence, to generate preliminary qualitative implications of fulfillment EU quantitative waste management goals.

MATERIAL AND METHODS

It is expected from Republic of Serbia to implement a solid waste management strategy that complies with the EU directive because Serbia represents a candidate European Union country. Waste management systems had been modeled to see how these goals can be met. With a population of 7.2 million, for the year 2030 it is estimated that 3.1 million metric tonnes a year will be generated, which is 435 kilograms a year per a habitant. Therefore, as a functional unit of the system, an amount of 3,120,000 tonnes of municipal waste per year was adopted.

Scenario development

Consumer goods that became waste at the end of use are divided into waste fractions and defined as inputs to the system, while emissions from waste treatment plants (gaseous and liquid), secondary raw materials, biogas and compost are defined as outputs from the system.
Waste management consists of several basic processes:

- waste generation;
- collection and transportation;
- waste treatment;
- final disposal.

Waste generation is an activity in which goods are transformed into waste and eventually discarded. Waste collection and transportation involves the collection of waste and the transportation of waste to a treatment plant or to a landfill. This paper analyzes the collection and transportation of waste separated at source into two bins (wet and dry). At the mechanical separation plant, the recyclables are only sorted, no chemical or physical changes occur in the waste characteristics. The composting process is the decomposition of biodegradable waste by aerobic microorganisms and the formation of compost, a humus-like material that can be used as a fertilizer or soil improver. Composting can also be used for biological stabilization of waste before disposal and it reduces the amount of waste that is landfilled. Although the composting is useful, there have to be made careful decisions about introducing this technology, which needs to be market-oriented and based on careful economic analysis.
The systems are modeled to meet the objectives of the EU directives. Therefore, the Republic of Serbia has been taken as the spatial boundary of the system, as it should fulfill these goals as a candidate for EU membership.

Defining material and substance flows

Six categories of municipal solid waste have been defined as inputs in scenarios. These fractions represent the most common materials in municipal solid waste and are therefore defined here as well. For the year 2030, the quantities of each fraction of municipal solid waste are foreseen for the Republic of Serbia and they are represented in the table 1.

Table 1. Estimated quantities of generated waste

Fractions:	**2030 (t year^{-1}):**
Biodegradable waste (garden, kitchen and green)	1,340,000
Paper and cardboard	210,000
Glass	75,000
Metal	480,000
Plastic	665,000
Other (textiles, leather, diapers, batteries, fine elements)	350,000
Total	3,120,000

* values are rounded

Cadmium is a heavy metal. Although it occurs in small quantities, it is very import and consequently, substance flow analysis is shown in this paper. Since awareness of the negative impact of cadmium has been recently expanded, developed countries have reduced its use. At the end of the twentieth century, cadmium was used as an additive in durable plastic materials and paints, but also as a coating layer. The use of cadmium as an additive is decreasing, while cadmium in batteries is still the main use of this metal. Recycled cadmium is mainly contained in metals and plastics [2]. Batteries contain 45% and plastics contain 38% of the cadmium [4].

Material flow analysis and substance flow analysis

Material flow analysis represents a method which is used to describe, investigate, and evaluate the metabolism of anthropogenic and geogenic systems. MFA defines terms and procedures in order to establish material balances of systems. MFA is a systematic assessment of the flows and stocks of materials within a system defined in space and time [5]. It connects sources, paths, intermediate and final sinks of the material. The term material flow analysis can have a double meaning: it can serve to describe the material flow analysis that forms the basis for all other methods, and can formulate more detailed method, in this case, for evaluating different waste management systems.

Establishing a mass balance is the basis for determining the balance of substances. Substance flow analysis does not provide complete and good information without a good basis in material flow analysis. SFA is a method based on the input of a substance concentration in specific fraction, which flow can be tracked throughout the system. Mass balance at the level of goods and at the level of substances is necessary and very useful tool for evaluation. Since the balance principle is applied to all processes, cross-checking of flows and stocks becomes possible at many points within the system investigated. A waste management planning based on material flow analysis and substance flow analysis was performed by Arena and Gregorio [6].

STAN is a free software that supports material flow analysis and substance flow analysis and takes into consideration data uncertainties [7]. STAN combines all necessary features of a MFA in one software [8]. Scenarios in this paper are modeled in STAN software.

RESULTS AND DISCUSSION

In scenario in Fig. 1 material flow of the modeled system with emphasis on composting is presented. Waste is source separated into separate bins: the wet bin contains only biodegradable waste, while the dry bin contains all the other kinds of waste. The dry bin is sent to a mechanical separation where the recyclables are sorted and impurities are separated. The wet bin is sent to the composting plant. After composting, we get compost that will be able to be used, while one part represents impurities that are sent to landfill. This system fulfills the objectives of the EU directives as 65% of biodegradable waste is treated.

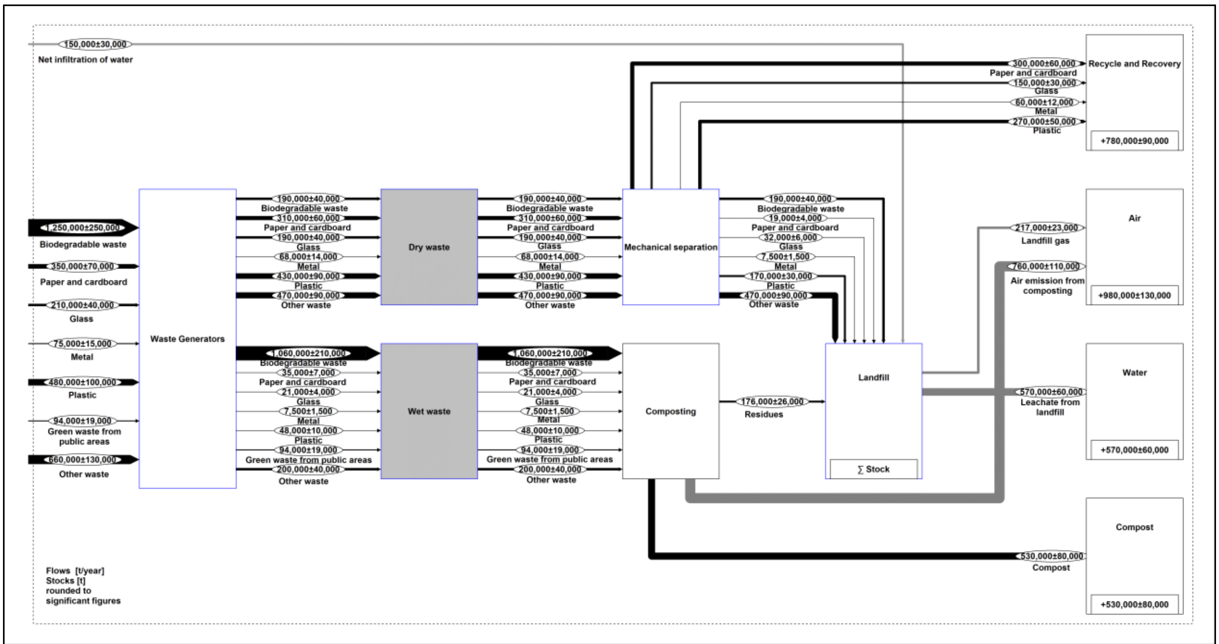

Figure 1. Material flow analysis of modeled system

Cadmium is very important element to consider during the evaluation of a waste management system because a significant portion of cadmium ends up in municipal solid waste. Anthropogenic fluxes of cadmium outweigh natural fluxes, and cadmium reserves in the anthroposphere grow 3% annually.

In Serbia, 92% of generated waste is landfilled [3] and that leads to significant accumulation of anthropogenic cadmium in the soil. It is very important to manage these stocks carefully in the future so as to avoid negative environmental impacts. Substance flow analysis for cadmium is shown in Fig. 2.

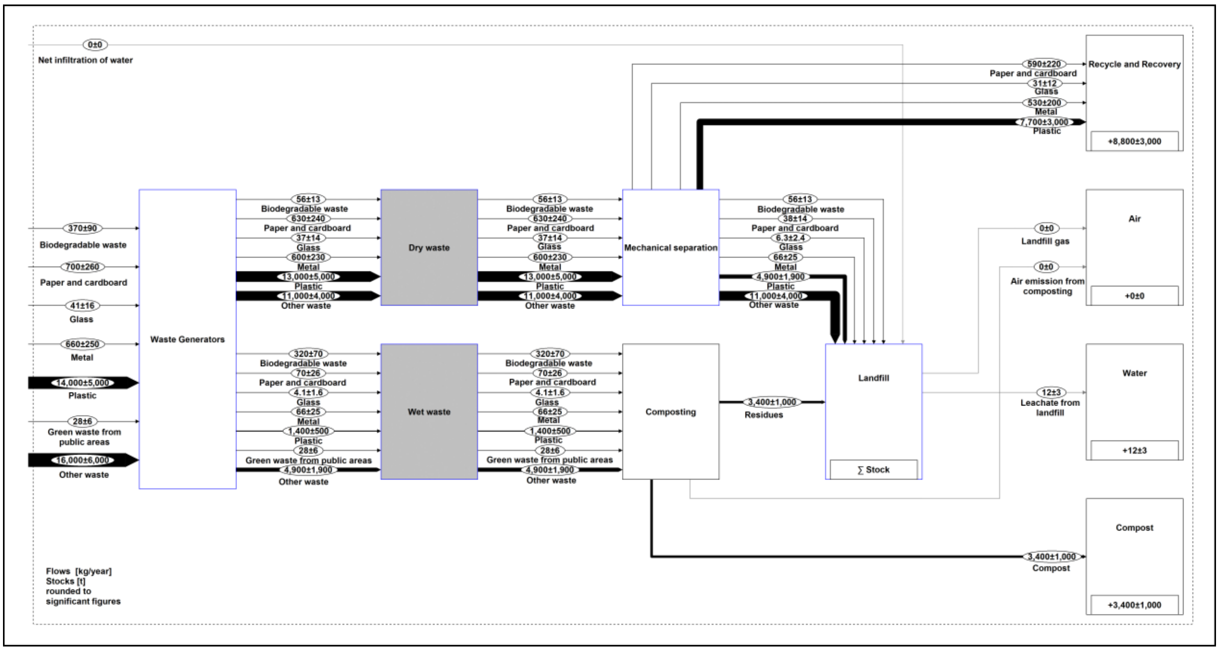

Figure 2. Cadmium flow analysis of modeled system

Input and output values of material flow analysis and substance flow analysis are shown in Table 2. In terms of mass inputs, there is 43% of biodegradable waste, 11% of paper and cardboard, 7% of glass, 2% of metal and 16% of plastic; while the rest of the total amount of solid municipal waste is 21%. As for the mass of the compost, the amount will be 530,000 tons per year.

Considering the concentrations of substances and the mass amounts of the fractions of waste given, it has been calculated that the most of cadmium would be in plastic with the amount of 14,000 kilograms per year and in other waste with the amount of 16,000 kilograms per year. Most of cadmium will end up in plastic, when it comes to output quantities of recyclables. Cadmium will not end up in air emissions. Just a small amount will end up in water. A certain amount (3,400 kilogram per year) will end up in compost material.

Table 2. Input and output values of modeled system

Inputs	**System**		
		Mass flow (t year $^{-1}$)	Cd (kg year $^{-1}$)
	Biodegradable waste (garden and kitchen)	1,250,000	370
	Paper and cardboard	350,000	700
	Glass	210,000	41
	Metal	75,000	660
	Plastic	480,000	14,000
	Green waste from public areas	94,000	28
	Other waste	660,000	16,000
Outputs	**Recycle and Recovery**		
		Mass flow (t year $^{-1}$)	Cd (kg year $^{-1}$)
	Paper and cardboard	300,000	590
	Glass	150,000	31
	Metal	60,000	530
	Plastic	270,000	7,700
	Air		
		Mass flow (t year $^{-1}$)	Cd (kg year $^{-1}$)
	Landfill gas	217,000	0
	Air emission from composting	760,000	0
	Water		
		Mass flow (t year $^{-1}$)	Cd (kg year $^{-1}$)
	Leachate from landfill	570,000	12
	Compost		
		Mass flow (t year $^{-1}$)	Cd (kg year $^{-1}$)
	Compost from composting plant	530,000	3,400

CONCLUSION

The focus on waste management should be multiple, qualitative and quantitative. EU waste management goals must be taken into account, however not only qualitative goals like protection of human health and environment, but also the resource conservation and sustainable waste management must be considered. The current waste management system in Serbia is largely based on the disposal of municipal solid waste into landfills, without any pre-treatment. Such a system should be improved to implement sustainable waste management and it is therefore necessary to divert biodegradable waste from landfills. When designing future waste management systems, it is very important to keep in mind whether waste treatment technologies concentrate or disperse substances and how they are partitioned, particularly hazardous substances.

The results of material flow analysis and substance flow analysis provide the necessary information when it comes to setting priorities and can be used as a very effective method of decision support for the development and improvement of waste management systems and enable monitoring of useful and harmful substances throughout the systems. As a candidate country for European Union (EU) membership, Serbia is expected to implement solid waste management strategies that meet EU directives. The modeled system shows how the waste management system can be improved. The results showed one possible option for biodegradable waste diversion from landfills. Considering that biodegradable waste represents 43% of the total amount of generated waste, a large amount of landfill space would be provided. The most cadmium ends up in plastic with the amount of 14,000 kilograms per year and in other waste (especially in batteries) with the amount of 16,000 kilograms per year. Most of cadmium will ends in plastic, while cadmium will not end up in air emissions and just a small amount will end up in water while a certain amount (3,400 kilogram per year) will end up in compost material.

Furher analysis should include more substance indicators and quality oriented waste management evaluation. Future development of waste management system should focus not only on quantitve but also on qualitative goals: protection of humans and environment, resource conservation and sustainable waste management.

REFERENCES

[1] Stanisavljevic, N., Brunner, P.H.: Quantity AND quality: New priorities for waste management, Waste Management and Research, 37 (7), 665–666, 2019.
[2] Allesch, A., Brunner, P. H.: Material Flow Analysis as a Tool to improve Waste Management Systems: The Case of Austria, Environmental Science and Technology, 51 (1), 540–551, 2017.
[3] Stanisavljević, N., Ubavin, D., Batinić, B., Fellner, J., Vujić, G.: Methane emissions from landfills in Serbia and potential mitigation strategies: A case study, Waste Management and Research, 30 (10), 1095–1103, 2012.
[4] Burnley, S. J.: The use of chemical composition data in waste management planning - A case study, Waste Management, 27 (3), 327–336, 2007.
[5] Stanisavljevic, N., Brunner, P.H.: Combination of material flow analysis and substance flow analysis: A powerful approach for decision support in waste management, Waste Management and Research, 32 (8), 733–744, 2014.
[6] Arena, U., Di Gregorio F.: A waste management planning based on substance flow analysis, Resources, Conservation and Recycling, 85, 54–66, 2014.
[7] Cencic, O.: Nonlinear data reconciliation in material flow analysis with software STAN, Sustainable Environment Research, 26 (6), 291–298, 2016.
[8] Cencic, O., Rechberger, H.: Material Flow Analysis with Software STAN, Journal of Environmental Engineering and Management, 18 (I), 440–447, 2008.

ADSORPTION BEHAVIOR OF CHLORINATED PHENOLS IN PRESENCE OF POLYETHYLENE TEREPHTHALATE IN DANUBE WATER

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Abstract: Microplastic pollution currently presents an environmental hazard, which has become a major cause of concern worldwide. The accumulation of plastic debris in aquatic environments is one of the major but least studied topic in aquatic ecosystems. Besides the general waste present in freshwater bodies, microplastic debris gives rise to ecological and social problems. Related to marine ecosystems, these problems are already in the center of interest of science policy, and public. The issue of microplastic pollution in freshwater bodies is one of the major but least studied human topics on aquatic ecosystems, and further research is required on this issue. Furthermore, there are many indications for negative environmental impacts that should lead to preventive measures. Results of studies in last few years showed that organic chemicals have tendency to adsorb on microplastic debris and can act as a carrier for hazardous organic pollutants in the aquatic ecosystems. In order to understand the possible impact of microplastic on the environment and human health the aim of this study was to investigate adsorption behavior of chlorinated phenols (CPs) in presence of polyethylene terephthalate (PET) as a type of most commonly used microplastic detected in fresh water matrices. In order to better understand adsorption mechanisms of chlorinated phenols in presence of PET three kinetic and two adsorption isotherm models were used. The pseudo-second order kinetic model described well the sorption process for all chlorinated phenols on all four selected chlorinated phenols in presence of PET (R^2 = 0.900-0.998) which indicated that chemical interactions are responsible for adsorption behavior of this selected organic pollutants onto surface of PET. Adsorption isotherms were best described by the Langmuir adsorption model for all CPs which indicated that it is a monolayer adsorption process. Obtained results indicate that MPs can serve for the transport of the chlorinated phenols through the freshwater bodies.

INTRODUCTION

Microplastics (MPs) are emerging globally distributed pollutants that receive considerable attention, both from research communities and the public audience. MPs are defined as plastic particles not exceeding a 5 mm size limit, while the smallest size classes of plastic particles (<100 nm or <1000 nm, definition is unclear) are instead referred to as nanoplastics (NPs) [1-5]. In earlier studies regarding aquatic environments, much more investigation has been made in topic of seas and oceans compared to freshwater [6,7]. On the other hand, freshwater bodies are usually used as drinking water sources for human consumption and, therefore, potential sources of microplastics to humans. Some raw water samples from different drinking water treatment plants have been analyzed for MPs presence, and it was confirmed that MPs reach up to >4000 items per litre [8,9]. Beside drinking water treatment plants, MPs have also been reported as present in lakes, rivers and dams globally [10-12].

Notably, the risk associated with toxicological effects of MPs (and NPs) is still not fully described. Due to their physic-chemical properties, microplastics were found able to accumulate waterborne contaminants including polycyclic aromatic hydrocarbons, polychlorinated biphenyls, perfluoroalkyl acids, and metals [13-16]. Microplastics can therefore act as carriers for the transport of those contaminants. When ingested by aquatic organisms, contaminants carried by microplastics can be released and induce associated harmful effects [17-19].

Other than those persistent organic compounds (POPs) and metals, pharmaceuticals and personal care products (PPCPs) are another important group of pollutants of emerging concern frequently detected in the environment [20]. However, there is a lack of information about the sorption behaviour of group of industrial chemicals on microplastics, such are the chlorinated phenols (CPs). Chlorinated phenols are the most widespread and the largest group of phenols which are formed in the environment by chlorination of mono and polyaromatic compounds present in soil and water. Chlorophenols are also present in drinking water due to substitution of organic matter and low molecular weight compounds (present in purified water) with chlorine atoms derived from inorganic chlorine oxidants [21]. Exposure of chlorophenols may occur *via* ingestion, inhalation or dermal absorption mainly through the ingestion of food and drinking water [22]. Due to this a better knowledge about interactions between CPs and microplastics in freshwater bodies is of vital importance for evaluating the possible influence of microplastics on the moving dynamics of these organic chemicals in aquatic environments. In order to address this issue, the present study was to achieve a better understanding of the interactions between microplastics and organic pollutants in freshwater bodies such as Danube river by comparative analysis of different sorption kinetic and isotherm models.

MATERIAL AND METHODS

Adsorbents and adsorbats

In this study the polyethylene terephthalate standard substance (PET; manufactured by Sigma-Aldrich) was investigated. It's particle size distributions are discussed in detail further in the text. Four chlorinated phenols (purchased from Pestanal® Sigma-Aldrich), 4-chlorophenol (4-CP), 2,4-dichlorophenol (2,4-DCP), 2,4,6-trichlorophenol (2,4,6-TCP) and pentachlorophenol (PCP) were used in this study. The physico-chemical properties of the CPs are presented in Table 1. These CPs differ in hydrophobicity (octanol-water partition coefficient, logK_{ow}), water solubility (S_w) and acid dissociation constant (pK_a).

Table 1. Physico-chemical properties of the investigated chlorophenols

Compounds	*MW*	logK_{ow}[a]	V_i[a]	S_w[a]	pK_a[a]
4-CP	129	2.40	1.02	27100	8.85
2,4-DCP	163	3.06	1.14	4500	7.90
2,4,6-TCP	197	3.69	1.26	800	6.40
PCP	266	5.12	1.39	14	4.80

MW, molecular weight (g/mol); K_{ow}, octanol-water partition coefficient; V_i, McGowan volume in units of (cm^3/mol)/100; S_w, water solubility (mg/l); pK_a dissociation constant.
[a]Kragulj et al. (2013).

Hexane and methanol were purchased from J.T.Baker (for organic residue analysis), acetic anhydride and hydrogen peroxide from Sigma-Aldrich. Analytical grade reagents, anhydrous calcium chloride ($CaCl_2$), sodium hydrogen carbonate ($NaHCO_3$), and magnesium sulphate heptahydrate ($MgSO_4 \cdot 7H_2O$), were also purchased from Sigma-Aldrich.
The point of zero charge (pH_{ZPC}) of the investigated microplastic was also determined following the method given by Ofomaja et al. *(2008)* [23]. To each flask, 10-20 mg of selected microplastics was added and the pH was adjusted in the range 2–10. After that, the samples were shaken at 200 rpm for 48 h at room temperature. The difference between the initial (pH_i) and final pH (pH_f) values ($\Delta pH = pH_f - pH_i$) was plotted against the pH_i. pH_{ZPC} was determined as pH value where the net surface charge was zero.

Adsorption experiments

All kinetics experiments were conducted in 30-mL glass vials at room temperature (25°C) using 20 mg of investigated adsorbents which were added to freshwater. Stock solutions of all investigated CPs (1000 µg/mL) were prepared in MeOH (J.T. Baker, for organic residue analysis). The initial concentration of CPs in the experiments was 100 µg/L. The vials were sealed and placed on a digital shaker at a speed of 150 rpm (IKA® Orbital shaker KS 501 Digital). All experiments were performed in triplicate. Samples were collected at specified time intervals and filtered through a 0.45 µm membrane filter. Filtered samples were prepared for gas chromatographic analysis. The obtained experimental data were fitted with three kinetic models: the pseudo-first-order, pseudo-second-order and Weber-Morris models.

Adsorption isotherm experiments were carried out at CP concentrations in the range of 0-100 µg/L. All experiments were carried out at pH of Danube (pH = 7.70±0.5). After being continuously agitated for 48 h (equilibrium time), samples were collected to quantify the equilibrium concentrations of CPs in the aqueous phase. The Freundlich and Langmuir adsorption models (see Li et al. *(2018)* for the formulae applied) were used to fit the adsorption isotherms [24].

Analytical procedure, quality assurance and quality control

Determination of the selected chlorinated phenols in water was performed using gas chromatography with mass spectrometry (Agilent Technologies, 7890A GC System/5975C VL MSD) after derivatization and liquid-liquid extraction with hexane. Blank and control experiments were performed with the sorption experiments. Blank tests, containing the same amounts of water matrix and solid particles as the samples, but without the addition of chlorinated phenols, were carried out using conditions similar to those described previously, and no target compound was found. Control tests were carried out in 20 mL of water matrix containing a same gradient of CP concentrations as the samples, but without solid particles, in order to evaluate the loss of CP resulting from some additional removal processes, such as volatilization and/or sorption to the wall of glass bottles. Recovery of selected CP after derivatization with acetanhydride and liquid-liquid extraction with hexane ranged from 80-116% with the relative standard deviations (RSD) being below 10% for all CPs. The method detection limits (MDLs) of the applied analytical methods ranged between 0.11-0.53 µg/L. The correlation coefcient for the chlorinated phenols calibration curve was higher than 0.99. All the reported concentrations of CP were corrected with the recovery efficiency and internal standard.

RESULTS AND DISCUSSION

Kinetics experiments

Figure 1 shows the adsorption kinetics of the selected chlorinated phenols on PET as a model material for microplastic. Uptakes of chlorinated phenols by PET increased with time until the achievement of sorption equilibrium after 48 h. Sorption kinetics experiments provides a valuable informations about the mechanisms involved in the transport of sorbates within sorbents [25].

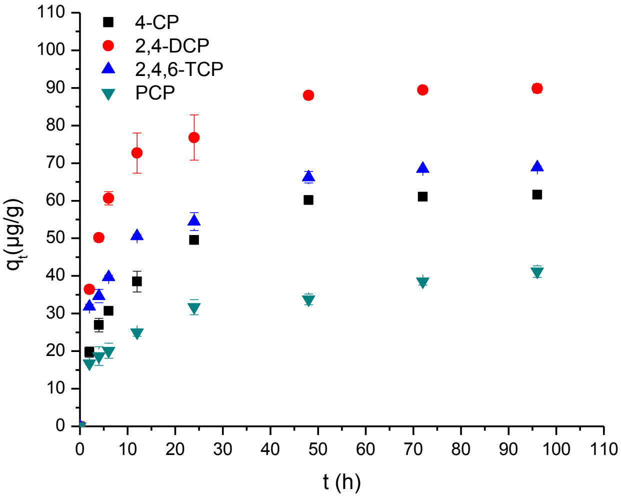

Figure 1. Experimental data (n = 3, mean value ±SD) for sorption kinetics of chlorinated phenols on PET

The obtained results also indicate that the CPs showed different adsorption affinities towards particles of PET, by the following order: 2,4-DCP>2,4,6-TCP>4-CP>PCP. Adsorption of 2,4-

DCP on PET was the highest (around 90% of the initial concentration). In contrast, adsorption of PCP on PET was the lowest around 30%. The different behaviour of the investigated CPs on PET could be due to the different physico-chemical properties of the investigated CPs and adsorbents.

In order to describe the adsorption kinetics of CPs on PET in real water matrics, three models were applied: the pseudo-first-order, pseudo-second-order and Weber Morris models (Figure 2, 3 and 4 and table 2). The obtained R^2 values for the pseudo-first order model were lower than 0.7500 and for the pseudo-second order model ranged from R^2=0.900-0.998. Furthermore, theoretical q_e values calculated by the pseudo-second order model were similar to the experimental q_e values, with significantly lower standard deviations than the pseudo-first order model.

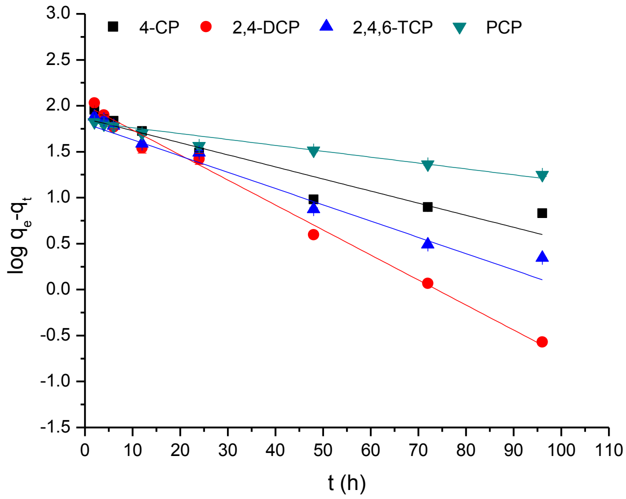

Figure 2. Linear plots for sorption kinetics of chlorinated phenols on PET based on pseudo-first-order model

Based on the R^2 values and the comparison between the experimental and theoretical q_e values, the pseudo-second-order model better describes the experimental adsorption data. This indicates that chemical interactions between the CPs and surface of the PET can be successfully used to describe the adsorption process. Similar results were obtained by Wang and Wang (2018) and Li et al. (2018), who investigated the adsorption of hydrophobic organic compounds on PE [26,27].

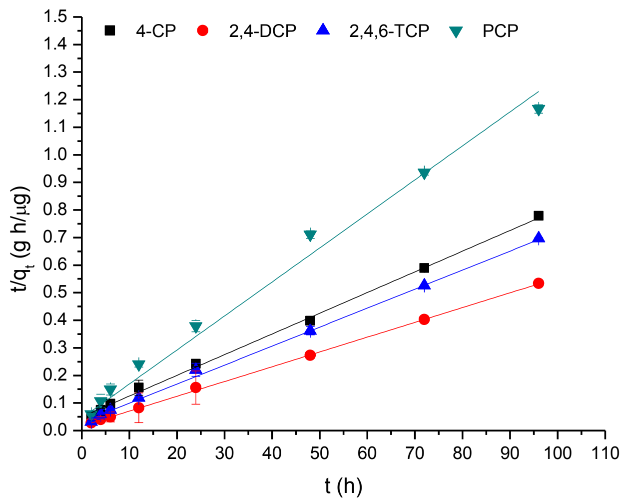

Figure 3. Linear plots for sorption kinetics of chlorinated phenols on PET particles based pseudo-second order model

Table 2. Theoretical and experimental q_e values obtained with pseudo-second-order model

Jedinjenje	k_1 (h^{-1})	R^2	q_e (theoretical)	q_e (experimental)
4-CP	0,00112	0,9991	130,1	133,2
2,4-DCP	0,00168	0,9999	179,7	186,6
2,4,6-TCP	0,00155	0,9996	143,8	145,1
PCP	0,00333	0,9927	82,30	81,1

In order to investigate the contribution of intraparticle diffusion to the overall adsorption process of CPs on PET, the intraparticle diffusion model was applied (Figure 4). Intraparticle diffusion may be the rate limiting factor which controls the adsorption process [28]. The plots of the intraparticle diffusion model show the first and fastest adsorption step in the first few hours. The second, slower step occurs during the equilibrium stage with much lower slope compared to the initial adsorption step. Generally, if the regression of q_t versus $t^{1/2}$ is linear and passes through the origin, then intraparticle diffusion is the only rate-limiting step.

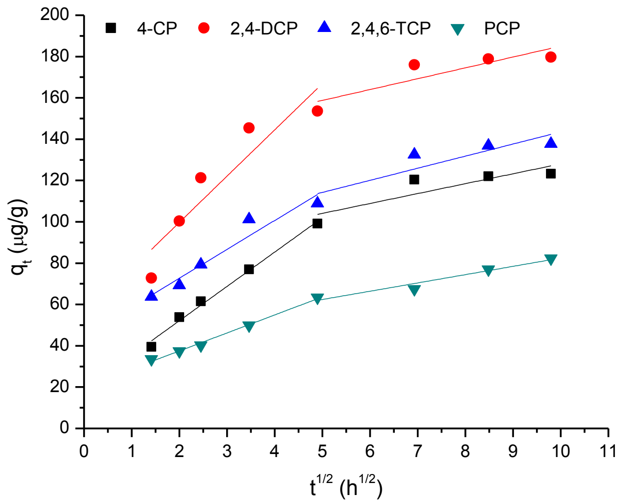

Figure 4. Linear plots for sorption kinetics of chlorinated phenols on PET particles based on intraparticle diffusion model

Figure 4 shows that the plots do not pass through the origin indicating that intraparticle diffusion is not the only rate controlling adsorption process. Based on these results, two-step adsorption processes was determent for the selected chlorinate phenols investigated on PET, which is in accordance with the results obtained by Cheung et al. (2007)[29]. However, since intraparticle diffusion depends on many factors, such as temperature, particle size of the selected pollutant and others, the time required for it to occur is difficult to control or predict [28].

Adsorption experiments

In order to investigate the adsorption mechanisms of CPs on PET, Freundlich and Langmuir adsorption models were applied. The parameters of the Freundlich and Langmuir models (Figure 5) are presented in table 3. In Figure 5, average values of three measurements with corresponding error bars for each point are shown.

Table 3. Freundlich and Langmuir parameters for adsorption of CPs on MPs

Compounds	Freundlich model			Langmuir model			
	R^2	n	K_F $(\mu g/g)/(\mu g/l)^n$	R^2	q_{max} $(\mu g/g)$	K_L $(l/\mu g)$	R_L
4-CP	0.8914	0.84	2.2132	0.9310	56.12	0.0519	0.325-0.988
2,4-DCP	0.9742	0.89	3.0859	0.9858	92.42	0.0395	0.472-0.992
2,4,6-TCP	0.9967	0.78	4.8069	0.9989	90.36	0.0485	0.336-0.992
PCP	0.8677	0.76	1.8263	0.9628	38.26	0.0657	0.200-0.984

The Freundlich model is an exponential equation based on the assumption that sorption process takes place on the heterogeneous surface of a sorbent, and is applicable to both monolayer and multilayer sorptions [30]. As is shown in Table 2, the values of the Freundlich exponent n for PET in case of all investigated chlorinated phenols are in a range of 0.76-0.89, all lower than unity, reflecting a favorable sorption of chlorinated phenols on surface of PET [31]. On the other hand, the Langmuir model assumes monolayer coverage of the sorbate over a homogenous sorbent surface [32]. In this case, sorption of the sorbate molecule occurs at a specific site of the sorbent, with no further sorption occurring at the same site [30]. Correlation coefficients for Langmuir and Freudlich models were R^2=0.9310-0.9989 and R^2=0.8677-0.9967, respectively, for all investigated CPs on PET. The values of maximum sorption capacity (q_{max}) for all investigated CPs were in the range 38.3-92.4 µg/g. The values of the separation factor (R_L) for all selected CPs on PET were in range from 0-1, which indicates that the adsorption process is favourable (table 3).

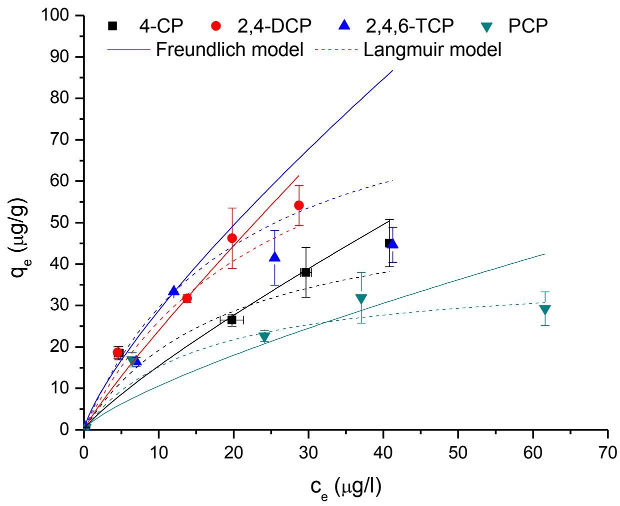

Figure 5. Plot of Freundlich and Langmuir adsorption isotherms for 4-CP, 2,4-DCP, 2,4,6-TCP and PCP on a) PE, b) PE_PCPs_1, c) PE_PCPs_2 and d) PET

As shown in Table 3, the values of the Freundlich exponent n for all four selected CPs in presnce of PET was nonlinear resulting in a decrease in adsorption affinity as the CPs concentrations increased. Previous studies have shown that the sorption isotherms of different organic pollutants onto different microplastics were highly nonlinear [16,28]. However, it should be noted that the linearity of adsorption isotherms depends on the properties of the pollutants and the types of plastic [33].

Adsorption affinities increased in the following order: 4-CP< PCP<2,4,6-TCP<2,4-DCP. In the case of all the PET samples, adsorption may partially result from the electrostatic attraction between the negatively charged surface of PET and the ionisable form of 2,4,6-TCP and 2,4-DCP. The importance of electrostatic interactions in the overall adsorption mechanisms of ionisable organic compounds such as CPs on carbon-rich materials was previously demonstrated by Kragulj et al., 2015, which is in accordance with results given in this paper [34].

CONCLUSION

In this study, the sorption process of chlorinated phenols onto PET was investigated with different kinetic and isotherm models. Based on the results of kinetic studies sorption rates of chlorinated phenols onto PET were mainly controlled by intraparticle diffusion although the kinetic profiles fitted well to the pseudo-second-order kinetic model. Based on the results of adsorption isotherm models, the Langmuir model fitted the data best indicating that it was a monolayer adsorption process. The present study could give significant information toward a better understanding of sorption mechanisms of organic pollutants onto microplastics.

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REFERENCES

[1] Andrary, A.L., Microplastics in the marine environment. Marine Pollution Bulletin, Vol.62, pp. 1596–1605, 2011.
[2] Eerkes-Medrano, D., Thompson, R.C., Aldridge, D.C., Microplastics in freshwater systems: a review of the emerging threats, identification of knowledge gaps and prioritisation of research needs. Water Resorses, Vol.75, pp. 63–82, 2015.
[3] Koelmans, A.A., Besseling, E., Shim, W.J., Nanoplastics in the Aquatic Environment. Critical Review Marine Anthropogenic Litter. Springer International Publishing, pp. 325–340, 2015.
[4] da Costa, J.P., Santos, P.S.M., Duarte, A.C., Rocha-Santos, T., (Nano)plastics in the environment – sources, fates and effects. Science of the Total Environment, Vol.566-567, pp. 15–26, 2016.
[5] Hahladakis, J.N., Velis, C.A., Weber, R., Iacovidou, E., Purnell, P., An overview of chemical additives present in plastics:migration, release, fate and environmental impact during their use, disposal and recycling. Journal of Hazardous Materials, Vol.344, pp. 179–199, 2018.
[6] Cole, M., Lindeque, P., Halsband, C., Galloway, T.S., Microplastics as contaminants in the marine environment: a review. Marine Pollution Bulletin, Vol.62, pp. 2588–2597, 2011.
[7] Auta, H.S., Emenike, C.U., Fauziah, S.H., Distribution and importance of microplastics in the marine environment: a review of the sources, fate, effects, and potential solutions. Environment International, Vol.102, pp. 165–176, 2017.
[8] Pivokonsky, M., Cermakova, L., Novotna, K., Peer, P., Cajthaml, T., Janda, V., Occurrence of microplastics in raw and treated drinking water. Science of the Total Environment, pp. 1644–1651, 2018.
[9] Mintenig, S.M., Löder, M.G.J., Primpke, S., Gerdts, G., Low numbers of microplastics detected in drinking water from ground water sources. Science of the Total Environment, 648, 631–635, 2019.
[10] Anderson, P.J., Warrack, S., Langen, V., Challis, J.K., Hanson, M.L., Rennie, M.D., Microplastic contamination in Lake Winnipeg, Canada. Environmental Pollution, Vol.225, pp. 223–231, 2017.
[11] Di, M., Wang, J., Microplastics in surface waters and sediments of the Three Gorges Reservoir, China. Science of the Total Environment, Vol.616-617, pp. 1620–1627, 2018.
[12] Triebskorn, R., Braunbeck, T., Grummt, T., Hanslik, L., Huppertsberg, S., Jekel, M., Knepper, T.P., Krais, S., Müller, Y.K., Pittroff, M., Ruhl, A.S., Schmieg, H., Schür, C., Strobel, C., Wagner, M., Zumbülte, N., Köhler, H.-R., Relevance of nano- and microplastics for freshwater ecosystems: a critical review. Trends in Analytical Chemistry. Vol.110, pp. 375–392, 2019.
[13] Holmes, L.A., Turner, A., Thompson, R.C., Adsorption of trace metals to plastic resin pellets in the marine environment. Environmental Pollution, Vol.160, pp. 42–48, 2012.

[14] Lee, H., Shim, W.J., Kwon, J.H., Sorption capacity of plastic debris for hydrophobic organic chemicals. Science of the Total Environment, Vol.470–471, pp. 1545–1552, 2014.
[15] Rochman, C.M., Hoh, E., Hentschel, B.T., Kaye, S., Long-term field measurement of sorption of organic contaminants to five types of plastic pellets: implications for plastic marine debris. Environmental Science & Technology, Vol.47, pp. 1646–1654, 2012.
[16] Wang, F., Shih, K.M., Li, X.Y., The partition behavior of perfluorooctanesulfonate (PFOS) and perfluorooctanesulfonamide (FOSA) on microplastics. Chemosphere, Vol.119, pp. 841–847, 2015.
[17] Bakir, A., Rowland, S.J., Thompson, R.C., Enhanced desorption of persistent organic pollutants from microplastics under simulated physiological conditions. Environmental Pollution, Vol.185, pp. 16–23, 2014.
[18] Besseling, E., Wegner, A., Foekema, E.M., van den Heuvel-Greve, M.J., Koelmans A.A., Effects of Microplastic on fitness and PCB bioaccumulation by the lugwormArenicolamarina (L.). Environmental Science & Technology, Vol.47, pp. 593–600, 2012.
[19] Rochman, C.M., Hoh, E., Hentschel, B.T., Kaye, S., Long-term field measurement of sorption of organic contaminants to five types of plastic pellets: implications for plastic marine debris. Environmental Science & Technology, Vol.47, pp. 1646-1654, 2013.
[20] Caliman, FA, Gavrilescu, M., Pharmaceuticals personal care products and endocrine disrupting agents in the environment—a review. CLEAN – Soil, Air, Water, Vol.37, pp. 277–303, 2009.
[21] Niedan, V., Pavasars, J. Oberg, G., Chloroperoxidasemediated chlorination of aromatic groups in fulvic acid. Chemosphere. 41, 779, 2000.
[22] NRCC . Chlorinated phenols: Criteria for environmental quality, Ottawa, Associate Committee on Scientific Criteria for Environmental Quality, National Research Council of Canada, pp. 191, 1982 (NRCC Publication, No. 18578).
[23] Ofomaja, A.E., Ho, Y.S. Effect of temperatures and pH on Methyl Violet biosorption by Mansonia wood sawdust. Bioresource Technology, Vol.99, pp. 5411–5417, 2008.
[24] Li, J., Zhang, K., Zhang, H., Adsorption of antibiotics on microplastics. Environmental Pollution, Vol.237, pp. 460-467, 2018.
[25] Azizian, S., Kinetic models of sorption: a theoretical analysis. Journal of Colloid and Interface Science, Vol.276, pp. 47-52, 2004.
[26] Wang, W., Wang, J. Comparative evaluation of sorption kinetics and isotherms of pyrene onto microplastics, Chemosphere, Vol.193, pp. 567-573, 2018
[27] Wu, F.-C., Tseng, R.-L., Juang, R.-S., Initial behavior of intraparticle diffusion model used in the description of adsorption kinetics. Chemical Engineering Journal, Vol.153, pp. 1-8, 2009.
[28] Cheung, W.H., Szeto, Y.S., McKay, G., Intraparticle diffusion processes during acid dye adsorption onto chitosan. Bioresource Technology.,Vol.98, pp. 2897-2904, 2007.
[29] Foo, K.Y., Hameed, B.H., Insights into the modeling of adsorption isotherm systems. Chemical Engineering Journal, Vol. 156, pp. 2-10, 2010.
[30] Gimbert, F., Morin-Crini, N., Renault, F., Badot, P.M., Crini, G., Adsorption isotherm models for dye removal by cationized starch-based material in a single component system: error analysis. Journal of Hazardous Materials, Vol.157, pp. 34-46, 2008.
[31] Abdullah, M.A., Chiang, L., Nadeem, M., Comparative evaluation of adsorption kinetics and isotherms of a natural product removal by Amberlite polymeric adsorbents. Chemical Engineering Journal, Vol. 146, pp. 370-376, 2009.
[32] Huffer, T., Hofmann, T., 2016. Sorption of non-polar organic compounds by microsized plastic particles in aqueous solution. Environmental Pollution, Vol.214, pp.194-201.
[33] Kragulj, M., Tričković, J., Kukovecz, A., Jović, B., Molnar, J., Rončević, S., Konya, Z., Dalmacija, B., Adsorption of chlorinated phenols on multiwalled carbon nanotubes, RSC Advances, Vol.5 (32), pp. 24920-24929, 2015.

PETROSELINIC ACID CELLULOSE ACETATE MEMBRANE (PECAM) AS A QUICK TOOL FOR ASSESSMENT OF PAH BIOAVAILABILITY IN SOIL TO PLANT ROOT

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Abstract: This study compared the uptake kinetics of PAHs by petroselinic acid embedded cellulose acetate membrane (PECAM) and radish root (*Raphanus sativus* L.) in a field contaminated soil under greenhouse conditions during the period of 40 days. Results showed that sorption of PAHs in PECAM from soil pore water was rapid (up to 4.26 days), while radish root couldn't achieve steady state with soil even after 40 days of experiment due to growth dilution and other physiological processes involved. These results indicate that PECAM has potential to be used as a replacementfor plant bioassay in determination of PAH bioavailability to crop plants, both because of short assessment time scale and low analytical costs. However, biomimicing capability of this passive sampler should be tested in different soils in order to justify its applicability as a simulation tool for plant root uptake.
Key words: PECAM, uptake kinetics, PAH, radish root, soil

INTRODUCTION

Employing exhaustive extraction techniques may lead to overprediction in estimating the potential bioaccumulation of PAHs in soil and sediments by living organisms [1]. Determination of the bioavailable i.e. freely dissolved fraction of PAHs is proposed to be a more efficient approach[2]. Therefore, deployment of passive sampling devices (PSDs) which determine the freely dissolved fraction may be advantageous. A number of these samplers have been the focus of scientific research for mimicking bioavailability for a more than a decade such as semi-permeable membrane devices (SPMDs)[3]and polyoxymethylene (POM)[4], which are based on equilibrium partitioning theory. This theory assumes that partitioning concentrations of a compound of interest between two immiscible phases (such as water and organic matter of soils or sediments) will in time reach equilibrium and that these equilibrium concentrations can be calculated using appropriate partitioning coefficients [5]. However, one of the main disadvantages of these methods is slow sorption kinetics which can take weeks of exposure[6]. This is especially true for SPMDs.
Another equilibriumpassive sampler,petroselinic acid cellulose acetate membrane (PECAM), is a type of cellulose acetate membrane that was specificallydesigned to biomimic plant root uptake of PAHs[7]. The invention was based on the idea that lipids in plant membranes are mainly composed of 16 and 18 carbon fatty acids with up to three double bonds, and petroselinic acid contains one chain of 18 carbons.Their study showed that PECAM was capable to mimic partitioning and uptake of PAHs from hydroponic solution by selected grass roots in a short period of time. PECAM uptake kinetics of PAHs and its capacity for biomimicing was further investigated in sand [8], using carrot and cabbage root as reference bioassays. The results showed much quicker PECAM uptake kinetics of PAHs in comparison to plant roots and promising biomimicing capabilities, especially for the fibrous cabbage root system. As sand represents a soilless medium and excludes the potential influence of soil organic matter (SOM) on the sorption kinetics of PAHs,the aim of this study was to compare PECAM and radish root (*Raphanus sativus*L.) dynamic of PAH uptake from soil and thus test the capability of this passive sampler to reduce the time needed to determine bioavailability of these contaminants from soil to crop plants.Radish is chosen as it has thick central root system and grows faster than carrot and cabbage plants.

MATERIAL AND METHODS

PECAM and plant preparation

PECAM was prepared following the procedure proposed by Li et al. [7], using cellulose acetate, petroselinic acid, anhydrous magnesium perchlorate, acetone and 1,4-dioxane. Membrane thickness after preparation was 100 µm with average petroselinic acid content of 7.37±0.23%.
Radish seeds were surface-sterilized by soaking in 3% H_2O_2 for 10 minutes, followed by 10 rinses with sterilized deionised water. Germination was then achieved by placing the sterilized seeds in a Petri dish on a wet filter paper and the seeds were kept in darkness at 26℃ until they germinated. Three uniform germinated seeds were transferred to each plastic pot filled with acid washed sand, moistened with dilute ¼ Hoagland's solution. After sprouting, plants were cultivated under greenhouse conditions with 16h day/8h night regime and mean temperatures 22/15°C (day/night), to develop globular tap root. Plants were watered every other day using ¼ Hoagland's solution followed by ½ Hoagland's solution when the stem reached 10 cm in height. After 60 days, plants were transferred to pots with field-contaminated soil described below.

Soil samples

The soil was collected from an allotment in Brentford, UK, 40m^2 in size, positioned close to the railway station and on a waterside of river Brent (51°29'09.3"N and 0°18'49.1"W). On the area with allotments, gardening, barbequing and making fireworks were practiced. Soil was sampled at 10 different spots, from depth of 5-20 cm, using "X" shaped sampling pattern. Soil samples were then air-dried, ground and sieved through 2 mm sieve, transferred to paper bags and subsequently stored in a cool and dry place prior to analysis and experiment set-up.
For soil background characterisation, particle size determination was done using Mastersizer 3000 laser diffraction particle size analyser, while water holding capacity was determined according to Rowell [9]. PAH characterisation was performed using GC/MS.

Membrane and plant root accumulation

A PECAM membrane (2x3 cm) was buried into 200g of the field-contaminated soil placed in a 500 ml amber glass bottle. Soil was previously moistened with deionised water to reach 60% of water holding capacity. The bottles were then sealed and stored in boxes in a greenhouse with mean temperatures of 22/15°C (day/night). Three replicates of PECAM were collected after 7, 14, 21 and 40 days, membranes were rinsed with deionised water, wiped with a wet tissue and subsequently extracted using 10 ml of iso-hexane for 24 hours. The membranes were then removed and the extraction solution was evaporated to 1 ml, resuspended in toluene, re-evaporated to 200 µl and transferred into GC vials with 200 µl inserts and stored at - 20℃ prior to analysis.
When the radish stems had grown to 10 cm in height, plants were transferred into plastic pots, filled with 200g of the field contaminated soil, previously moistened with deionised water to reach 60% of water holding capacity. The same soil subsample was used for a given replicate in the membrane and plant accumulation experiment. Three plants were added to each pot. Plants were grown under the same greenhouse conditions as those for cultivation prior to transplanting. The soil moisture was maintained constant by watering with deionised water every other day. Three replicates of pots with plants were collected after 7, 14, 21 and 40 days, roots were thoroughly washed with tap water, then soaked in a glass beaker filled with deionised water and sonicated in an ultrasonic bath for 5 minutes to remove remaining soil particles. Samples were subsequently wiped with a dry tissue, roots were separated from shoots using a stainless steel knife, weighed on a laboratory balance, cut to small pieces and freeze-dried for 72h. They were weighed again and ground using a pestle and mortar. Homogenised root samples were then extracted using Dionex ASE 200 Accelerated solvent extractor (ASE) using instrument parameters and amount of plant material previously determined in the laboratory. SPE clean-up was performed using 500 mg/3 ml C18 columns. Eluted samples were resuspended with 200 µl of toluene, transferred to GC vials with 200 µl inserts and stored in a freezer prior to GC/MS analysis.

Extraction of PAHs from soil samples

Soil samples collected before and during the course of the experiment were air dried for 4 days, ground and sieved through a 2 mm sieve prior to extraction. 4g of each soil subsample were sonicated with 10 ml of acetone/hexane mixture (1:1) for 15 minutes in an ultrasonic bath filled with hot water. One hour shaking on end-over-end shaker at 60rpm followed. Hexane layer with hydrophobic compounds including PAHs was then separated from hydrophilic layer of acetone and water, by adding 4 ml of deionised water. Extracted samples were left in a freezer for 30 minutes to allow soil to settle and SPE clean-up was performed using SPE cartridges filled with 500mg of previously activated silica and 250mg of anhydrous sodium sulphate. The collected eluate was evaporated under a gentle nitrogen stream, solvent was resuspended with 1 ml of toluene, transferred to GC vials and stored at -20℃ prior to analysis.

PAH analyses, lipid content determination and total organic carbon in soil

All PAH extracts were analysed using GC/MS system described in[8]. Programmed temperature vaporization injector (PTV) operated in large volume mode if injection volume was 5 µl (membranes) or in split mode (10:1) for 1 µl (plant and soil samples).
Lipid content in PECAM was determined gravimetrically following procedures described in [10]. Membrane lipid was Soxhlet extracted while extraction of plant lipid content was done by ultrasonication of plant material with dichloromethane. Total organic carbon in soil was determined using a Flash 2000 nitrogen and carbon analyser. In order to exclude inorganic carbon, soil was pre-treated with hydrochloric acid.

Statistical and data analyses

Statistical analysis was undertaken using Minitab. First-order kinetics model was fitted to mean PAH concentration values to obtain kinetic parameters. In order to compare relationships between two parameters such as accumulated concentrations in PECAM and radish root, linear regression analysis and F-tests were performed, while normality of data was checked using the Anderson-Darling test. Where needed, a 2 sample t-test was applied. Graphs were designed using SigmaPlot software.
Uptake kinetics parameters for PECAM and plant root in field contaminated soil were determined by applying the first order kinetics model, proposed by Tao *et al*.[11]

$$C_m(t) = C_e\,(1 - e^{-kt}) \tag{1}$$

where $C_m(t)$ represents concentration of PAHs accumulated in a unit of mass of PECAM or plant root in a given time (t); C_e is mass of the target compound in membrane or plant root at the moment of evident equilibrium; k represents exchange rate constant. Time that membranes and plant roots need to achieve 90% of equilibrium concentration with soil is calculated according to Mayer et al. [5]:

$$t_{90\%} = \ln 10/k = 2.302/k \tag{2}$$

Freely dissolved PAH concentrations in soil were determined using PAH concentrations found in PECAM at equilibrium, by dividing them by predetermined PECAM-water partitioning coefficient $K_{p,w}$ [5]:

$$C_w = C_{PECAM}/K_{p,w} \tag{3}$$

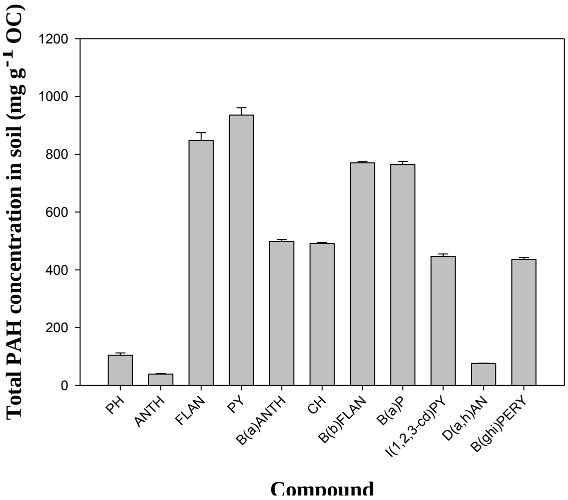
where C_w represents mass of a target compound in soil pore water; C_{PECAM} is mass of a compound accumulated per unit mass of PECAM at equilibrium; $K_{p,w}$ is PECAM-water partitioning coefficient obtained in the equilibrium experiment for a given compound from the established relationship with K_{ow} value[10]:

$$K_{p,w} = 0.85 \log K_{ow} + 0.87 \tag{4}$$
$$r^2 = 0.942, \qquad p < 0.001$$

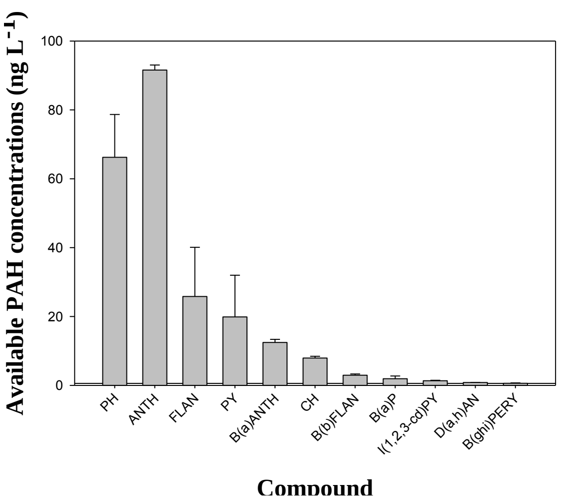
RESULTS AND DISCUSSION

Background properties of the soil

According to results of particle size analysis (Table 1), the soil used in the experiment had 35.12% of sand, 56.12% of silt and 8.71% of clay and thus is classified as silt loam containing 5.65% of organic matter. Contamination of soil with PAHs was high prior to the experiment. Total organic carbon normalized concentrations ranged from 39.53 µg/g for anthracene to 935 µg/gfor pyrene and didn't related to hydrophobicity of PAHs, while available concentrations extracted with PECAM were higher for lower hydrophobic PAHs and were in a range from 0.61 ng/L (benzo(g,h,i)perylene) to 91.56 ng/L for anthracene (Figure 1).



a)



b)

Figure 1. PAH concentrations in soila) organic carbon normalized total concentrations extracted using acetone-hexane (1:1 v/v) mixture b)concentrations in soil pore water measured by PECAM. Standard error is represented with error bars (n=3).

Table 1. Physicochemical characterisation of the soil used for the experiment.

pH	Organic Matter (%)	Sand (%)	Silt (%)	Clay (%)
7.5	5.65	35.12	56.12	8.71

Uptake kinetics of PAHs by PECAM and radish root

PAH uptake kinetics in PECAM and radish root from field contaminated soil under greenhouse conditions were examined for 40 days. All PAHs accumulated in PECAM equilibrated with soil pore water rapidly, in less than 7 days (first sampling point) as shown in Figure 2 and Table 2. Even though more sampling dates at the beginning of the experiment are needed for getting more accurate PECAM uptake kinetics results, the data presented in Table 2 still give information about accumulation dynamic of PAHs in PECAM. Assimilation of three-ring phenanthrene was the most rapid and 90% of equilibrium concentration of 2.31 µg/g was achieved in half a day (0.53 days). Compounds with higher mass weight were accumulated slower and mainly lesser, reaching the maximum of 4.26 days and minimal concentration of 1.04 µg/g for 6-ring benzo(g,h,i)perylene**.**A closer look at the data indicates that uptake rate constants (k) for PECAM were dependent on hydrophobic character of accumulated PAHs. When plotted rate constants against log K_{ow} values (Figure 3a), negative and significant relationships were found (r^2=0.798, p<0.001 respectively). If k–values higher than 1 were excluded, correlation become even stronger (r^2=0.818, p<0.001) and regression line gradient smaller (Figure 3b). This is due to low reliability of obtained rate constants for PAHs which reached steady state quickly, as there was lack of sampling points within first sampling date.

Table 2. Estimated uptake parameters and concentrations of accumulated PAHs in PECAM and radish root. Rate constants (k) and equilibrium concentrations (Ce) for PECAM were obtained by fitting a first-order kinetics model to mean PAH concentration values obtained in the experiment with three replicates per sampling point. $t_{90\%}$ represents time needed to reach 90% of equilibrium concentration.

Compound	**PECAM**			**log K_{ow}**	**Radish root**		
	k (day^{-1})	**$t_{90\%}$ (day)**	**Ce (µg/g)**		**k (day^{-1})**	**$t_{90\%}$ (day)**	**Ce (µg/g)**
Phenanthrene	4.378	0.53	2.31	4.46	0.435	5.30	0.52
Anthracene	3.992	0.58	2.67	4.54	0.401	5.74	0.16
Fluoranthene	4.048	0.57	2.39	5.20	0.318	7.24	0.88
Pyrene	3.488	0.66	2.33	5.30	0.339	6.79	0.63
Benz(a)anthracene	1.548	1.49	2.04	5.91	0.276	8.33	0.64
Chrysene	0.934	2.46	1.92	5.61	0.295	7.81	0.64
Benzo(b)fluoranthene	0.868	2.65	1.56	5.78	0.236	9.76	1.19
Benzo(a)pyrene	0.845	2.72	1.37	6.35	0.256	9.00	0.97
Indeno(1,2,3-cd)pyrene	0.747	3.08	1.18	6.51	0.196	11.77	0.88
Dibenz(a,h)anthracene	0.708	3.25	1.11	6.75	0.166	13.91	0.40
Benzo(g,h,i)perylene	0.541	4.26	1.04	6.90	0.153	15.10	0.88

The data also appear to suggest a decrease in 3-ring phenanthrene and 4-ring pyrene concentrations after 21 days while accumulation of 5-ring benzo(a)pyrene and 6-ring benzo(g,h,i)perylene remained steady (Figure 2). This phenomenon can be related to degradation of PAHs from soil in time and PECAM accumulation followed it well. As known from literature, degradation of PAHs depends on molecular weight and their solubility [12] and their half lives in soil are thus longer if they are composed of 5 or more benzene rings.

Accumulation of PAHs in radish root was assessed in addition to determination of uptake kinetics of PAHs in PECAM. When a first-order kinetics model was fitted to mean PAH concentrations obtained in the experiment, equilibrium partitioning after 5 (phenanthrene) to 15 days (benzo(g,h,i)perylene) was estimated (Figure 4a, Table 2).Calculated rate constants, from which equilibration times were derived, decreased with the hydrophobicity of PAHs (r^2=946, p<0.001), from 0.435 $days^{-1}$ for phenanthrene to 0.153 $days^{-1}$ for benzo(g,h,i)pyrene. These data suggest significantly quicker uptake kinetics of PAHs in PECAM in comparison with radish root (p<0.001). Nevertheless, steady-state PAH concentrations in root didn't follow hydrophobicity of PAHs. There was an initial increase in concentrations with the increase of molecular weight, with the lowest concentration for anthracene and phenanthrene (0.16µg/g and 0.52 µg/g respectively). Accumulation then reached a peak for benzo(b)fluoranthene (1.19 µg/g) and started to decrease towards the PAHs with the highest molecular weight. In addition, assimilated concentrations were 1.18 times (benzo(g,h,i)perylene) to 16.70 times (anthracene) higher in PECAM in comparison with radish root, indicating that this passive sampler is more suitable for prediction of high end PAH uptake by radish root.

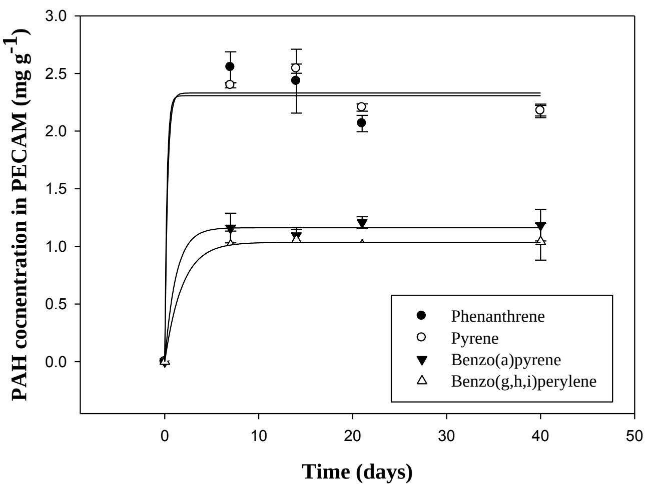


Figure 2. Uptake kinetics of representative PAHs with specific number of benzene rings (phenanthrene – 3; pyrene – 4; benzo(a)pyrene – 5; benzo(g,h,i)perylene - 6) by PECAM from soil. Error bars represent standard errors (n=3).

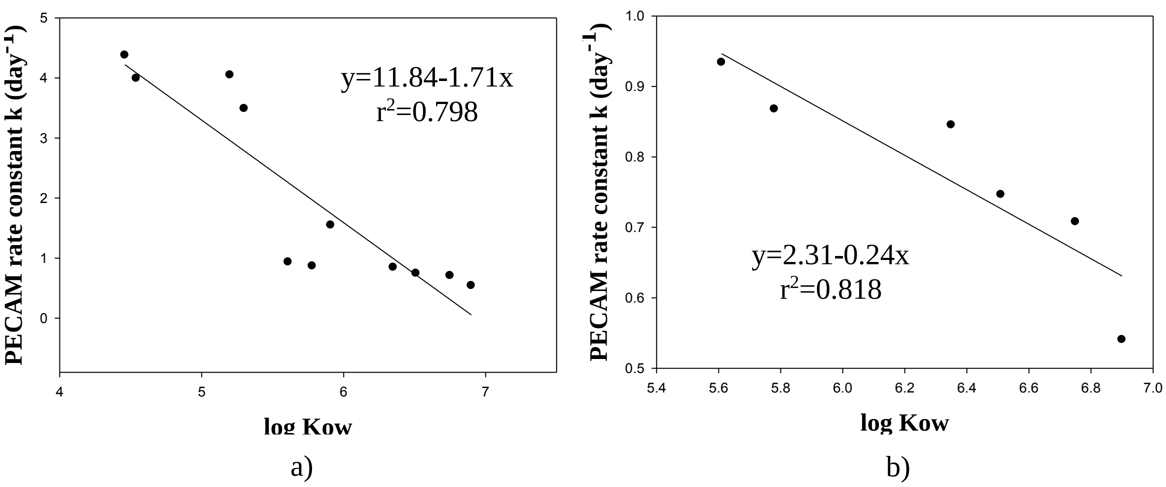
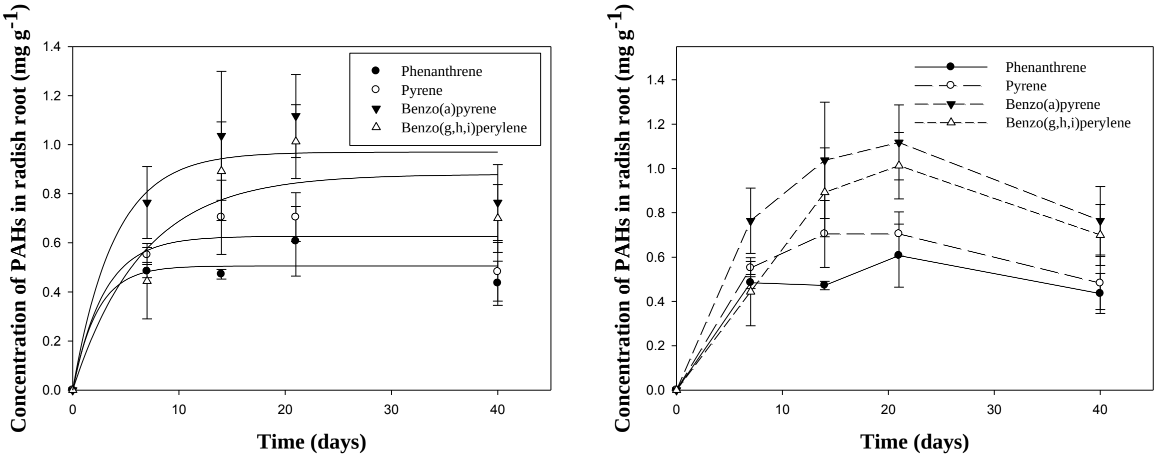


Figure 3. Relationship between lipophilicity of PAHs (log K_{ow}) and the dynamic of their uptake by PECAM expressed using a) rate constant (k) with all k-values b) rate constant (k) where k-values higher than 1 are excluded.

However, as shown in Figure 4b, if only experimental data were analysed, no equilibrium points for root were reached during the course of the experiment. Concentrations of all PAHs constantly increased during the first 21 days, generally accumulating lower weighted PAHs faster than higher weighted ones. After that point, assimilation of the majority of PAHs in PECAM was decreasing towards the end of the experiment. The only exception was indeno(1,2,3-cd)perylene which concentration already started dropping after 14days. A closer look at the change of radish root fresh weight in time (Figure 5) indicates an influence of growth dilution on PAH concentrations at different sampling points, thus preventing equilibrium occurring. Namely, during the first 21 days uptake of PAHs was faster than root growth. However, after that point, root accumulation of PAHs was held unchanged or started dropping while root mass continued to increase, causing growth dilution of PAH concentrations in root.



a) b)

Figure 4. Assimilation kinetics for representative PAHs with specific number of benzene rings (phenanthrene – 3; pyrene – 4; benzo(a)pyrene – 5; benzo(g,h,i)perylene - 6) by radish root from soil. a) first order kinetics model applied b) without fitting with kinetics model. Each point symbolises mean value of 3 replicates, while standard errors are presented by error bars. Concentration values are expressed on dry weight basis.

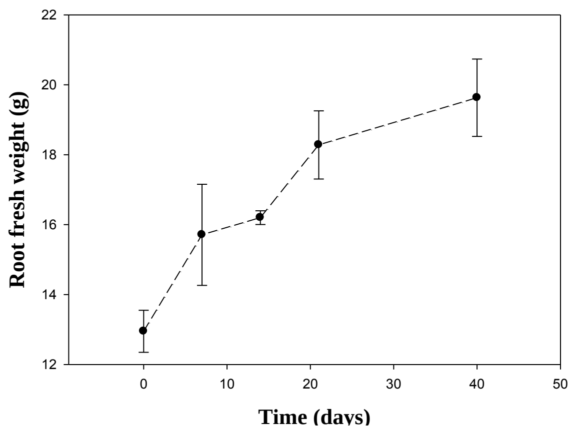


Figure 5. Radish root growth dynamics during the course of the experiment based on root fresh weight. Error bars represent standard deviation values (n=3).

CONCLUSION

The main aim of uptake kinetics investigations was to compare the rates of PAH accumulation between radish root and PECAM passive sampler. Results of this study showed that PECAM had the ability to equilibrate quickly (in up to 4 days) even in soil, where competition sink is involved. Radish root influenced by growth dilution (presumably due to growth of edible bulb over time), couldn't achieve steady state with soil even after 40 days, thus giving the advantage to PECAM as passive sampler over usage of plant bioassay in determination of PAH bioavailability to crop plants, both because of assessment time scale and analytical costs. Even though fast sorption kinetics is advantageous attribute, PECAM biomimicing capability needs to be investigated in soils with varying absorption pools and compared with a variety of crop plants in order to justify its applicability as a simulation tool for plant root uptake.

REFERENCES

[1] Ortega-Calvo, J.J., Harmsen, J., Parsons, J.R., Semple, K.T., Aitken, M.D., Ajao, C., et al., From Bioavailability Science to Regulation of Organic Chemicals, Environmental Science & Technology, Vol.49, No.17., pp. 10255-10264, 2015.

[2] Bartolome, N., Hilber, I., Sosa, D., Schulin, R., Mayer, P., Bucheli, T.D., Applying no-depletion equilibrium sampling and full-depletion bioaccessibility extraction to 35 historically polycyclic aromatic hydrocarbon contaminated soils, Chemosphere, Vol.199, pp. 409-416, 2018.

[3] Gourlay, C., Miège, C., Noir, A., Ravelet, C., Garric, J., Mouchel, J-M., How accurately do semi-permeable membrane devices measure the bioavailability of polycyclic aromatic hydrocarbons to Daphnia magna?, Chemosphere, Vol.61, No.11., pp. 1734-1739, 2005.

[4] Jonker, M.T.O., Koelmans, A.A., Polyoxymethylene solid phase extraction as a partitioning method for hydrophobic organic chemicals in sediment and soot, Environmental Science & Technology, Vol.35, No.18., pp. 3742-3748, 2001.

[5] Mayer, P., Tolls, J., Hermens, J.L.M., Mackay, D., Equilibrium sampling devices, Environmental Science & Technology, Vol.37, No.15., pp. 185A-191A, 2003.

[6] Cachada, A., Pereira, R., da Silva, E.F., Duarte, A.C., The prediction of PAHs bioavailability in soils using chemical methods: State of the art and future challenges, Science of The Total Environment, Vol.472, pp. 463-480, 2014.

[7] Li, X., Zhu, Y., Wu, T., Zhang, S., Christie, P., Using a Novel Petroselinic Acid Embedded Cellulose Acetate Membrane to Mimic Plant Partitioning and In Vivo Uptake of Polycyclic Aromatic Hydrocarbons, Environmental Science & Technology, Vol.44, No.1., pp. 297-301, 2010.

[8] Koković, J., Passive samplers as a predictability tool for uptake evaluation of PAHs by crop plants, ECOLOGICA, Vol.26, No.95., pp. 319-324, 2019.

[9] Rowell, D.L., Soil water suction and its mesurments, In: Soil Science - Methods and applications, Harlow, Longman Group UK Ltd., Chapter 5, pp.88-92, 1994.

[10] Koković, J., Assessing uptake kinetics of PAHs in water using passive samplers, In: Assessment of different passive samplers to predict bioavailability of polycyclic aromatic hydrocarbons to vegetable crops, Reading, University of Reading, Chapter 3, pp. 24-51, 2016.

[11] Tao, Y., Zhang, S., Wang, Z., Christie, P., Predicting bioavailability of PAHs in field-contaminated soils by passive sampling with triolein embedded cellulose acetate membranes, Environmental Pollution, Vol.157, No.2., pp. 545-551, 2009.

[12] Alexander, M., Predicting biodegrability, In: Biodegradation and bioremediation, Second edition ed. San Diego, CA, Academic Press, Chapter 11, pp. 191-193, 1999.

PHOTOCATALYTIC WATER TREATMENT USING ZINC AND TITANIUM BASED METAL-OXIDE NANOPARTICLES

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Abstract: This work describes the possibility of using the advanced oxidation processes by metal-oxide-semiconductor photocatalysis for the removal of pharmaceutical contaminants in water. Heterogeneous semiconductor photocatalysis is a cheap and easy alternative water treatment proven efficient especially in the degradation of smaller pollutants such as pharmaceuticals that often lag after the usual water purification. Here we compared the efficiency of selected mixtures of M-oxide-semiconductor nanoparticles (M = zinc, titanium, tin, indium) as photocatalysts in the heterogeneous photocatalytic degradation of some pharmaceuticals from water solutions. In one of the European Commission documents regarding the European Union Strategic Approach to Pharmaceuticals in the Environment in 2019, the presence of several pharmaceuticals in the surface, ground and even drinking waters, soils and animal tissues across the European Union was reported. This complicates already existing problem of water pollution and demands a quick and efficient solution that would also help in an ongoing evaluation of the water legislation process in the EU.
Key words: photocatalysis, water treatment, pharmaceuticals in the environment

INTRODUCTION

Photocatalytic advanced oxidation processes (AOPs) have been the subject of systematic investigations over the past three decades. Historically rooted in the discovery of photoelectrochemical water splitting at the TiO_2 electrode surface photocatalysis quickly become a promising method in water treatment [1]. Usually, AOPs use the oxidants such as O_3 or H_2O_2 and energy source like UV irradiation for initial reactive oxygen species (ROS) production that can completely degrade the organic contaminants from water. On the other hand, heterogeneous semiconductor photocatalysis provides advanced oxidation by the following mechanism. Photons of light absorbed by a semiconductor catalyst with the energy equal or higher than its bandgap produce the pair of conduction electron (e_{CB}^-) and valence band hole (h_{VB}^+) that further undergo the surface reactions with the electron donors or acceptors adsorbed on the surface of the catalyst or from the near surrounding solution. Such electron donors and acceptors are for example hydroxide ions (OH^-) and dissolved oxygen molecules (O_2) in water, respectively (Fig. 1). These redox reactions create the ROS like hydroxyl radical ($^{\bullet}OH$) and superoxide anion ($O_2^{\bullet-}$) that in the further chain reactions mineralize the harmful organic compound to harmless CO_2 and H_2O. The most dominant ROS in the photocatalytic reactions are hydroxyl radicals ($^{\bullet}OH$), either surface- or balk-bound, because of their high oxidizing power. Development of new semiconductor photocatalytic materials is nowadays uppermost inspired by the progress made in materials nanotechnology. Therefore, the advances in this area are mostly focused on finding new materials with improved properties that would have more efficiency in the photocatalytic degradation of water pollutants using UV or even better solar sun irradiation. Usually, new and improved catalysts are searched and found among nanomaterials based on either modified anatase titanium dioxide (TiO_2) or a mixture of anatase TiO_2 and rutile TiO_2 phases so-called Degussa P25 TiO_2, which is the most used commercial type of photocatalyst. However, in recent years ZnO (zinc oxide) and ZnO-based materials have shown also significant efficiency in the photocatalytic processes for water purification treatment. ZnO is the most promising photocatalyst to replace the TiO_2, as it possesses higher absorption efficiency across a large fraction of the solar spectrum compared to TiO_2 [2]. Besides, ZnO has antifouling and antibacterial properties as well. Improvement of TiO_2 and ZnO as photocatalysts is possible in several ways, and one of those is mixing/coupling with another metal-oxide-semiconductors. Mixing/coupling of two metal-oxide photocatalysts enables higher light absorption, better suppression of photo-induced electron-hole pair recombination and increased charge separation. In this paper, we describe the most important steps in photocatalytic water treatment using metal-oxide-semiconductor powder materials and show comparatively the efficiency of some of these photocatalysts tested so far in the degradation of selected pharmaceutically active compounds (PhACs) that are potential water contaminants due to its increasing introduction into the environment. The pollution caused by PhACs is an emerging problem [3]. The PhACs residues enter the environment during pharmaceuticals manufacturing, using and disposal.

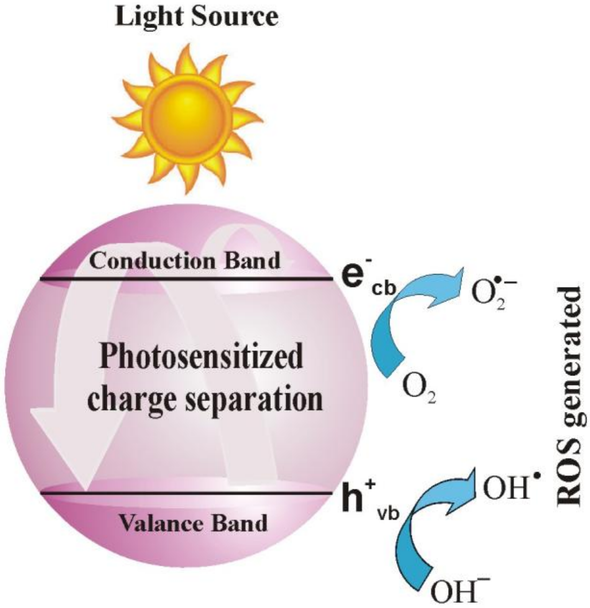

Figure 1. Generation of ROS by redox reactions at the catalyst surface which are initiated by the electron/hole pair produced via photons absorbed by a catalyst [1]

MATERIALS AND METHODS

Metal-oxide-semiconductor powder photocatalysts were prepared by a mixing-calcination solid-state method when precursors (starting commercial powders of ZnO, TiO_2, SnO_2, and In_2O_3) were mechanochemically treated in an agate mortar for adequate time intervals and calcinated at an appropriate temperature [4-7]. The obtained powder particles were characterized using X-ray diffraction (determination of the crystallite sizes) and diffuse reflectance spectroscopy (estimation of the optical band gap value), while its photocatalytic efficiency in the degradation of selected PhACs (amitryptiline, alprazolam, naproxen) water solutions was examined using the photocatalytic experimental setup described below and ultra-high-performance liquid chromatography with diode array detector (UFLC-DAD). In general, for the UFLC-DAD kinetic studies, the aliquots of 0.50 cm^3 were taken from the reaction mixture (suspension of catalyst in PhACs water solution) at the beginning of the experiment and at regular time intervals up to 60 min, which was the total duration of each of the photocatalytic experiments. The aliquots of the reaction mixtures were firstly filtered through a membrane filter for the catalyst to be removed, and then a 10-μl of this solution was injected and analyzed on UFLC-DAD to determine the percentage of PhACs degraded. The UV/Vis DAD detector was set at the wavelength of the individual PhACs maxima absorption in each of the experiments [4-7] and by monitoring the decrease in the intensity of this peak, the percentage of the PhACs degradation was determined.

Photocatalytic experimental setup

The photocatalytic degradation of the standard solution of the chosen PhACs was carried out in a cell described previously [8]. Generally, the standard solutions of PhACs were prepared by dissolving the appropriate mass of pharmaceuticals in the ultra-pure water. 125 W high-pressure mercury lamp and 50 W halogen lamp are used as UV and simulated solar (SSI) irradiation sources, respectively. Experiments were mainly carried out using 20 cm^3 of the prepared PhACs solutions (0.03 mmol/dm^3) while the photocatalyst loading was 1.0 mg/cm^3. The aqueous suspension (reaction mixture) was sonicated (50 Hz) in the dark for 15 min before the irradiation for uniform dispersion and reaching the adsorption equilibrium. The suspensions were thermostated at 25 °C in a stream of O_2 (3.0 cm^3/min) and then irradiated. During irradiation, the suspensions were stirred at a constant rate under continuous O_2 flow. The described photocatalytic experimental setup is presented in Fig. 2.

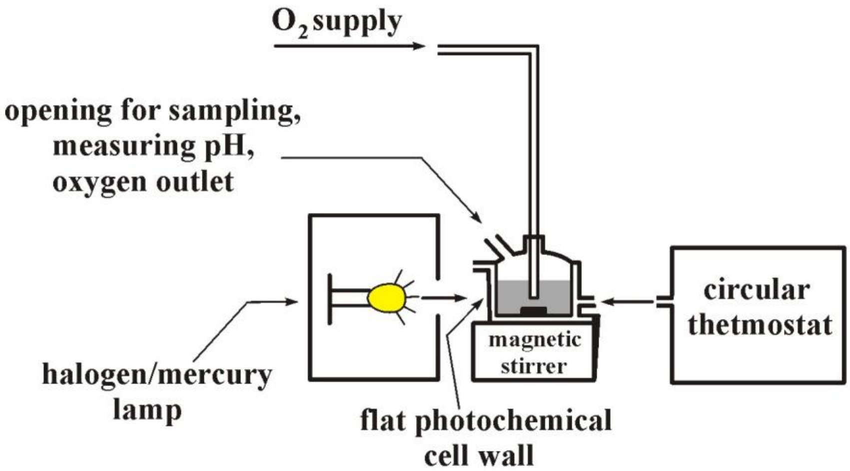

Figure 2. Photocatalytic experimental setup

RESULTS AND DISCUSSION

Photocatalytic degradation efficiency

The degradation efficiencies of several metal-oxide-semiconductor nanocrystalline photocatalysts in the removal of the selected PhACs as potential organic contaminants in water systems are summarized in Table 1.

Table 1. Some properties and photocatalytic efficiency of M-oxide-semiconductor nanoparticles in the photocatalytic degradation of the selected PhACs under UV and/or SS irradiation

Metal-oxide semiconductor photocatalyst type	Crystallite size (nm)	Optical band gap (eV)	Pharmaceutical water contaminant	Irradiation type		References
				UV	SSI	
				Degradation efficiency (%)		
ZnO/SnO_2	96 nm/78 nm	3.04 eV	Amitriptyline* Alprazolam*	100% 100%	82.6% 77.5%	[4] [5]
ZnO/In_2O_3	93 nm/75 nm	3.16 eV	Amitriptyline Alprazolam		72.7 % 53.7 %	[6]
ZnO/TiO_2	83 nm/84 nm	3.27 eV	Naproxen*	100%		[7]

*Amitriptyline and alprazolam are representatives of a large group of psychoactive drugs that include narcoleptics, ataractics/tranquilizers, hypnotics, sedatives, and antidepressants, while naproxen is among the most widely used nonsteroidal anti-inflammatory drug for treating pain, menstrual cramps, inflammatory diseases such as rheumatoid arthritis, and fever.

In all of the performed experiments (results summarized in Table 1), the used photocatalysts have shown better efficiency than the commercially most used Degussa P25 TiO_2 photocatalyst which is itself a mixture of two allotropes of TiO_2, anatase and rutile phases in 3:1 ratio with an average crystallite size of about 20 nm. Mixed ZnO/SnO_2 and ZnO/TiO_2 types of catalysts showed 100 % efficiency, within the experimental conditions and under the UV light irradiation, in the degradation of amitriptyline, alprazolam and naproxen drugs (Table 1). Especially commendable are the results obtained under the simulated solar irradiation conditions where the degradation efficiency reached almost 83 % and 78 % in the case of ZnO/SnO_2 type, and 73 % and 54 % in the case of ZnO/In_2O_3 type of semiconductor photocatalyst used. The results presented in Table 1 show the good potential of this method as water purification treatment in the removal of PhACs.

CONCLUSION

The conventional water purification treatments often cannot completely remove the organic contaminants from the aqueous environment. Photocatalysis is an alternative method of water purification especially for the removal of the pharmaceutically active compounds from aqueous systems when they stay behind after the conventional water purification procedures. Here we have presented the latest results on the efficiency of some metal-oxide-semiconductor nanopowders in the photocatalytic treatment of water contaminated by PhACs. The results are encouraging and the method was proven quite efficient. On the other hand, it should be noted that there is a noticeable gap between the excellent laboratory results in designing efficient photocatalyst materials, and actual reactor setup and testing methods in the natural environment that would allow the widespread implementation of this method. Therefore, the future perspective of using the photocatalytic water purification treatment by metal-oxide-semiconductors is to bridge this gap and take further steps towards the application of this method beyond the laboratory.

ACKNOWLEDGMENT

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REFERENCES

[1] Loeb, S.K., Alvarez, P.J.J., Brame, J.A., Cates, E.L., Choi, W., Crittenden J., Dionysiou, D.D., Li, Q., Li-Puma, G., Quan, X., Sedlak, D.L., Waite, T.D., Westerhoff, P., Kim, J-H., The Technology Horizon for Photocatalytic Water Treatment: Sunrise or Sunset?, Environmental Science and Technology, Vol. 53, pp. 2937-2947, 2019.

[2] Ong, C.B., Ng, L.Y., Mohammad, A.W., A review of ZnO nanoparticles as solar photocatalysts: Synthesis, mechanisms and applications, Renewable and Sustainable Energy Reviews, Vol. 81, pp. 536-551, 2018.

[3] https://ec.europa.eu/environment/water/water-dangersub/pdf/strategic_approach_pharmaceuticals_env.PDF

[4] T.B. Ivetić, N.L. Finčur, B.F. Abramović, M. Dimitrievska, G.R. Štrbac, K.O. Čajko, B.B. Miljević, Lj.R. Đačanin, S.R. Lukić-Petrović, Environmentally friendly photoactive heterojunction zinc tin oxide nanoparticles, Ceramics International Vol. 42, pp. 3575-3583, 2016.

[5] T.B. Ivetić, N.L. Finčur, B.F. Abramović, G. Štrbac, S.R. Lukić-Petrović, The possibility of applying mixed nanocrystal oxide photocatalysts for removal of pharmaceutically active compounds, potential wastewater contaminants of the Danube river basin in Vojvodina, 11th International Conference on Risk and Safety Engineering, 25-27 January 2016, Kopaonik, Serbia, Proceedings, pp. 39-44, 2016.

[6] T. Ivetić, N. Finčur, B. Miljević, Lj. Đačanin Far, S. Lukić-Petrović, B. Abramović, Indium-zinc-oxide nanocrystallites: Preparation, properties and visible-light-generated photocatalytic efficiency in degradation of psychoactive drugs from waters systems, Romanian Journal of Physics, Vol. 63 pp. 608(1-12), 2018.

[7] D. Štrbac, C.A. Aggelopoulos, G. Štrbac, M. Dimitropoulos, M. Novaković, T. Ivetić, S.N. Yannopoulos, Photocatalytic degradation of Naproxen and methylene blue: Comparison between ZnO, TiO_2 and their mixture, Process Safety and Environmental Protection, Vol. 113, pp. 174-183, 2018.

[8] Abramović, B., Šojić, D., Despotović, V., Vione, D., Pazzi, M., Csanádi, J., A comparative study of the activity of TiO_2 Wackherr and Degussa P25 in the photocatalytic degradation of picloram, Applied Catalysis B: Environmental, Vol. 105, pp. 191-198, 2011.

THE ECOLOGICAL UNSUSTAINABILITY OF MODERN CAPITALISM AND THE RESOURCE WARS AS ITS MOST DRASTIC FORM

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Abstract: This paper will try to provide arguments which support the idea of the ecological unsustainability of the current capitalist world system, analysing the phenomena of the existing economic model and the wars over resources as the greatest threats to the future of humanity. The idea has two aspects. The first relates to ecology and the second to the war economy, treating both as absolute limits that the contemporary capitalism is faced with. The emphasis is placed on the need to re-problematize the relationship between capital and nature under the paradigm of systemic crisis in its ecological, economic and security dimension.
Key words: ecology, environment, capitalism, resource wars

INTRODUCTION

"Nature is man's *inorganic body* – nature, that is, insofar as it is not itself human body. Man *lives* on nature – means that nature is his *body*, with which he must remain in continuous interchange if he is not to die. That man's physical and spiritual life is linked to nature means simply that nature is linked to itself, for man is a part of nature" [1]. Karl Marx, *Economic and Philosophic Manuscripts of 1844.*

Since the 19 century it has become increasingly obvious that it is land and nor so much labour or production (viewed separately) that represents the basic condition of human existence. Class conflicts, ethnic clashes, religious strife, or racial intolerance are slowly being joined by ecological collapse as additional variable demonstrating the antagonistic nature of the world capitalist system. In the last two hundred years, despite different scales of influence, all these phenomena have influenced the creation of a "risk society" which has the potential for a planetary catastrophe. While such a likelihood is small, should the disaster actually occur, it would be definitive. Theoretical approaches to the phenomenon of risk are just another way of understanding capitalism, which refers to the uncontrolled use of science and technology under the conditions in which the market is fully focused on immediate material profit, and does not really have long-term consequences, whether for the environment or for the health of mankind. We are facing a radically new scenario, uncertain and fraught with uncertainty. In order to determine the spatial and temporal context and to announce the whole era and point out its boundaries and achievements, in recent years various authors have adopted the term anthropocene[1] [2]. The term refers to the advent of a new geological epoch in which humans virtually take the lead in all changes to the systems occurring on planet Earth. Interpreted as the "new man", the anthropocene symbolizes ecological collapse as a consequence of the growing tension between modern capitalist society and nature. This collapse refers not only to "endangering the sustainability of human society, but also to the diversity of life on Earth" [3]. In this respect, it should be pointed out that ecological collapse is present at all times as a global projection, unlike many other class, ethnic, religious or racial collapses which have local or regional reach. In addition to the environmental issue, another, equally devastating and absolutely limiting factor regarding the future of humanity are the resource wars which will be discussed in the second part of this text.

[1] The term was first used in an article co-written by Paul Crutzen and Eugene Stormer [2] within the International Geo-Biosphere Program: A Study on Global Change by the International Science Council (Global Change Newsletter, No. 41, May 2000)

DISCUSSION

Ecology as the absolute limiting factor of life on Earth

Regardless of the various theoretical approaches that have been developed in the last decades, such as ecological economics, environmental history and sociology of the environment, system ecology, and the like, and the unanimous rejection of Cartesian dualism that has continued for centuries separating society from nature as if these were two sets without many features in common, eight[2] global limits have recently been registered, which function as destabilizing factors for the planet, triggering the unstoppable destruction of the environment. The table below [4] presents the stratification of these limits, their progress through history and the burdens that humanity can impose on the environment in an unsustainable way when it is no longer able to support and nurture human activity.

Table 1. Global limits measured. Levels: Pre-industrial era and present period

Aspect	Unit of measurement	Limit	Pre-industrial value	Current value
Climate changes	(ppm) CO_2	350	280	390
Loss of biodiversity	Species loss rate (of billion)	10 of billion	- 1 of billion	100 of billion
Nitrogen cycle (N)	Tones extracted from the atmosphere	35 billion tones	0 tones	121 billion tones
Phosphorus cycle (P)	The amount of P reaching the Ocean	11 billion tones	1 billion tones	8.5 – 9.5 billion tones
Ocean acidity	Acidity of the Ocean (inverted scale)	2.75	3.44	2.90
Global use of fresh water	km^3	4,000 km^3	415 km^3	2,600 km^3
Land use change	Arable land without ice [%]	15%	Very low	11.7 %
Low stratospheric density of ozone	Dobson Units	276	290	283

Source: www.jornada.unam.mx/2015/01/02/opinion022o1eco

As can be seen, three of these aspects have already exceeded the limits: climate change, the nitrogen cycle and loss of diversity can be interpreted as part of the growing crash in the Earth system. Regarding the ozone depletion in the stratosphere, its largest decline was observed during the 1990s, which led to measures that stabilized and even reduced this tendency. On the other hand, global water consumption, land use change, ocean acidity and the phosphorus cycle continue to be global problems that, although present, do not yet cause excessive damage. As can be seen from the table, the limit values measured for seven aspects have changed dramatically from the industrial era to the present. With the first three items, we are facing a specific red alarm that warns us that if everything continues

[2] These are: a) climate change; b) ocean acidity; c) loss of stratospheric ozone; d) nitrogen and phosphorus cycles; e) fresh water consumption globally; f) change of land use; g) loss of biodiversity; h) emission of aerosols into the atmosphere; i) contamination by pollutants. Whether directly or indirectly, these global limits were one of the main reasons for initiating a process of significant re-conceptualisations of the human-nature relationship and of world ecology within historical capitalism, presented in the work of recognized experts in the above fields: Foster et al. [3], Benton [5], Foster [6], O' Conor [7], Martinez [8], Smith [9], Moore [10], [11], and Altvater [12], [13].

at the current and planned pace, we are likely to witness the loss of one-third of the species on planet Earth [3]. Coastal areas are constantly exposed to nitrogen fertilizer disposed of as waste which causes devastation of coastal zones as marine life is destroyed. The latest mapping of ocean acidity caused by CO_2 decay does not present a very encouraging picture, especially in the areas designated as critical, including the northern Pacific and Atlantic oceans. However, the fundamental problem is the inevitable fact that the economic system in expansion, with a tendency of infinite growth, creates an additional burden on planet Earth, which, in turn, represents a limited and established system until this reaches the point of overload[3]. The result is what Foster, Clark and York refer to as global "ecological rift" which destroys all human connection to nature as a result of a system alienated by unlimited accumulation. The consequences can be catastrophic for life on the planet, but are we really facing a perniciously contradictory phenomenon that the world capitalist system cannot reverse in its favour?
Before discussing the topic of resource wars, there is a need to highlight the issue of environmental imperialism and its international geo-economic dialectic. Here again, the old Marxian idea of creating a world market as something inseparable from capital resurfaces [14]. In other words, globalization as a phenomenon in full force has always been part of the capitalist mode of production and its social nature, despite its rapid expansion over the last fifty years. It can therefore be said that "the capitalist economy is first and foremost geo-economics and that its participants are fighting on all fronts" [11]. We are talking, therefore, about a spatial system based on the principle of competition, which often strives for monopolistic practice. Hence, two logics emerge that differ in the motivation and interest of the factors that use them to achieve their goals. On the one hand, there is the logic of capital (represented by phenomena such as commodity, market, accumulation, profit), which operates in an unlimited spatial and temporal structure, is supranational in nature and has powers beyond any principle of territoriality. On the other hand, there is the logic of political power of a centralist state, which is national in character and completely subordinated to territorial dynamics. Confronted and embodied in the personalities of capitalists and politicians, these logics lead to a series of inevitable conflicts that lead us today to re-examine the relationship between classical and new imperialism, with particular reference to the ecological dimension of the latter[4]. In a nutshell, the problem is focused on two closely related phenomena (capital volatility versus territorial anchoring) and between them there is a lot of tension and there is apparently no effective solution within the structure of the current world capitalist system. The primitive accumulation was only an early phase of classical imperialism in which violent expropriation, plunder of nations and deceit, developed from a simple historical process of social and political violence into a mechanism of repression and exploitation, resulting in a colonial system designed to transfer resources and wealth from the periphery to the centre of the world capitalist system. That whole period also had an ecological dimension, which was primarily based on the largely inconspicuous destruction of the environment of the natives subjected to European colonization by much of the rest of the world[5].

The resource wars and their pernicious impact on the future of the world

It follows, therefore, that the current resource wars are not merely an undesirable by-product of the dysfunctionality of the logic of capital. Whole countries of devastated resources, altered ecosystems, mass movements of labour and population dependent on national economies, economy of resources and resource transfer, over-exploitation of the environmental weaknesses of certain societies in order to promote greater imperialist control, disposal of waste that deepens the gap between the centre and

[3] Foster, Clark and York [3] estimate that "in the early 1960s, humanity used *half of the planet's biocapacity* in a year. Today, that figure exceeds the planet's regenerative capacity by 30 percent. Predictions based on 'business as usual' indicate a state in which, by mid-2030, humanity's *ecological footprint will be equated with the regenerative capacity of twice the planet*" [3].
[4] David Harvey describes this contradiction by stating that "politicians and people in power usually seek results that would maintain or increase the power of their state over others, the capitalist seeks individual profit and is responsible only before his immediate social circle (although he sees that the laws restrict him)…" [15].
[5] John Bellamy Foster & Brett Clark [6] referred to the ideas of Alfred Crosby who in 1986 published a book entitled Ecological Imperialism: The Biological Expansion of Europe, 900-1900, in which this American historian argues that "the introduction of the flora and fauna of the Old World into the environment of the New World has caused demographic explosions of negative consequences for native species". But these authors rightly point out that the "biological expansion" of which Crosby speaks has absolutely "no direct connection with imperialism as a political-economic phenomenon." In other words, environmental imperialism acted as a "purely biological" force.

the periphery, all these are the factors that lead to an acute "metabolic discontinuity" which, globally extended, becomes a major feature of the relationship between capitalism and the environment, stopping, simultaneously and paradoxically, capitalist development.

With the end of the Cold War, the collapse of the Soviet bloc and the supposed victory of world capitalism (parliamentary democracy, liberal ideology, free market and Western values), the world has entered a new evolutionary phase, almost always presented as the "new world order". The fact that, for the first time in the history of the modern nation-state, the major powers were not involved in direct geopolitical and military rivalries provided a certain level of optimism regarding the possibility of achieving long-term world peace which would lead to general prosperity. However, a few months after the fall of the Berlin Wall, a period full of wars began, which, regardless of its origin, nature and outcome, became part of the internationalization of capitalist imperatives[6]. From the 1990-1991 Gulf War through the dissolution of the former Yugoslavia 1991-1995, the mass bombing of Serbia and Montenegro from March to June 1999, the invasion of Afghanistan in 2001 and Iraq in 2003, up to the intervention in Libya in 2011, the civil wars in Syria in 2011 and Ukraine in 2014, to name just a few, one can observe a panorama of startling and chronic instability in international security. What are the causes of such systemic extreme violence in the script, seemingly without the tension caused by the confrontations of the big blocs or the hegemonic forces of global character?

Almost all contemporary wars represent the struggle for power which is focused on the following three spheres: control over territory, natural wealth and wealth producing people. In short, all the wars of today are part of the production dynamic of historical capitalism, in order to give continuity to the social, economic and political restructuring of the various forms of accumulation required by the hegemonic powers that are being replaced. It is, therefore, a phenomenon that, if put into an analytical framework, can be emphasized through: 1) the globalization of capitalist economy operating in a single accumulation space that manages economic, financial and monetary flows; organizing production and distribution activities in accordance with the unitary logic of exploitation, hierarchy and stratification; 2) the temporal dimensions of the world capitalist system in its "long term cycles" (Brodel), which, for more than five centuries of existence, can be characterized as a set of processes interconnected by systemic cycles of accumulation and their corresponding hegemonic models that, at various moments, impose certain global order. The first dimension indicates that resource wars will be inevitable, while the second warns of their long duration.

The energy production of the world capitalist system based on the exploitation of non-renewable fossil resources has fallen sharply. Global markets and political-military forces are making geopolitical compromises, thereby confirming the progressive decline of democracy in the institutional spaces of the international system. The rapid union of military forces and corporate interests of large transnational powers lacking any legitimacy creates the feeling that Mussolini’s old dream has come true: “a free market limited by the military”. It is a complex process whose incredible continuity has become the new "great transformation" (Polanyi), causing: a) a definitive dissolution of the Welfare State and its political, economic and social model of governance; b) as a result of the aforementioned, the end of the traditional concept of sovereignty led by the nation-state; c) a conservative turn where democracy is reduced to “electoral engineering” serving large capital and interests beyond demos, both locally and globally. At the same time, progressive privatization of public goods at all levels (local, state - national, regional and global) has taken place, significantly endangering human security and its relationship with the development of human and human rights. Today, there are at least six major threats to human security whose common denominator is the competition for natural resources and the world's geopolitical background: 1) socio-economic threats affecting phenomena such as

[6]Nowadays, wars and tensions offer different forms of military confrontation, such as international conflicts, civil wars, serious internal disturbances, independence movements, border disputes, although negotiations are ongoing and efforts are being made to reach a peace agreement. The geographical spread of the new wars is concentrated in the first axis originating in the Balkans (Bosnia, Kosovo), extending to the Caucasus (Chechnya) and the Middle East (Palestine, Lebanon) to reach the Middle East (Iraq), Central Asia (Afghanistan). and the Indian subcontinent (Kashmir). The second axis is located on the African continent, starting from the Gulf of Guinea (Sierra Leone) to central Africa (Democratic Republic of the Congo, Burundi, Rwanda ...) and eastern Africa (Sudan, Eritrea, Somalia). The specific case that permeates both axes is the presence of the Islamic State (ISIS) from Iraq and Syria, which crosses the Arabian Peninsula to reach Libya, Nigeria and West Africa.

poverty, migration, infectious diseases and environmental destruction; 2) interstate conflicts, most of which are latent but not less dangerous; 3) internal tensions with the most serious consequences ranging from civil war, crimes against humanity to genocide; 4) the arms industry and increasingly less controlled purchase and sale of weapons of mass destruction; 5) terrorism and its global projection; 6) internationally organized crime, often fuelled by the lack of a rule of law in several countries.

In short, the resource wars and their geopolitical scenario will continue to affect the fields of international politics and the world economy as well as the global financial system in the coming decades and present at the same time a major obstacle to achieving the desired balance between sustainable human development, human security and human rights.

CONCLUSION

Nature is a social category. Humanity has always seen in it a useful tool, not a power in itself. The goal of trying to discover the autonomous laws of nature is to conquer them and expose them to human needs, as an object of consumption or a means of production. Marx argued that every mode of production of life creates a socio-natural metabolic order. Capitalism was no exception. But the specific difference of capitalism compared to the modes of production that preceded it lies in the enormous contradiction between the forces and relations of production, on the one hand, and the constant exhaustion of the conditions of an external nature, on the other. According to Michael Löwy, "protecting the ecological balance of the planet and preserving a favourable environment for living species, including our own is not in line with the expansive and destructive logic of the capitalist system" [16]. That is, any attempt to restore the metabolic balance between society and nature would inevitably be accompanied by the transition to a new post-capitalist civilization pattern. If anti-system forces manage to separate capitalist production from dependence on non-renewable fossil natural resources by destroying the establishment of a closed world energy system, and if in the future the production system shifts to the exclusive use of renewable non-fossil resources through an open and democratic energy system, we will attend the "end of capitalism as we know it" (Altvater).

While it is true that economic globalization has transformed the nation-state into a mere instrument of global capital, it does not imply the disappearance of political power. The ubiquity of corporate powers, which comprise the bulk of the world's capital, still depends on the political-military apparatus of the states that still protect the processes of enrichment and the acquisition of power. State and political authorities fit perfectly into the expansionist logic of capital, which recognizes neither borders nor physical-natural barriers. That is why the resource wars pose the greatest threat to humanity at the moment. Their destructive potential will have lasting consequences for society and nature. Therefore, the greatest imperative that today's world must face is to abolish market fundamentalism through democratic regulation and to put capital under social control, in order to prevent global transformations from causing social and environmental catastrophe.

REFERENCES

[1] Marx, K., Manuscritos económico-filosóficos. Madrid, Alianza Editorial, 1968.
[2] Krutzen, P., Stroemer, E., The Anthropocene. Global Change Newsletter, No. 41, The International Geosphere–Biosphere Programme (IGBP), A Study of Global Change of the International Council for Science (ICSU), p.17, 2000.
[3] Foster, J.B., Clark, B., York, R., The Ecological Rift: Capitalism´s War on the Earth. New York, Monthly Review Press, pp.14;18, 2010.
[4] www.jornada.unam.mx/2015/01/02/opinion022oleco
[5] Benton, T., (ed.), The Greening of Marxism. New York, The Guilford Press, 1996.
[6] Foster, J. B., La ecología de Marx. Materialismo y naturaleza. Barcelona, El Viejo Topo, pp. 231-232, 2004.
[7] O´ Connor, J., Causas naturales: ensayos de marxismo ecológico. México, Siglo XXI, 2001.
[8] Martínez Alier, J., The Environmentalism of the Poor: A study of ecological conflicts and valuation. Northampton, MA, Edward Elgar, 2002.

[9] Smith, N., Nature as accumulation strategy. En Panitch, L., Leys, C., (Eds.), Socialist Register 2007: Coming to terms with nature, pp. 16-36, London, Merlin Press, 2006.
[10] Moore, J., Ecology, Capital, and the Nature of Our Times: Accumulation and Crisis in the Capitalist World-Ecology. Journal of World-Systems Research 17(1), pp. 108-147, 2011.
[11] Moore, J., De objeto a Oikeios: la construcción del ambiente en la ecología-mundo capitalista. Revista Sociedad y cultura, Vol. 2, pp. 87-107, 2014.
[12] Altvater, E., Hacia una crítica ecológica de la economía política. Mundo Siglo XXI, 1, (2), pp. 9-27, 2005.
[13] Altvater, E., ¿Existe un marxsimo ecológico? En Boron, A., Amadeo, J., González, S. (Eds.), La teoría marxista hoy: problemas y perspectivas, pp. 341-363, Buenos Aires, CLACSO, 2006.
[14] Marx, K., El Capital, 3 tomos. México, Siglo XXI, 1975.
[15] Harvey, D., El nuevo imperialismo. Madrid, AKAL, p.40, 2004.
[16] Löwy, M., Ecosocialismo. La alternativa radical a la catástrofe ecológica capitalista. Buenos Aíres, Ediciones Herramienta-Editorial el Colectivo, p.11, 2011.

SOME ISSUES IN CLIMATE CHANGE: IMPACTS AND POLICIES

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Abstract: Anthropogenic greenhouse gas (GHG) emissions have increased since the pre-industrial era, driven widely by increasing numbers of the population, economic structure, human activities and economic growth and causes of the environmental pressures, influences and challenges. Influences of human on the climate and environmental systems are clearly and recently man-made GHG emissions globally are the largest in history. Nowadays, carbon dioxide (CO_2) concentrations in the atmosphere reached 400 parts per million (ppm), which representing the highest levels in 800.000 years. The aim of the present study is to give an overview, over the past decades and up-to-date in the climate change and its impacts as well as global warming in general, it serves as an introduction assessing atmospheric concentrations of GHGs and gives general background reviews on the climate change policies of reducing GHG emissions at European Union (EU) and at international levels for the climatic and environmental changes. Climate policy is an important tool [e.g., EU Emissions Trading System (ETS)] to combat the impacts of climate change caused by mankind in general. Therefore, meeting the Paris Agreement's climate objectives will require and needed drastic reductions in global GHG emissions and global transition towards decarbonisation of human activities, as well as moving towards a low-carbon economy of the future. At the same time, evidence of climate change impacts is clear and the problem will become more and more urgent as the GHG accumulation continues and the costs of damages and adaptation to climate change arise. In addition, climate change impacts are projected to increase in future years which may result in major environmental changes as well as economic and social difficulties.
Key words: Global Warming, CO_2, Climate Change Policy, GHG Reduction, Cost-effectively

INTRODUCTION

In general, climate change has far-reaching impacts on life on Earth. The Earth system provides the basis for all human societies and their economic activities. However, the 7 billion humans alive today is collectively exploiting the Earth's resources at accelerating rates and intensities that surpass the capacity of its systems to absorb the adverse effects on the environment [1]. Changes in the environment are caused by both natural and human processes, through the transformation and movement of energy and matter. Natural systems are constantly changing through various processes known as biogeochemical cycles. Human activities, directed towards transforming matter and energy into products and services for human consumption, affect these natural cycles [2]. There is unequivocal evidence that the Earth's climate is warming. Nowadays, the atmospheric concentration of CO_2, the most important and threatening GHG, is at its highest level for at least 800.000 years [3]. Scientific evidence suggests that man-made GHG emissions, especially CO_2 emissions, are a factor contributing to global climate change. This global climate change negatively impacts our Earth planet [4]. Therefore, by 2012, the average global surface temperature was 0.85 degree Celsius (°C) higher than in 1880, according to the UN Intergovernmental Panel on Climate Change (IPCC), which brings together thousands of the world's leading climate scientists. Each of the past three decades has been warmer than any preceding decade since records began in 1850 [3]. According to three different observational records of global average annual near-surface (land and ocean) temperature, the last decade (2006-2015) was 0.83 to 0.89 °C warmer than the pre-industrial average, which makes it the warmest decade on record. Of the 16 warmest years on record, 15 have occurred since 2000. The year 2015 was the warmest on record, around 1 °C warmer than the pre-industrial level, followed by 2014 [5]. In fact, over the past century, releases of gases and particulates derived from industrial processes and other human activities have led to significant changes in the composition of the atmosphere, many of which have been linked to detrimental effects on human health, ecosystems and the built environment [6]. The pressures arise from the production and consumption of goods and services, from the generation and treatment of wastes, and from the impact of those activities, which deplete and degrade the Earth's natural resources [2].

SOME ASPECTS OF CLIMATE CHANGE AND ITS IMPACTS ON ECOSYSTEMS

Climate change is a global problem that people are faced with in this century. Nowadays scientists mostly agree on the fact that climate change really occurs. Every country in the world will be affected in some way by climate change [7]. The consensus among climate experts is that it is extremely likely that the main cause of recent warming is the 'GHG's emitted by human activities, in particular the burning of fossil fuels - coal, oil and gas - and the destruction of forests [3]. Therefore, the main sources of man-made GHG emissions globally are the burning of fossil fuels for electricity generation, transport, industry and households - which together account for about two-thirds of total global emissions [8]. Generally, there is a need to reduce global GHG emissions substantially to avoid the most adverse impacts of climate change. However, even with substantial reductions in GHG emissions, the climate will continue to change, and the impacts will be felt across the world, including in Europe [5]. Further, the purpose of environmental protection is to keep the smooth operation of ecological systems, to maintain environmental assets as well as environmental conservation in general and to ensure the sustainable use of natural resources, which are essential to the life conditions of present and future generations [9]. Additionally, climate-friendly technology became promoted in order to mitigate and avoid of danger gas emission causing climate change and global warming at international level [10]. Further, over the last decade the emerging global trade in carbon has become increasingly central to efforts to govern climate change [11]. Carbon pricing, particularly in Europe, is achieved by a combination of ETS and carbon tax [12]. The key economic rationale behind emissions trading is to use market mechanisms to ensure that emissions reductions required to achieve a pre-determined environmental outcome take place where the cost of reduction is the lowest [13].

The environmental economic analyses became very actual, because of the negative influences of the human activities and the performances of the economies of the world economy including the EU-28 member states on the nature [14]. The sustainability includes the environment friendly technology and productivity of industry and agriculrual industry [15]. In general, environmental problems are the main challenge facing all countries in the world [16]. One of the main global environmental concerns is climate change resulting from the emissions of GHGs [17]. Changing climate has implications for a range of issues such as economic activity, flooding, storms, agriculture, fisheries, and energy demand [18]. Climate change will continue for many decades to come, having further impacts on ecosystems and society [5]. The United Nations Framework Convention on Climate Change (UNFCCC) defines climate change as "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods" [1]. Furthermore, the global, man-made warming is causing discernible climatic and environmental changes, such as rising sea levels, and the melting of glaciers and polar ice [3], increases in global mean ocean temperatures. Improved climate projections provide further evidence that future climate change will increase climate-related extremes (e.g. heat waves, heavy precipitation, droughts, top wind speeds and storm surges) in many European regions. Hence, global climate change has substantially increased the probability of various recent extreme weather and climate events in Europe [5]. So, some consequences of climate change impacts are: rising sea levels threaten low-lying island states and coastal communities; extreme weather events endanger food production, especially in the poorest developing countries; heat waves over the past decade have caused tens of thousands of premature deaths in Europe; water and food shortages could trigger regional conflicts, famine and refugee movements; some plant and animal species are at increased risk of extinction; and, the cost of not adapting to climate change is estimated to reach at least €100 billion a year by 2020 for the EU as a whole [19].

The main GHGs are carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). CO_2 emissions are primarily released through the burning of fossil fuels such as coal, oil, gas and peat. CO_2 is emitted through poor land management and land use changes such as deforestation and urbanisation. The main sources of CH_4 and N_2O emissions in general are from the agriculture sector including livestock, manure management and application of fertilisers. Over the last 200 years, the concentrations of the main heat-trapping GHGs have increased significantly in the atmosphere; CO_2 by 40%, CH_4 by 150% and N_2O by 20%. These three gases are now higher than they have been for at least 800.000 years. The consequences of this are most clearly evident in the global temperature records, which show that, on average, the global temperature has increased by 0.85 °C since records began in the mid-19th century.

Continued emissions at or above current levels will cause further warming and result in changes in the global climate system during the 21st century that would very likely be larger than those observed during the 20th century [20]. In addition, by 2012, global temperatures had increased by approximately 1 °C above pre-industrial temperatures [21, 22], equivalent to about 0.01 °C yr^{-1} with about 20cm sea-level rise [23, 22], and there are increasing numbers of unusual weather events that have been related to climate change [24, 22]. By the time, temperature increases reach 2 °C, or sea level rise reaches 40cm, would impacts be twice as bad or increase more sharply? If impacts increase sharply with increasing perturbations, then overall damages would be largely determined by impacts at the times of highest perturbations, whereas with a less steep impact response function, impacts at times with lesser perturbations would contribute more to overall damages [22]. So, climate change remains a major threat to humanity's future, and mitigation is necessary to avoid those threats [22].

Rapidly economic growth and human activity is largely responsible for the increase in the concentration of CO_2 in the atmosphere. In 2016, the average concentration of CO_2 in the atmosphere is close to 400 ppm, which is the highest level for at least the last 800 thousand of years and about 40% higher than the pre-industrial levels [5]. More recently, in September 2018, CO_2 concentrations in the atmosphere were 409.02 ppm, the highest levels in 400 thousand of years, and up approximately 6% since 2008, September (385.28 ppm), as rising in one decade [25].

In general, overwhelming scientific evidence has demonstrated the link between increasing atmospheric concentrations of GHGs and rising global temperatures. Average temperatures have increased over the past 50 years at a rate of 0.2 °C per decade, largely as a result of human activity [12]. Further, three different long-term observational records show that the global average annual near-surface (land and ocean) temperature in the decade 2006–2015 was 0.83 to 0.89 °C higher than the pre-industrial average. The year 2015 was the warmest on record globally, at about 1 °C above the pre-industrial level [5]. Furthermore, European land areas in the decade between 2006 and 2015 have warmed by around 1.5 °C since the pre-industrial age. The years 2014 and 2015 were jointly the warmest years on record in Europe. Moreover, global warming between 0.3 and 4.8 °C is projected for the 21st century, depending on the emissions scenario. The annual average land temperature across Europe is projected to continue increasing faster than global average temperature. The strongest warming is projected across north-eastern Europe and Scandinavia in winter and southern Europe in summer [5]. Nevertheless, there has been a progressive decoupling of GDP and GHG emissions since 1990, with an increase in GDP of about 50% alongside a decrease in emissions of almost 24% over a 25 year period (1990-2015), this decrease was a combined result of policies (e.g., increasing renewable energy sources, the use of less carbon-intensive fossil fuels like switch from coal to gas and improvements in energy efficiency), economic factors (e.g., structural changes in the economy and economic crisis) and climatic conditions in general [26]. So, almost all EU Member States reduced their emissions compared with 1990 and thus contributed to the overall positive EU performance [26]. In addition, EEA found that the decrease in primary energy intensity was the largest contributing factor to lower CO_2 emissions from fossil fuel combustion in the past. It is expected to remain a key factor in the transition to a low carbon economy. This means continued improvements in energy efficiency, both in transformation and end-use [27].

Overall, The global atmosphere is at a critical stage, particularly in relation to climate change [1]. So, climate change is one of the key drivers of global environmental change and has far-reaching consequences [28]. On one hand, climate change impacts are projected to increase in future years, which may result in major environmental changes as well as economic and social difficulties. The scientists mostly agree that further increase in the emission of harmful GHGs will result in global warming and would cause more damage than ever before in the climate system and that is a problem we need to solve. On the other hand, there is considerable scientific evidence of the causes and solutions that could protect human health and ecosystems, and effective action has resulted in the achievement of some internationally agreed goals [1]. Hence, to mitigate climate change, we must reduce or prevent GHG emissions [29], and policymakers must implement climate change policies in an effort to decrease carbon emission and mitigate its negative impacts. As such, several countries have implemented carbon taxes in an effort to curb the potential destruction from increasing carbon in our atmosphere [4].

SOME ISSUES IN CLIMATE CHANGE POLICIES ON REDUCING GHG EMISSIONS

Worldwide, GHG emissions continue to rise every year. This global challenge requires a global response [19]. Therefore, a major international agreements have been adopted to address climate change: the 1992 United Nations Framework Convention on Climate Change (UNFCCC) and its 1997 Kyoto Protocol. The Kyoto Protocol, which entered into force in 2005, is a first step towards reversing the global trend of rising emissions. The EU wants Kyoto to be succeeded by a truly global agreement that requires action not only from all developed countries - which have a duty to continue leading - but by all countries. And also, the EU, establishes a framework for international cooperation with the ultimate objective of preventing dangerous man-made interference with the global climate system [3]. In addition, the EU has a range of policies to reduce emissions, promote clean energy and energy efficiency, and stimulate Europe’s transition to a low-carbon economy [19].

The EU ETS, as the world’s largest carbon market and as the major source of demand for international credits under the Clean Development Mechanism (CDM) and Joint Implementation (JI), is an important driver of international carbon markets and the international carbon price [30]. Furthermore, the EU ETS is the world’s first international company-level ‘cap-and-trade’ system of allowances for emitting CO_2 and other GHGs. Building on the innovative mechanisms (e.g., flexible mechanisms) set up under the Kyoto Protocol - international emissions trading, the CDM and JI - the mandatory system has rapidly become the dynamo behind the expansion of the international carbon market. Therefore, by putting a price on each tonne of carbon emitted, the EU ETS is driving investment in low-carbon technologies. It has forced the cost of emissions onto the agenda of company boards, thus marshalling the ingenuity and creativity of the business community in finding innovative and least-cost ways to fight climate change. In general, the system or the scheme is one of the EU’s most important means of achieving emission reduction goals, established through binding legislation (Directive 2003/87/EC) proposed by the European Commission and approved by the EU Member States and the European Parliament, is based on four fundamental principles, which are as the followings [31]:

- It is a ‘cap-and-trade’ system;
- Participation is mandatory for businesses in the sectors covered;
- It contains a strong compliance framework; and,
- The market is EU-wide but taps into emission reduction opportunities in the rest of the world by accepting credits from emission-saving projects carried out under the Kyoto protocol’s CDM and JI instrument [31].

A key aspect of the EU ETS is that it allows companies to use credits from the Kyoto Protocol’s project-based mechanisms - the CDM and JI - to support them comply with their obligations under the system. This means the EU ETS not only provides a cost-effective means for EU-based industries to reduce their emissions but is also channelling considerable business investment into emission-reduction projects in developing countries and economies in transition. This stimulates the transfer of environmentally sound advanced technologies to these countries, giving a support to their efforts to achieve sustainable development [32]. In the context of the global climate change negotiations, tradable emission permits have emerged as an essential policy tool [33]. The primary purpose of the EU ETS is to reduce carbon emissions from power producers and energy-intensive industries [11]. Further, the objective of the EU ETS is the mitigation of a global environmental problem [34]. The basic idea is that one emission allowance is needed for every tonne of GHG emissions produced [35]. In addition, carbon pricing can persuade the most virtuous firms to invest in new technologies, with a twofold goal: firstly, to avoid purchasing costly tradable permits; secondly, to sell, and thus monetise, the available permits in excess [36]. The EU ETS is one of the key climate policy instruments implemented in the EU to reduce GHG emissions [37]. It was established by the Emissions Trading System or Emissions Trading Scheme Directive (Directive 2003/87/EC establishing a scheme for GHG emission allowance trading within the Community and amending Council Directive 96/61/EC) [38] and entered into force on 1 January 2005, in the context of international mitigation commitments by the EU under the Kyoto Protocol [39]. Finally, so far, emissions trading under the EU ETS has taken place as part of three trading periods: phase 1 (2005-2007), phase 2 (2008-2012) and phase 3 (2013-2020). Phase 4 is planned (European Commission presented a legislative proposal for the revision of the EU ETS for phase 4 in July 2015 [40] for the period 2021-2030 [41].

Further, the system covers around 45% of total GHG emissions from the EU-28 and is aimed directly at cutting emissions by 21% below 2005 levels by 2020. Under the third phase of ETS, auctioning becomes the default method of allocating allowances and at least 50% of the revenues generated should be used for climate-related purposes. Furthermore, there has been a gradual extension over time of EU policy objectives and targets relating to the reduction of GHG emissions and the transition to a low‑carbon economy. For 2020, there is a 20% reduction target for EU GHG emissions from 1990 levels, while for 2030 and 2040, 40% and 60% reductions are foreseen compared to 1990. The ultimate overall ambition is to cut the EU's emissions by 80% below 1990 levels by 2050 through domestic reductions alone [42]. Nevertheless, ETS emissions decreased by 24% compared to 2005. Emissions levels observed in 2014 were the lowest since the scheme was launched in 2005. Consequently, the 2020 target level set for stationary installations (represented by the cap in 2020) was already reached in 2014 [39]. And also, between 2005 and 2017, emissions from stationary installations declined by 26%. This reduction was largely the result of changes in the mix of fuels used to produce heat and electricity, in particular less use of hard coal and lignite fuels, and an increase in electricity generation from renewables, which almost doubled over the period 2005-2017 [43]. In general, the EU has set emissions reduction target for 2020, aim to reduction in the EU GHG emissions of at least 20% below 1990 levels, increase the share of renewable energy (e.g., wind and solar) to 20% of EU energy use, and improve energy efficiency by 20% [3]. The 20-20-20 targets were established using economic modelling to imply least-costs for the EU economy as a whole in moving towards a low-carbon economy [30].

The Paris Agreement is a legally binding international treaty. It entered into force on the 4th of November 2016, following its ratification by the EU [44]. In order to achieve the goal of the Paris Agreement, parties will prepare, communicate and maintain successive nationally determined contributions [45]. The EU was the first major economy to submit its Intended Nationally Determined Contribution to the Paris negotiations already in March 2015: a binding, economy-wide domestic emissions reduction target of at least 40% by 2030, compared to 1990 levels [3], with no contribution from international credits [46, 44]. As an economy-wide objective, all sectors of the economy are due to contribute to emissions reductions [44]. Further, the Paris Agreement provides the basis for emissions mitigation and adaptation from 2020 onwards [47]. In order to prevent the most severe impacts of climate change, the countries that signed up to the UNFCCC have agreed to limit the global mean surface temperature increase since pre-industrial times to less than 2°C. [29]. Meeting the Paris Agreement's climate goals will require an immediate and worldwide shift toward decarbonising human activities. According to the IPCC, global emissions will have to peak in the next few years and then rapidly decline over the following three decades, approaching zero by 2050, if the world is to have a likely chance of limiting warming in line with the 1.5°C or 2°C goals established in the Paris Agreement. In addition, emissions benchmarks that correspond with 1.5°C or 2°C scenarios are moving targets, and if the world misses them in the short term, climate trajectories would worsen and long-term goals would become more difficult to meet [48].

Furthermore, several EU initiatives aim to cut GHG emissions. After having achieved its objectives under the Kyoto Protocol for the period from 2008 to 2012, the EU adopted a GHG emissions reduction target of 20% below 1990 levels by 2020. To achieve this target - one of the main targets under the Europe 2020 Strategy - a cap for the EU ETS was set at EU level, and individual national targets for emissions in sectors not covered by the ETS were set under the Effort Sharing Decision [29]. However, the EU Effort Sharing Decision, which establishes binding emission targets for 2013-2020 for transport, agriculture, buildings and waste, all sectors that are currently not covered by the EU ETS [1]. The EU also aims to support the development of carbon capture and storage technologies to trap and store CO_2 emitted by power stations and other large installations [29]. A variety of renewable energy and efficiency policies could enable the climate and energy targets to be met while securing even better economic prospects [49]. According to the commission, total GHG emissions from the 28 members had by 2011 fallen to 16.9% below the 1990 level, and to 18% lower by 2012. Nevertheless, the 2011 and 2012 reductions partly reflect the drop in industrial output in Europe after the financial crisis, which plunged almost all of the bloc's nations into recession - something policy makers are desperate to reverse [50]. Ultimately, an important policy principle suggests that it is more efficient to promote practices that do not damage the environment rather than spending on cleaning up after a problem has been created [51].

CONCLUSION

In recent decades, changes in climate have caused impacts on human and natural systems, such as human diseases and environmental problems. So, the earth's average temperature has been increasing since the industrial revolution. The atmosphere and ocean have warmed, the amounts of snow and ice have diminished, sea level has risen, and the concentrations of GHGs have increased. Each of the last three decades has been successively warmer at the Earth's surface than any preceding decade since 1850. The build-up of GHGs in the atmosphere is projected to increase climate changes in future. Therefore, an effective response to the climate change problem at global level requires both a concerted international response and national efforts to reduce GHG emissions as well as much more robust and effective action than it was before. Moreover, as included in the IPCC reports if the atmospheric CO2 concentrations in 2100 reaching approximately 450 ppm or below are likely to maintain warming below 2 °C over the 21st century relative to pre-industrial levels. This limiting will require significant and sustained reductions in GHG emissions at global levels. And also, there is an urgent need to address the underlying drivers of the human pressures and influences on the climate and environmental systems. At the same time, scientists from all over the world are realising that the Earth is becoming warmer than ever before.

REFERENCES

[1] United Nations Environment Programme., Global Environment Outlook (GEO-5) - Environment for the future we want. UNEP, 2012. ISBN: 978-92-807-3177-4.
[2] Lehane, M., Le-Bolloch, O., Crawley, P., Environment in Focus 2002 - Key Environmental Indictors for Ireland. Environment Protection Agency, Ireland, 2002. ISBN: 1-84095-089-7.
[3] European Commission Climate Action., Climate Change. EU publications, November 2015. ISBN: 978-92-79-52756-2. DOI: 10.2834/34323
[4] Harper, C.K., Climate Change and Tax Policy. Boston College International and Comparative Law Review, Vol. 30, pp. 411-460, 2007.
[5] European Environment Agency., Climate change, impacts and vulnerability in Europe 2016 - An indicator-based report. EEA Report No 1/2017. Luxembourg: Publications Office of the EU, 2017. ISBN: 978-92-9213-835-6. ISSN: 1977-8449. DOI: 10.2800/534806
[6] United Nations Environment Programme/United Nations Economic Commission for Europe., Global Environment Outlook (GEO-6) - Assessment for the Pan-European Region. UNEP/UNECE, Nairobi, 2016. ISBN: 978-92-807-3545-1.
[7] Schürch, R., CO_2 Taxation versus Emissions Trading - An Analytical Representation for Switzerland [thesis]. Faculty of Science, University of Bern; 2011. Available at: http://occrdata.unibe.ch/students/theses/msc/39.pdf
[8] European Environment Agency., The European environment - State and outlook 2010: synthesis. EEA, Copenhagen. Luxembourg: Publications Office of the EU, 2010. ISBN 978-92-9213-114-2. DOI: 10.2800/45773
[9] Hungarian Central Statistical Office., "Environmental report, 2013," Prepared by Rural Development, Agriculture and Environment Statistics Department, HCSO. Xerox Magyarország Kft, Budapest, 2014, ISSN: 2064-017X. Available at: http://www.ksh.hu
[10] Gál, Zs., Zsarnóczai, J.S., Samara, B., "Green Policy in East Asian and Pacific Region," Economics and Working Capital, WCTC Ltd.: London, October, 2016, ISSN: 2398-9491.
[11] Bailey, I., Gouldson, A., Newell, P., Ecological Modernisation and the governance of carbon: a critical analysis. The Governance of Clean Development Working Paper 009/ Centre for Climate Change Economics and Policy Working Paper Series No 26. School of International Development, University of East Anglia UK and CCCEP, Leeds UK, 2010; 19 p. Available at: https://www.cccep.ac.uk/wp-content/uploads/2015/10/WP26_ecological-modernisation-carbon.pdf
[12] National Treasury., Reducing Greenhouse Gas Emissions: The Carbon Tax Option. Discussion Paper for Public Comment. South Africa: National Treasury, December 2010; 75 p. Available at:

http://www.treasury.gov.za/public%20comments/Discussion%20Paper%20Carbon%20Taxes%2081210.pdf

[13] Piovan, M., The European Union Emission Trading Scheme. Claremont-UC Undergraduate Research Conference on the European Union, Vol. 2009, Article 10, 2009. DOI: 10.5642/urceu.200901.10; https://scholarship.claremont.edu/urceu/vol2009/iss1/10/

[14] Zsarnóczai, J.S., Bence, O., "Environmental economics in EU and Hungary in 2010s," Economics and Working Capital, WCTC Ltd.: London, 1-2 issues, pp. 6-14, 2018.

[15] Zsarnóczai, J.S., Zéman, Z., Output value and productivity of agricultural industry in Central-East-Europe. Agricultural Economics - Czech, Vol. 65, No. 4, pp. 185-193, 2019.

[16] Awan, A., Relationship between environment and sustainable economic development: A theoretical approach to environmental problems. International Journal of Asian Social Science, Vol. 3, pp. 741-761, 2013.

[17] Delaney, J., McGettigan, M., Air quality and emissions to air report 2003. Environment Protection Agency, Wexford. Ireland, 2005. ISBN: 1-84095-147-8.

[18] Environment Protection Agency., Ireland's Environment 2004 - the State of the Environment. EPA, Wexford, Ireland, 2004. ISBN: 1-84095-134-6.

[19] European Commission Climate Action., The European Union explained: Climate action. Luxembourg: Publications Office of the EU, 2014. ISBN: 978-92-79-41342-1. DOI: 10.2775/83031

[20] Environmental Protection Agency., Greenhouse Gases & Climate Change Factsheet. EPA, Ireland, 2013. Available at: http://www.epa.ie/pubs/reports/indicators/epa_factsheet_greenhouse_v2.pdf

[21] Jones, P.D., Lister, D.H., Osborn, T.J., Harpham, C., Salmon, M., Morice, C.P., Hemispheric and large-scale land-surface air temperature variations: an extensive revision and an update to 2010. Journal of Geophysical Research: Atmospheres, Vol. 117, 2012. D05127, DOI:10.1029/2011JD017139

[22] Kirschbaum, M.U.F., Climate-change impact potentials as an alternative to global warming potentials. Environmental Research Letters, Vol. 9, No. 3, 2014. Available at: https://doi.org/10.1088/1748-9326/9/3/034014

[23] Church, J.A., White, N.J., Sea-level rise from the late 19th to the early 21st century. Surveys in Geophysics, Vol. 32, pp. 585-602, 2011.

[24] Trenberth, K.E., Fasullo, J.T., Climate extremes and climate change: The Russian heat wave and other climate extremes of 2010. Journal of Geophysical Research: Atmospheres, Vol. 117, 2012. D17103, DOI:10.1029/2012JD018020

[25] NASA., Global Climate Change - Vital signs of the Planet (Carbon Dioxide). National Aeronautics and Space Administration (NASA), Measurement: September, 2018. Available at: https://climate.nasa.gov/vital-signs/carbon-dioxide/

[26] European Environment Agency., Key trends and drivers in greenhouse gas emissions in the EU in 2015 and over the past 25 years. EEA, 2017. Briefing (Briefing no. 3/2017) Published 01 Jun 2017 Last modified 09 Jul 2019. ISBN: 978-92-9213-863-9. ISSN: 2467-3196. DOI: 10.2800/489536

[27] European Environment Agency., Trends and drivers in greenhouse gas emissions in the EU in 2016. EEA, 2018. Briefing (Briefing no. 5/2018): Published 31 May 2018. ISBN: 978-92-9213-965-0. ISSN: 2467-3196. DOI: 10.2800/691394

[28] European Environment Agency., Adaptation in Europe - Addressing risks and opportunities from climate change in the context of socio-economic developments. EEA Report No 3/2013. Luxembourg: Publications Office of the EU, 2013. ISBN: 978-92-9213-385-6. ISSN: 1725-9177. DOI: 10.2800/50924

[29] European Environment Agency., Climate change mitigation, EEA, 2017. Page Last modified 03 Feb 2017. Available at: https://www.eea.europa.eu/themes/climate/intro

[30] European Commission Climate Action., EU ETS Handbook. EU, 2015; 138 p. Available at: https://ec.europa.eu/clima/sites/clima/files/docs/ets_handbook_en.pdf

[31] European Commission., EU Action against climate change - The EU Emissions Trading Scheme. European Communities, 2008. ISBN: 978-92-79-12255-2.

[32] European Commission., EU Action against climate change - EU emissions trading: An open system promoting global innovation. European Communities, 2007. ISBN: 978-92-79-06862-1. Available at: https://ec.europa.eu/environment/pdfs/2007/pub-2007-015-en.pdf

[33] Organisation for Economic Co-operation and Development., The Tax Treatment of Tradable Permits for Greenhouse Gas Emissions. Centre for Tax Policy and Administration, Environment Directorate, OECD, December 2009. Available at: http://www.oecd.org/tax/tax-policy/44235444.pdf

[34] Martin, R., Muûls, M., de Preux, L.B.: Wagner UJ., On the empirical content of carbon leakage criteria in the EU Emissions Trading Scheme. Ecological Economics, Vol. 105, pp. 78-88, 2014. Available at: http://dx.doi.org/10.1016/j.ecolecon.2014.05.010

[35] Braschel, N., Posch, A., Pusterhofer, V., Allocation of Emission Allowances within the European Union Emissions Trading Scheme to the Waste Sector. Low Carbon Economy, Vol. 4, pp. 137-145, 2013.

[36] Borghesi, S., Montini, M., The European Emission Trading System: Flashing Lights, Dark Shadows and Future Prospects for Global ETS Cooperation. Transworld, Working Papers, No. 26. May 2013; 14 p. ISSN: 2281-5252. Available at: http://www.iai.it/sites/default/files/TW_WP_26.pdf

[37] European Environment Agency., Application of the EU Emissions Trading Directive - Analysis of national responses under Article 21 of the EU ETS Directive in 2014. EEA Technical report No 3/2015. Luxembourg: Publications Office of the EU, 2015. ISBN: 978-92-9213-639-0. ISSN: 1725-2237. DOI: 10.2800/814207

[38] European Union., Directive 2003/87/EC of the European Parliament and of the Council of 13 October 2003 establishing a scheme for greenhouse gas emission allowance trading within the Community and amending Council Directive 96/61/EC. OJ L 275. 25.10.2003; pp. 32-46. Available at: http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex:32003L0087

[39] European Environment Agency., Trends and projections in the EU ETS in 2015. EEA, Technical Report No 14/2015, Luxembourg: Publications Office of the EU, 2015. ISBN: 978-92-9213-695-6. ISSN: 1725-2237. DOI: 10.2800/472636

[40] European Commission., Proposal for a Directive of the European Parliament and of the Council amending Directive 2003/87/EC to enhance cost-effective emission reductions and low-carbon investments. Brussels, 15.7.2015, COM(2015) 337 final, 2015/148(COD). Available at: http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52015PC0337

[41] European Environment Agency., Application of the European Union Emissions Trading Directive - Analysis of national responses under Article 21 of the EU ETS Directive in 2016. EEA, report No 4/2017. Luxembourg: Publications Office of the EU, 2017. ISBN: 978-92-9213-849-3. ISSN: 1977-8449. DOI: 10.2800/624384

[42] European Environment Agency., Environmental taxation and EU environmental policies. EEA, Report No 17/2016. Luxembourg: Publications Office of the EU, 2016. ISBN: 978-92-9213-755-7. ISSN: 1977-8449. DOI: 10.2800/296823

[43] European Environment Agency., Trends and projections in the EU ETS in 2018 - The EU Emissions Trading System in numbers. EEA Report No 14/2018. Luxembourg: Publications Office of the EU, 2018. ISBN: 978-92-9480-003-9. ISSN: 1977-8449. DOI: 10.2800/542773

[44] European Commission., Commission Staff Working Document, Impact Assessment, Accompanying the Document, Proposal for a Regulation of the European Parliament and of the Council, amending Directive 2003/87/EC establishing a scheme for greenhouse gas emission allowance trading within the Community in view of the implementation of a single global market-based measure to international aviation emissions. Brussels, 3.2.2017, SWD(2017) 31 final. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52017SC0031&from=EN

[45] European Commission., Proposal for a Regulation of the European Parliament and of the Council, amending Directive 2003/87/EC to continue current limitations of scope for aviation activities and to prepare to implement a global market-based measure from 2021. Brussels, 3.2.2017, COM(2017) 54 final - 2017/0017 (COD). Available at: https://ec.europa.eu/transparency/regdoc/rep/1/2017/EN/COM-2017-54-F1-EN-MAIN-PART-1.PDF

[46] European Union., Intended Nationally Determined Contribution of the EU and its Member States. Submission by Latvia and the European Commission on Behalf of the European Union and Its Member States. Riga, 6 March 2015. EU, 2015. LV. Available at: https://www4.unfccc.int/sites/submissions/INDC/Published%20Documents/Latvia/1/LV-03-06-EU%20INDC.pdf

[47] Eurostat., Key figures on enlargement countries - 2017 edition. Luxembourg: Publications office of the EU, 2017. ISBN: 978-92-79-70772-8. ISSN: 2315-1943. DOI: 10.2785/3284

[48] United Nations Environment Programme., Renewable Energy and Energy Efficiency in Developing Countries: Contributions to Reducing Global Emissions. UN Environment Third Report. UNEP, 2017. ISBN: 978-92-807-3671-7.

[49] European Environment Agency., Environmental tax reform in Europe: Opportunities for eco-innovation. EEA Technical report No 17/2011. Luxembourg: Publications Office of the EU, 2011. ISBN: 978-92-9213-238-5. ISSN: 1725-2237. DOI: 10.2800/84889

[50] Castle, S.: Europe, Facing Economic Pain, May Ease Climate Rules. The New York Times, Jan. 22, 2014. Available at: http://www.nytimes.com/2014/01/23/business/international/european-union-lowers-ambitions-on-renewable-energy.html

[51] Pretty, J., Brett, C., Gee, D., Hine, R., Mason, C., Morison, J., Rayment, M., van der Bijl, G., Dobbs, T., Policy Challenges and Priorities for Internalising the Externalities of Modern Agriculture. Journal of Environmental Planning and Management. Vol. 44, pp. 263-283, 2001.

RAIL TRANSPORT INFLUENCE ON THE ENVIRONMENT

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Abstract: Recently, it's acknowledged that the rail transport are also a source of heavy metals pollution. Therefore, for a particular case, a literature review was performed to summarize the current knowledge regarding the concentration and distribution of heavy metals in the environment. The objectives of this paper were to compile information, to provide useful information for other future articles and to develop our common research activity.
Keywords: Heavy metals, railways, distribution, pollution, environment.

INTRODUCTION

Transport presents real challenges as society tries to ensure a more environmentally sustainable future. Environment is schematically presented in Figure 1 [7].

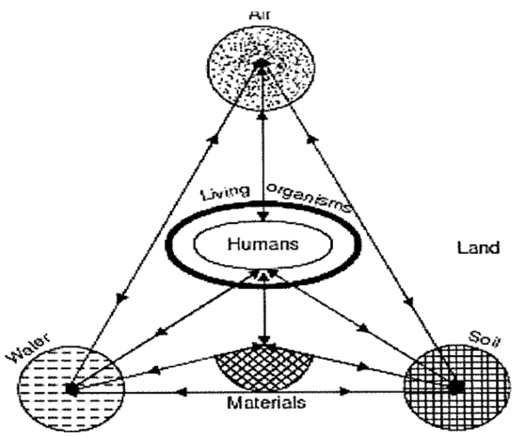

Figure 1. Concept of Environment [7]

According to the reference [1], „surface soil (0–10 cm) samples from 60 sampling sites along the length of railway tracks on the territory of Srem (the western part of the Autonomous Province of Vojvodina, itself part of Serbia) were collected and analyzed for seven polychlorinated biphenyls (PCBs) and ten heavy metals in order to see how the distance from the railroad aﬀ ects the concentration of some organic and inorganic pollutants in the soil.
From reference [2] point of view, heavy metal (As, Mn, Ni, Sn, Ti) concentrations were determined in soil and plant samples collected in different areas of the railway junction Iława Główna, Poland.
Reference [3] claims that railway transport is a source of pollution to soils and living organisms by e.g. PAHs, PCBs, oil-derived products, pesticides and heavy metals. Soil toxicity evaluation requires chemical analyses, indicating the type and content of particular pollutants, as well as biological analyses, which allow assessing the reaction of organisms to these pollutants.
This paper is focused on a multi-aspect evaluation of the degree of toxicity and pollution of soil in selected railway areas from north-eastern Poland by application of numerous biotests and chemical analyses.
According to the reference [4], the metal concentration in soil and plant is decreased with increasing distance from the road of highway and railway. Lead is one of the most toxic elements.

It is non-biodegradable and its toxicity does not change with time. Use of leaded gasoline in vehicles and train are known as the major source of lead pollution. Highway and railway of Tangail are two busiest routes of Bangladesh and pollution is rising day by day.
From reference [5] point of view, contamination of soils with three metals due to the highway and railway transport was studied. Copper was selected as a suitable indicator for both kinds of transportation. Sodium served to assess the level of contamination resulting from the road salting in winter. Mercury was determined in samples taken close to the railway in order to test its release from impregnated wooden ties.
Reference [6] claims that the paper describes environmental pollution in railroad right-of-way. The authors set a goal of collecting systematic data about concentration of pollutants in soils and surface run-off, which are close to railroad tracks and railway service enterprises. They also justified the choice of their research sites and described pollution forms typical for areas, which are close to railroad tracks. Petroleum products and iron were considered as main pollutants. The paper considers the Russian Legislation regulatory documents requiring enforcement of environmental protection measures to decrease dirty discharge into water bodies.
"The scientific paper aims at analyzing the current state of the railway infrastructure soil contamination with heavy metals (HM), namely, the three stations of Prydniprovska railway: Kamianske-Pasazhyrske, Zaporizhzhia-Kamianske and Trytuzna".[7]
„Multivariate statistical tools were employed to identify the sources of heavy metal introduction in soils across urban transportation facilities (roadside, railway, canal, airport, warehouse and bus stop) in Lagos Metropolis, Nigeria."[8]
„The aim of this work is the determination of petroleum hydrocarbons concentration in the soil samples and the investigation of the bioremediation technique for treatment heavily contaminated soil. Mineral oil leaking from vehicles or released during accidents is an important source of soil and ground water pollution."[9]

MATERIAL AND METHODS

"Samples were taken at a distance of 0.03–4.19 km from the railway. For the soil extraction was used USEPA 3540S method. The extracts were purified on a silica-gel column (USEPA 3630C). The analysis of the extracts was performed by gas chromatography with tandem mass spectrometry. PCBs were not detected only at two locations. Mean total concentration of PCBs for all other sampling locations was 0.0043 ppm dry weight (dw) with a range of 0.0005–0.0227 ppm dw". [1]
"Soil and plant samples were collected in four functional parts of the junction, i.e. the loading ramp, main track within the platform area, rolling stock cleaning bay and the railway siding. Four plant species occurring in relatively higher abundance were selected for heavy metals analysis, although in the loading ramp and platform areas only one species could be collected in the amount which makes chemical analysis possible. The selected species included three perennials (*Daucus carota, Pastinaca sativa and Taraxacum officinale*) and one annual plant (*Sonchus oleraceus*)". [2]
"The soils were sampled on railway tracks from the following railway stations: Białystok Fabryczny, Siemianówka, Hajnówka, Iława Główna and Waliły. The most toxic soils occur on the railway tracks at Białystok Fabryczny and Siemianówka. They had a significant toxic effect on test organisms from various trophic levels. The contents of PAHs, PCBs, heavy metals, oil-derived hydrocarbons and pesticide residues were determined in the examined soils.
In all cases the detected pollutants did not exceed the admissible levels. The highest content of oil-derived substances was noted in soils from Białystok Fabryczny and concentrations were moderate in soils from Siemianówka. Although the pollutants determined in soils from railway tracks did not exceed the admissible values, they had a toxic effect on numerous test organisms from different trophic levels". [3]
"To reveal the present situation in soil and plant samples were collected at various distances (0m, 15m, 30m) from Railway and highway roads and analyzed for lead by Atomic Absorption Spectrophotometric (AAS) method". [4]
"All analytes were determined using the methods of the trace element analysis; values are expressed as dry matter". [5]

“The authors carried out a set of field-tested experiments to measure the level of railroad right-of-way pollution”. [6]
“The research object is the soil of the above mentioned railway stations, the research subject is the total content of HM. Sampling was carried out every 15 m between and outside both rails up to the end of railway ties. The total area of the investigated sites is 600 m^2. The total form of Fe, Pb, Zn, Cu, Ni, Cd and Mn concentration was determined by the atomic absorption spectrometry method. The obtained data were compared with the background concentration of HM for Dnipropetrovsk oblast and the results of analyzing the reference control located at a distance of 250 m from the railway stations”. [7]
„Data for the study was obtained by collecting 30 surface soil samples (0 – 15cm) across 6 transportation facilities. Data obtained was taken to the laboratory for analysis of Cd, Cr, Cu, Fe, Ni, Pb and Zn using Atomic Absorption Spectrophotometer (AAS) technique”.[8]
„In the railway junction Niš (Serbia) total 90 soil samples polluted with mineral oil derivatives were investigated. Field work at the railway Niš sites included the opening of soil profiles and soil sampling. For determination of petroleum hydrocarbons in the soil samples method of gas-chromatography was carried out”.[9]

RESULTS AND DISCUSSION

“According to values of Nemerow pollution index Cu, Co, Zn and Ni were the most ubiquitous heavy metals in the area near railroad. Based on these results, it can be said that railway transport is a potential source of PCBs and some heavy metals”. [1]
“The entire area of the railway junction showed elevated concentrations of heavy metals when compared to the control level. It was most pronounced for the platform area and railway siding. The concentration of arsenic, manganese and nickel in plants growing in these parts of the junction exceeded the toxic level. The highest contamination of soil and plants found in the platform area suggested advanced emission process of the analyzed metals from wheel and track abrasion”. [2]
“This suggests a synergistic effect of low concentrations (within the admissible levels) of several pollutants together, which resulted in a toxic effect on the organisms. Thus, there is a strong need of not only chemical, but also ecotoxicological analyses during the evaluation of environmental conditions. Based on data obtained from biological and chemical analyses, we concluded that railway transport may pose a hazard to the natural environment to a larger extent that hitherto expected”. [3]
“The results show that the soil and plant samples along these places are contaminated with lead. The highest lead contents 0.1931 ppm in soil and 0.1358 ppm in plant was found for highway on road at 0m distance. Conversely, the highest lead contents 0.0967 ppm in soil and 0.0652 ppm in plant was found for railway on road at 0m distance.
Among two types of major transportation system railway pollution is smaller than highway and hence railway transportation system is environment friendly”. [4]
“The highest concentrations of copper, sodium and total mercury in soil samples were 52.7 mg/kg, 770 mg/kg and 0.181 mg/kg respectively. The highest copper content was observed in soils taken close to the railroad and the highway. Elevated sodium levels originated from winter road salting – the highest winter value was 770 mg/kg as compared with maximal summer value of 416 mg/kg. The concentration of total mercury in soils depended on the type of railway ties used – the highest values for location with wooden and concrete ties were 0.181 mg/kg and 0.145 mg/kg, respectively. Wooden railroad ties are considered as a potential source of mercury because of impregnation with antifungal mercury compounds”. [5]
“The results are summarized in graphs showing how the level of pollutant concentration in surface run-off depends on the level of the same pollutant in soil sample. Theoretical and experimental research made it possible to calculate surface waste water and soils pollution concentration in railroad track right-of-way”. [6]
“It is found out that rail transport is a source of HM emission into soil. The findings indicate that the soil state of the Kamianske-Pasazhyrske station corresponds to a low ecological risk and a low degree of pollution, since the station is a passenger one only and pollution occurs mostly due to the friction of wheels and rails and that of the pantograph and overhead system, as well as the pesticide use. The results of the study can be used as a justification of the reasonability of introducing the environmental monitoring programs for the railway land, the environmental protection measures for the soil treatment

from HM, correcting the railway exclusion zone, as well as protection of adjacent territories from the propagation and accumulation of the mentioned pollutants". [7]
"Result showed that four principal components (PCA) were identified as responsible for the data structure explaining 83.5% of the total variance in the data set of which anthropogenic source contributed 68.4% and natural (lithogenic) source contributed 15.1% to the buildup of heavy metals along transportation corridors. PCA further identified Co, Zn, Cu, Pb and Fe as metals with considerable levels in the soil. Cluster analysis (CA) grouped the 8 parameters into two statistically significant clusters; of Co, Pb, Cd, Ni and Cu as well as Cr and Zn. Discriminant analysis further identified Cd, Cr, Ni, Fe, Cu and Zn as the most significant heavy metal parameters to discriminate across the transportation facilities.
The study showed that metal pollution in the identified transportation facilities was majorly induced by anthropogenic source because it contributed the larger percentage of the variation in metal introduction in to the soil".[8]
„On the basis of measured concentrations of petroleum hydrocarbons in the soil it can be concluded that: Obtained concentrations of petroleum hydrocarbons in 60% of soil samples exceed the permissible values (5000 mg/kg). The heavily contaminated soils, according the Regulation on the program of systematic monitoring of soil quality indicators for assessing the risk of soil degradation and methodology for development of remediation programs, must be treated using some of remediation technologies".[9]

CONCLUSION

The evaluation of heavy metals pollution in critical areas of railway track is a complex and laborious process that involves different methods, experiences and expanse many resources.
Practical applications determine the use of special methods with the optimisation as most important objective. Such modern methods involve, in the same time, both use of nonconventional elements and, also, the use of modern application of statistical methods.
One important part is the application of the collection of samples from critical areas through a statistically optimized distribution so that number of samples to be minimum and relevance to be maximum.
Taking into account the above we consider that the current research is bringing an added value by further scientific research on the influence of transport on the railway with all its implications on environmental pollution.
Our future research activity will be focus on finding viable solution to reduce harmful concentrations of heavy metals and a mathematical relationship between the concentration of heavy metals, atmospheric factors and characteristics of the railway track.

REFERENCES

[1] Natasa Stojic, Mira Pucarevic, Gordan Stojic, Railway transportation as a source of soil pollution, Transportation Research Part D 57 (2017) 124–129
[2] Tomasz Staszewski, Małgorzata Malawska, Barbara Studnik-Wójcikowska, Halina Galera, Bogusław Wiłkomirski, Soil and plants contamination with selected heavy metals in the area of a railway junction, Archives of Environmental Protection Vol. 41 no. 1 pp. 35–42, PL ISSN 2083-4772 DOI 10.1515/aep-2015-0005
[3] Małgorzata Wierzbicka, Olga Bemowska-Kałabun, Barbara Gworek, Multidimensional evaluation of soil pollution from railway tracks, Ecotoxicology (2015) 24:805–822
[4] Arjun Chandra Bhowmick, Md. Moustafijur Rahman Khan, Majharul Islam Moim, Nikhil Chandra Bhoumik, A.S.M Saifullah, Comparative Study of Heavy Lead Pollution in Roadside Soil and Plants by Railway and Highway at Tangail District in Bangladesh, Universal Journal of Applied Science 3(3): 21-25, 2015.

[5] Martin Šeda, Jan Šíma, Tomáš Volavka, Jan Vondruška, Contamination of soils with Cu, Na and Hg due to the highway and railway transport, Eurasian Journal of Soil Science 2017, 6 (1) 59 – 64

[6] Alexandr K. Strelkov, Sergey V. Stepanov, Svetlana Yu. Teplykh*, Ashot M. Sargsyan Monitoring pollution level in railroad right-of-way, Procedia Environmental Sciences 32 (2016) 147 – 154

[7] A.V.Samarska,Y.V.Zelenko, Science and progress of transport. Bulletin of Dnipropetrovsk National University of Railway Transport, 2018, № 4 (76), ISSN 2307–3489 (Print), ISSN 2307–6666 (Online)

[8] Ogundele, F. O., Tiamiyu, I. A. and Iwara, A. I., Assessment of heavy metal sources across urban transportation facilities in Lagos Metropolis, Nigeria, Confluence Journal of Environmental Studies, 2017 11(2): 19-26, ISSN: 1597-5827,
http:www.journalhome.com/cjes

[9] Larisa Jovanovic, Gorica Aleksic, Milan Radosavljevic, Antonije Onjia, Soil pollution in the railway junction Niš (Serbia) and possibility of bioremediation of hydrocarbon-contaminated soil, Geophysical Research Abstracts, Vol. 17, EGU2015-14733, 2015

WATER PROTECTION IN SERBIA: HARMONIZATION WITH THE LEGISLATION OF THE EUROPEAN UNION

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Abstract: In the Republic of Serbia, the water status is not at a level it could be. In this paper are discussed legal frameworks relevant for the protection of the water both globally and within the Republic of Serbia borders. There was also emphasised the need for further harmonisation of national legislation with international trends in the field of water, as well as with the obligations arising from the process of European integration. Although a significant progress in this area in the Republic of Serbia began with the process of European Union integration and harmonisation of the national legislation with the European Union, the authors suggest that there is still a need to improve institutional and legal framework at both national and local levels.
Key words: water protection, legislation of the Republic of Serbia, harmonization, European Union.

INTRODUCTION

Water pollution is one of the biggest problems of the biosphere with unimaginable consequences for the environment and mankind. Water is, among other things, polluted by improper waste disposal, water traffic, fertilizers and pesticides on arable land, solvents and detergents for home and factory use, as well as metals, for example, lead or mercury from industrial processes [1]. Water is considered polluted when its physical-chemical biological content is considerably changed due to human activity.
Inland waters and the oceans are polluted physically (solid waste, oil, temperature), chemically (organic and inorganic substances, oil, heavy metals, pesticides), biologically (introduced – foreign species, pathogenic organisms, viruses) and radioactively (nuclear tests, submarine accidents, nuclear waste, etc.) [2].
Pollutants reach water in direct and indirect ways. Direct pollution includes the forming of special wastewater where humans put dangerous substances and which, as a rule, directly disembogue into watercourses.
Prevention of water pollution is very important, and it is of extreme importance for agriculture, too. Plant production, especially the production of high-quality food that is safer to eat, is unimaginable without clean, unpolluted surface water and groundwater. With that in mind, protection of water from pollution within the framework of agroecosystem protection, as well as much more broadly, is of extreme importance for agricultural production.
The international practice in the field of water quality control has prescribed a number of activities which have made possible the establishment of organizations, boards and committees of an international character which have, after numerous discussions on the political, and later professional level as well, resulted in a great number of agreements, protocols and provisions in the field of water quality control [2].
Since water protection, protection from harmful effects of water, and the use and management of water are public interest categories, and that greater involvement of the public is necessary in the decision-making process in the field of water management, a need arises for greater availability of information about the state of water in Serbia [3].
In the Republic of Serbia, the water status is not at a level it could be. Groundwater is polluted due to using obsolete technology in factories as well as, to much the same extent, to agriculture, because of wastewater from rural settlements and the use of artificial fertilizers. Unregulated landfills are also a problem since every waste sooner or later ends up in groundwater.

WATER MANAGEMENT AND PROTECTION IN EUROPEAN UNION LAW

The harmonization of legal regulations in the field of water and the environment is part of the process of integration of the Republic of Serbia into the European Union (EU).

Water management and water protection are considered the most broadly regulated questions within the EU legislation in the field of environment. Water protection policy in the EU began in the seventies with the First Action Programme from 1973. After that, the Groundwater Directive was issued in 1975, as well as the Drinking Water Directive in 1980. The first stage of legislation in the field of water includes the legislation which has determined the water quality standards (for bathing, for fish, for shellfish, groundwater, etc.). A Directive on emission limit values has been adopted too (1976), as well as the directives that have regulated emission limits for different substances.

The second stage of the development of water protection legislation commenced by the issuing of the Urban Waste Water Treatment Directive (1991) and the Nitrates Directive (1991), after which the drinking water and bathing water directives were revised, and the Wastewater Action Plan and an ecological water quality directive proposal followed (1994). The adoption of Directive 2008/1/EC of the European Parliament and of the Council of 15 January 2008 concerning integrated pollution prevention and control (IPPC Directive) was a huge contribution to further development in this field.

When it comes to the further approach to water protection, the starting point is the fact that efficient water protection requires adequate regulations that regulate emission limits, as well as regulations concerning water quality standards (the so-called combined approach). There are three key aims: the prevention of overexploitation of drinking water for industrial and other purposes, the prevention of groundwater pollution and better ecological quality of surface water and seawater. In accordance with that, the measures for aim achievement are combined between the measures of the EU and the measures of the Member States, while on the other hand, the field of water protection is regulated by a different number of authorities and institutions in the EU as well as the Member States.

In that way, the list of effective EU regulations concerning water protection and management comprises 55 different acts [1]. According to the basic subject of regulation, all the most significant EU sources in the field of water protection can be grouped into several groups: regulations that regulate the emission of dangerous substances into surface waters, regulations that determine water quality aims, regulations that regulate the treatment of urban wastewater, regulations in the field of river protection, regulations concerning groundwater protection, and regulations that regulate the protection of seas from pollution.

1) The basic conceptual approach to political questions concerning water in the EU was defined in Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy (OJ L 327, 22.12.2000, p. 1–73), which determined a framework for EU activity in the field of water policy [4].

2) Water quality is regulated by: a) Directive 2008/105/EC of the European Parliament and of the Council of 16 December 2008 on environmental quality standards in the field of water policy, amending and subsequently repealing Council Directives 82/176/EEC, 83/513/EEC, 84/156/EEC, 84/491/EEC, 86/280/EEC and amending Directive 2000/60/EC of the European Parliament and of the Council, (OJ L 348, 24.12.2008. p. 84-97), which prescribes the Environmental Quality Standards (EQS) for priority substances and other pollutants (Article 16 Directive 2000/60/EC), with the aim of achieving a good chemical status for surface waters; b) Directive 98/83/EC of 3 November 1998 on the quality of water intended for human consumption (OJ L 330, 5.12.1998, p. 32–54) more clearly formulates certain elements which are significant for drinking water protection, by defining the essential quality standards for water intended for human consumption; c) Directive 2006/7/EC of the European Parliament and of the Council of 15 February 2006 concerning the management of bathing water quality and repealing Directive 76/160/EEC (OJ L 64, 4.3.2006, p. 37–51) regulates: (a) the monitoring and classification of bathing water quality; (b) the management of bathing water quality; and (c) the provision of information to the public on bathing water quality; d) The primary aim of Directive 78/659 on the quality of fresh waters needing protection or improvement in order to support fish life is fresh water protection in order to provide the conditions necessary for preservation of different species of fish; e) Directive 2006/113/EC of the European Parliament and of the Council of 12 December 2006 on the quality required of shellfish waters (codified version) (OJ L 376, 27.12.2006, p. 14–20) regulates the water quality that is necessary for shellfish cultivation and it is applied to those waters which the Member States have designated as the waters in need of protection or improvement in order to support shellfish life and cultivation (bivalves, whelks).

3) The discharge of pollutants into the water is regulated by: a) Directive 2006/11/EC of the European Parliament and of the Council of 15 February 2006 on pollution caused by certain dangerous

substances discharged into the aquatic environment of the Community (Codified version) (OJ L 64, 4.3.2006, p. 52–59) and b) Directive 91/271/EEC of 21 May 1991 concerning urban waste-water treatment (OJ L 135, 30.5.1991, p. 40–52), which concerns the collection, treatment and discharge of urban wastewater and the treatment and discharge of wastewater from certain industrial sectors. The aim of Directive 91/271/EEC is the protection of the environment from the adverse effects of wastewater discharges. In addition, according to the estimates of the European Commission, one of the main reasons behind the achieved improvement of the water quality status during the period of the Fifth Action Programme is attributed to progress related to the implementation of Directive 91/271/EEC [5]. In particular, the amount of extreme river pollution has significantly decreased due to reductions in waste discharges from point sources.

4) Groundwater is regulated by Directive 2006/118/EC of the European Parliament and of the Council of 12 December 2006 on the protection of groundwater against pollution and deterioration (OJ L 372, 27.12.2006, p. 19–31), which determined specific measures to prevent and control groundwater pollution, pursuant to Article 17, paragraphs 1 and 2 of Directive 2000/60 EC. In addition to that, Directive 2006/118/EC also complements the provisions preventing or limiting inputs of pollutants into groundwater already contained in Directive 2000/60/EC, and aims to prevent the deterioration of the status of all bodies of groundwater.

5) Council Directive 91/676/EEC of 12 December 1991 concerning the protection of waters against pollution caused by nitrates from agricultural sources (OJ L 375, 31.12.1991, p. 1–8) aims to reduce water pollution caused or induced by nitrates from agricultural sources and to prevent further such pollution (Article 1 Directive 91/676/EEC).

6) Flood risk management is regulated by Directive 2007/60/EC of the European Parliament and of the Council of 23 October 2007 on the assessment and management of flood risks (OJ L, 288, 6.11.2007, p. 27-34), which aims to establish a framework for the assessment and management of flood risks, in order to reduce the adverse consequences of floods in the EU for human health, the environment, cultural heritage and economic activity (Article 1 Directive 2007/60/EC).

HARMONIZATION OF THE REGULATIONS OF THE REPUBLIC OF SERBIA WITH EU REGULATIONS

In order to harmonize the regulations of the Republic of Serbia with EU regulations, the implementation of different measures has been planned, as well as the introduction of new regulations such as: the introduction of subordinate legislation based on the Law of Water which will cover Directive 2000/60/EC, Directive 98/83/EC as well as Directive 2006/7/EC; Directive 2007/60/ EC, Directive 80/68/EEC, Directive 2006/118/EEC, Directive 75/440 EEC, Directive 2007/2/EC, Directive 2008/105/EC and Directive 98/83/ EC. The provisions of Directive 91/271/EEC and Directive 91/676/EEC have been partially covered, as well as the completely converted provisions of Directive 2000/60/EC; The adoption of the new Law on Meteorological and Hydrological Activities, which will cover Directive 2000/60/EC and Directive 2007/2/EC, as well as the adoption of various subordinate legislation, based on the Water Law, which will completely cover Directive 2000/60/EC and Directive 2007/2/EC.; the adoption of appropriate regulations for establishing a state network and agenda for meteorological and hydrological stations. The adoption of the Law on Navigation and Ports on Inland Waters which will cover Directives 2006/87/EEC and 2006/137/EC, Directive 96/50/EC, regulations 1356/96/EC and 3921/91/EC, Directive 2005/44/EC, 416/2007/EC, 414/2007/EC and Directive 415/2007/EC and thus include them into internal legislation [1].

The European regulation concerning urban wastewater treatment, Directive 91/271/EEC, requires the drafting of national water regulations which would define water bodies, categorize the types of water bodies, identify anthropogenic pressures and analyze the sensitivity of the water body status. Different parts of Europe noted changes in the emission level of pollution from all sources during the last decade of the 20th century, which is a result of the environmental protection measures that have been proclaimed by the above-mentioned directive [2]. On the other hand, regional projects also play a significant role in water quality protection and improvement; namely, the *Danube River Enterprise Pollution Reduction (DREPR*) project which has been launched after the signing of the Convention on Cooperation for the Protection and Sustainable Use of the River Danube (the Convention has been ratified in 2003). Within the project, the best real-life examples are presented so that the legislation of the Republic of Serbia would comply with the demands of the EU Water Framework Directive [6].

WATER POLLUTION PREVENTION WITHIN THE LAW OF THE REPUBLIC OF SERBIA

In the Republic of Serbia, the field of water management and protection is controlled by several key laws, the Law of Water being the most important one [7], as well as a number of by-law and regulations. *Water protection* involves a number of measures and activities which protect and improve the quality of surface water and groundwater, from overpollution as well, in order to: preserve human life and health; reduce pollution and prevent further deterioration of the water status; enable safe and unhampered use of water for different purposes; protect aquatic and coastal ecosystems and set environmental quality standards in accordance with the regulations that regulate environmental protection and environmental aims.

In order to prevent the deterioration of water and environmental quality, physical-chemical parameters and limit values for pollutant emission are set, as well as the ways and conditions of pollutant discharge and the use of emission limit values, for: 1) industrial wastewater before it is discharged into the public sewerage system; 2) industrial and other wastewater that is directly discharged into the recipient; 3) water that is discharged from the public sewerage system into the recipient after treatment; 4) wastewater that is discharged into the recipient from septic tanks and cesspits.

In order to prevent water and environmental quality deterioration, and assess the status of surface water and groundwater, environmental quality standards and pollutant limit values for surface water, groundwater and sediment are determined. The criteria for sediment quality assessment are determined as pollutant limit values for assessing the status and trend of sediment quality as well as assessing the sediment quality during desilting. Water protection is carried out in accordance with the water pollution protection plan.

In order to provide a compliant and all-encompassing examination of the surface water and groundwater status, the Republic of Serbia is establishing the monitoring of the water status in the water region and making sure it is performed. The monitoring involves: 1) for surface water – the volume, level and discharge at the extent that is significant for the ecological and chemical status and ecological potential, as well as the parameters of the ecological and chemical status and ecological potential, 2) for groundwater – levels and control of the chemical and quantitative status. Water status monitoring in protected areas also involves additional water status indicators, in accordance with the regulations which identify that area as protected.

DRINKING WATERREGULATIONS

According to the Directive 98/83/EC for the water quality for human consumption and Directive 2006/118/EC for groundwater quality standards, the legislation of the Republic of Serbia in the field of water quality have been changed and harmonized. The following section gives an example of the harmonization of the limit values of certain parameters with EU law regulation for physico-chemical characteristics of drinking-water.

Increased risks of arsenic related diseases have been reported to be associated with ingestion of drinking-water at concentrations of <50 µg/L (WHO, 2008). However, considering the significant uncertainties surrounding the risk assessment for arsenic carcinogenicity and the practical difficulties in removing arsenic from drinking-water, a provisional guideline value for arsenic was set by WHO. This organization recommended the maximum permissible concentration (MPC) of arsenic in drinking water of 10 µg/L in the 1993 Guidelines [8]. In view of the scientific uncertainties, the guideline value is designated as provisional. A new maximum concentration limit of 10 µg/L for arsenic in drinking water was set by US EPA in 2001 [9] and EU law in 2003 (2003/40/EC) requiring public water supply systems to reduce arsenic in drinking water not later than January 2006. In the Republic of Serbia the new arsenic concentration limit was set in 1998 (MPC for arsenic was 50 µg/L). Recommendations from these have been adopted in the legislation of the Republic of Serbia in the By-law on the hygiene of drinking water (Official Gazette of Republic of Serbia, No. 42/98 and 44/99) [10]. The concentration of arsenic into the drinking-water in the area of Bačka and Banat is in the range of 50 – 200 µg/L (the maximum concentrations were measured in Zrenjanina - 194 µg/L and

Novi Bečej – 273 μg/L). In some parts of Vojvodina, as concentration are 10 to 50 time higher than the allowed.
In the Table 1 and 2 are given the physico-chemical parameters for drinkinf-water prescribed by current legislation of the Repablic of Serbia, EU Directive,WHO and US EPA

Table 1. Limit values of parameters prescribed by current legislation of the Repablic of Serbia, WHO and US EPA

Parameter	Serbia	WHO*	US EPA**
Color (°Pt/Co)	5	-	15
Conductivity (μS/cm)	1000	-	400 - 850
pH	6.8 - 8.5	7 - 8.5	6.5 - 8.5
$KMnO_4$ consumption (mg/L)	8	1 - 19	-
Ammonia ion (NH_4^+(aq)) (mg/L)	1	1.5	1.5
Total Fe (Fe^{2+}/Fe^{3+}) (mg/L)	0.3	0.1 - 0.3	0.3
Calcium (Ca^{2+}(aq)) (mg/L)	200	75	-
Magnesium (Mg^{2+}) (mg/L)	50	30	-
Sodium (Na^+(aq)) (mg/L)	150	200	100
Arsenic (As^{3+}/As^{5+}) (mg/L)	0.01	0.001 - 0.01	0.01

*** WHO - World Health Organization**
**** US EPA – United States Environmental Protection Agency**

Table 2. Maximum permissible concentration of cations and anions by current legislation of the Repablic of Serbia, EU Directive and WHO

Parameter	Serbia	EU Directive	WHO
NH_4^+ (mg/L)	0,1	0,5	1,5
Sb (μg/L)	3	5	20
As (μg/L)	10	10	10
Cu (mg/L)	2	2	2
Ba (mg/L)	0,7	-	0,7
B (mg/L)	0,3	1	0,5
CN^- (μg/L)	50	50	70
Zn (mg/L)	3	-	3
F^- (mg/L)	1,2	1,5	1,5
Cr (μg/L)	50	50	50
Cl^- (mg/L)	200	250	250
Cd (μg/L)	3	5	3
Ca (mg/L)	200	-	-
K (mg/L)	12	-	-
Mg (mg/L)	50	-	-
Mn (mg/L)	0,05	0,05	0,4
Mo (μg/L)	70	-	70
Na (mg/L)	150	200	200
Ni (μg/L)	20	20	20
Nitrate (mg/L)	50	50	50
Nitrite (mg/L)	0,03	0,5	0,2
Pb (μg/L)	10	10	10
Se (μg/L)	10	10	10
U (μg/L)	-	-	15
Hg (μg/L)	1	1	1

Also, we have some non-compliance with drinking water quality standards for inorganic substances. For example, the concentration of ammonia ion is 5 times lower than the EU Directive, and we consider that it is a harsh norm. Further, our Regulations prescribe for sodium a sharper standard (150 mg/L) than recommendation from the WHO and the EU Directive who are listing 200 mg/L. The similiar situation is with the chloride and nitrite ion, and boron.

CONCLUSION

In the Republic of Serbia, the water status is not at a level it could be. Groundwater is polluted due to using obsolete technology in factories as well as, to much the same extent, to agriculture, because of wastewater from rural settlements and the use of artificial fertilizers. Unregulated landfills are also a problem since every waste sooner or later ends up in groundwater.

In order to harmonize the regulations of the Republic of Serbia with The harmonization of legal regulations in the field of water and the environment is part of the process of integration of the Republic of Serbia into the European Union. EU regulations, the implementation of different measures has been planned, as well as the introduction of new regulations such as: the introduction of subordinate legislation based on the Law of Water which will cover Directive 2000/60/EC, Directive 98/83/EC as well as Directive 2006/7/EC; Directive 2007/60/ EC, Directive 80/68/EEC, Directive 2006/118/EEC, Directive 75/440 EEC, Directive 2007/2/EC, Directive 2008/105/EC and Directive 98/83/ EC. The provisions of Directive 91/271/EEC and Directive 91/676/EEC have been partially covered, as well as the completely converted provisions of Directive 2000/60/EC.

Since water protection, protection from harmful effects of water, and the use and management of water are public interest categories, and that greater involvement of the public is necessary in the decision-making process in the field of water management, a need arises for greater availability of information about the state of water in the Republic of Serbia.

REFERENCES

[1] Todić, D., Vodič kroz EU politiku – Životna sredina, Evropski pokret Srbije, Istraživački centar Slovačke asocijacije za spoljnu politiku i Slovačka agencija za međunarodnu razvojnu pomoć, Beograd, 2010.
[2] Lilić, S., Drenovak, Ekološko pravo, Pravni fakultet Univerziteta u Beogradu, Beograd, 2013.
[3] Milenković, D., Zbirka propisa iz oblasti zaštite životne sredine, Beograd, 2006.
[4] Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy (OJ L 327, 22.12.2000, p. 1–73).
[5] Ljubojev, N., Osnove ekološkog prava, Tehnički fakultet "Mihajlo Pupin" Univerziteta u Novom Sadu, 2018.
[6] Changes in organic matter emissions from all sources in regions of Europe between 1990 and 2000. EEA-ETC/WTR based on Member States data reported to OECD/EUROSTAT Joint Questi- onnaire 2002. http://web.worldbank.org/external/projects/main?menuPK=228424&theSitePK=40941&pagePK=64283627&piPK=73230& Projectid=P084604.
[7] Low on waters (Official Gazette of Republic of Serbia, Nº. 30/2010, 93/2012, 101/2016, 95/2018 and 95/2018)
[8] World Health Organization, Guidelines for Drinking-water Quality, *Third Edition Incorporating The First And Second Addenda, Volume 1 Recommendations World Health Organization*, WHO Press, World Health Organization, Geneva, Switzerland, 306, 2008.
[9] USEPA, National primary drinking water regulations: arsenic and clarifications to compliance and new source contaminants monitoring, in: Final Rule, *Code of Federal Regulations,* title 40, parts 141 and 142, 2001.
[10] By-law on the hygiene of drinking water (Official Gazette of Republic of Serbia, No. 42/98 and 44/99).

APPLICATION OF MULTIVARIATE STATISTICAL TECHNIQUES (CA AND PCA) IN ANALYSIS AND EVALUATION OF HEAVY METALS IN URBAN SOIL

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Abstract: In this study, two statistical techniques - descriptive statistics and multivariate analysis of experimental data were employed. Descriptive statistics was performed to provide basic information about variables in a dataset and to highlight potential relationships between variables. Multivariate methods (Cluster Analysis and Principal Component Analysis), were used to interpret complex data and to distinguish pollution sources. Surface soil samples were taken from 121 locations in Novi Sad city area in the vicinity of roads with different traffic density. Concentrations of As, Co, Cr, Cu, Mn, Ni, Pb, and Zn were determined using the ICP-OES device. The results of statistical analysis indicate natural origin of arsenic, chrome, cobalt, manganese and nickel, while the origin of copper, lead and zinc is determined to be anthropogenic.
Key words: multivariate statistical methods, heavy metals, urban soil.

INTRODUCTION

An ecosystem is a very complex entity with many interactive components. In the natural environment, the different components of the natural ecosystems are highly variable. Therefore, it is necessary to interpret the large sets of environmental data with the help of statistical methods. Multivariate statistical methods are used in environmental studies to quantify relationships between more than two variables under simultaneous consideration of their interactions. Statistical analysis of data begins with the description of quantities, their relationships, and structure [1]. Multivariate statistical techniques have been employed in numerous studies to identify heavy metals sources in industrial and urban areas [2,6]. There are many ways to perform multivariate analysis depending on the goals of the studies. Some of these methods include Cluster Analysis (CA) and Principal Component Analysis (PCA).
Cluster analysis is a statistical tool used to classify objects into groups, such that the objects belonging to one group are much more similar to each other and rather different from objects belonging to other groups [7]. Cluster Analysis is done using two categories of methods - Hierarchical Cluster Analysis methods and Non-hierarchical Cluster Analysis, or a two-step procedure. A hierarchical procedure in cluster analysis is characterized by the development of a tree like structure. A hierarchical procedure can be agglomerative or divisive. Agglomerative methods in cluster analysis consist of linkage methods, variance methods, and centroid methods. Linkage methods in cluster analysis are comprised of single linkage, complete linkage, and average linkage. The non-hierarchical methods in cluster analysis are frequently referred to as K - means clustering. The two-step procedure can automatically determine the optimal number of clusters by comparing the values of model choice criteria across different clustering solutions. The choice of clustering procedure and the choice of distance measure are interrelated. The relative sizes of clusters in cluster analysis should be meaningful. The clusters should be interpreted in terms of cluster centroids.
Principal component analysis is an approach to factor analysis that considers the total variance in the data, which transforms the original variables into a smaller set of linear combinations [7]. The diagonal of the correlation matrix consists of unities and the full variance is brought into the factor matrix. The term factor matrix is the matrix that contains the factor loadings of all the variables on all the factors extracted. The term ‘factor loadings’ are the simple correlations between the factors and the variables. Original variables are transformed to principal components using the eigenanalysis. The eigenvalues refer to the total variance explained by each factor. The standard deviation measures the variability of the data. The main objective of PCA is to reduce high dimensionality of the

sample/variable space by projecting the data into a much smaller subset of new uncorrelated variables called principal components (PCs) [8].

MATERIAL AND METHODS

A total amount of 121 surface soil samples (0 – 10 cm depth) were taken across the central part of the city covering a surface area of 20 km^2. The samples were analyzed for “pseudo-total” contents of As, Co, Cr, Cu, Mn, Ni, Pb, and Zn after digesting the soil in concentrated HNO_3 and H_2O_2 (5 HNO_3:1 H_2O_2, and 1:12 solid:solution ratio) by stepwise heating up to 180 °C using a Milestone Vario EL III for 55 min. The concentration of metals was measured by ICP-OES (Vista Pro-Axial, Varian) in accordance with US EPA method 200.7:2001. The limits of detection for examined metals were: 1.5 mg/kg (As); 2.5 mg/kg (Co); 5 mg/kg (Cr); 5 mg/kg (Cu); 5 mg/kg (Mn); 1 mg/kg (Ni); 5 mg/kg(Pb); and 5mg/kg (Zn).

Descriptive statistical analysis was carried out using Microsoft Office Excel 2003. The Pearson's correlation coefficients between analyzed metals were calculated using Statistica 10 software package (Statistica 10, 2012). Multivariate statistics including cluster analysis (CA) and principal component analysis (PCA) of the raw data was performed using Statistica 10 software package. The data were standardized to the Z-score (with a mean of 0 and a standard variation of 1) and then classified using the Ward's method [9]. In the PCA, the principal components were determined based on the correlation matrix. Varimax rotation with Kaizer's normalization was used in order to facilitate the interpretation of results [10].

RESULTS AND DISCUSSION

Concentrations of all metals investigated in urban soils of Novi Sad and basic statistical parameters of the raw data set are given in Table 1. The metals, in descending order of mean concentrations, were Mn, Zn, Pb, Cu, Ni, Cr, Co, and As. The mean concentration of Cu (38.8 mg/kg) slightly exceeds the limit value (36 mg/kg), while the mean concentration of Pb (82.3 mg/kg) is very close to the limit value (85 mg/kg). The remediation values exceeded for two metals - at three locations for Cu (with the largest concentration of 459.2 mg/kg) and at one location for Pb, where a concentration of 999 mg/kg is obtained. The widest range of values is observed for Pb and Cu. Pb concentrations range from 8.9 to 999.1 mg/kg and Cu concentrations from 4.4 to 459.2 mg/kg. The medians for these two metals are significantly lower than the mean value, showing that there were some very high values (outliers).

Table 1. Metal concentrations (mg/kg) in urban soils of Novi Sad (N = 121)

	As	**Co**	**Cr**	**Cu**	**Mn**	**Ni**	**Pb**	**Zn**
Mean	6.5	7.3	28.0	38.8	368.6	28.7	82.3	100.3
Median	6.3	7.2	28.4	27.7	363.6	27.7	48.7	100.5
Min	2.1	3.5	10.6	4.4	199.7	10.2	8.9	46.2
Max	11.1	11.2	50.8	459.2	622.6	74.2	999.1	193.8
Range	9.0	7.7	40.2	454.8	422.9	64.0	990.2	147.6
SD	1.7	1.4	6.7	58.0	70.0	8.7	110.9	29.9
RSD	0.26	0.19	0.24	1.49	0.19	0.30	1.35	0.30
[a] Backg. v.	2.2	/	30.0	17.1	/	14.8	17.2	60.3
[b]TV	29	9	100	36	/	35	85	140
[c] RV	55	240	380	190	/	210	530	720

[a] Backg. v. –Background metal concentrations for agricultural soils of the region [11].

[b] Dutch standard target values for soil [12].

[c] Dutch standard intervention values for soil: Values for soil remediation proposed by Dutch Ministry of Housing, Spatial Planning and Environment [12].

Table 2 presents the correlation coefficients between investigated metals. Strong positive correlation exists between As, Co, Cr, Mn, and Ni, for example: As–Co (r = 0.73), As–Ni (r = 0.73), Co–Mn (r = 0.80), Cr–Mn (r = 0.63) and Cr–Ni (r = 0.64). These results, together with relatively low concentrations and standard deviations, suggest a major natural origin from parent material (sandy alluvial deposit). On the other hand, there are statistically significant correlations between Cu, Pb, and Zn: Pb–Zn (r = 0.50) and Cu–Zn (r = 0.40), showing a possibility of a common source. Taking into account the high concentrations obtained for these metals, it can be concluded that they are derived from anthropogenic sources. Similar observations are reported in Manta et al. [3] and Massas et al. [13].

Table 2. Correlation matrix of the metal concentration in study area

	Co	**Cr**	**Cu**	**Mn**	**Ni**	**Pb**	**Zn**
As	**0.73**	**0.57**	-0.10	**0.57**	**0.73**	-0.10	0.14
Co		**0.70**	-0.16	**0.80**	**0.54**	-0.21	-0.11
Cr			0.05	**0.63**	**0.64**	0.16	0.32
Cu				-0.10	0.04	0.18	**0.40**
Mn					0.34	0.01	0.02
Ni						0.03	0.29
Pb							**0.50**

Bolded values are significant at 0.01 level

Aiming to identify two distinct groups of metals as tracers of natural or anthropogenic sources an explorative hierarchical cluster analysis is performed on the data set of metal concentrations. The results are illustrated by a hierarchical dendrogram in Figure 1. The lower the value on the distance cluster, the more significant association is [14]. According to the degree of association between metals, two distinct clusters could be identified: the first cluster includes As, Co, Cr, Mn, and Ni and the second Cu, Pb, and Zn. Such result is consistent with the elemental relationship in correlation matrix (Table 2), supporting a natural origin of As, Co, Cr, Mn, and Ni, while Cu, Pb, and Zn predominantly derive from anthropogenic inputs. Pb, Cu, and Zn could be emitted from fuel combustion [15]. Lead content is controlled by a long term anthropic activity related to the use of Pb in gasoline (leaded gasoline was still in use in Serbia in the time of sample taking). Zn and Cu are emitted through tire/brake abrasion, some mechanical vehicle parts contain Cu, and Zn is often added to motor oil [16].

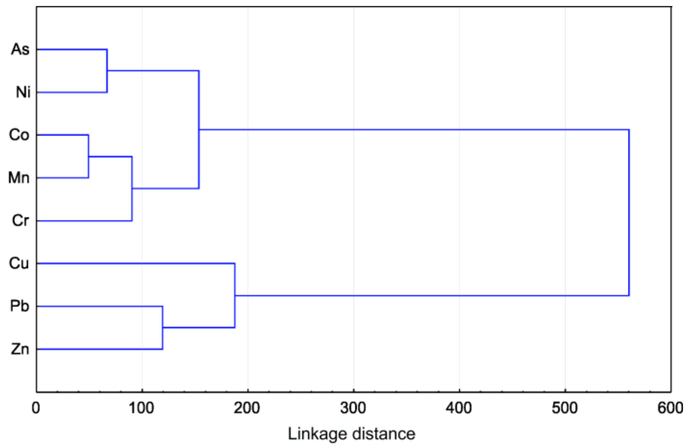

Figure 1. Hierarchical dendrogram for eight metals obtained by Ward's method.

PCA was performed on the data set of eight variables and 121 samples. The plot of PC loadings is shown in Figure 2. Two principal components with eigenvalues greater than 1.0 are extracted from the available dataset, with cumulative variance of 67.6%. After varimax rotation the corrections for percentages of variance are minimal. The first component explaining 43.8% of the cumulative variance has high PC loadings for As, Co, Cr, Mn, and Ni and suggests that the distribution of these elements is mainly influenced by natural sources. The second component explaining 23.9% of cumulative variance, exhibits elevated loadings for Cu, Pb, and Zn, indicating anthropogenic contribution in the soil samples. The PCA is in total agreement with the cluster analysis, where two strong clusters with equal grouping of the metals are obtained.

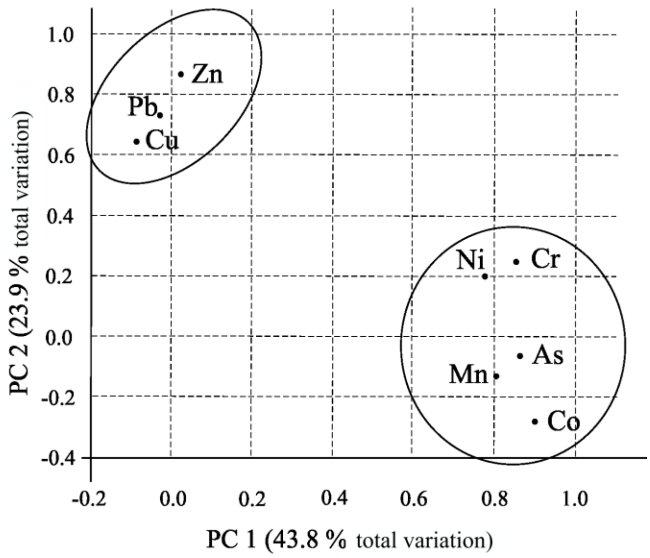

Figure 2. Factor loadings for two principal components (PCs) after varimax rotation.

CONCLUSION

The concentration of As, Co, Cr, Cu, Mn, Ni, Pb, and Zn in urban soils of Novi Sad was determined using ICP-OES technique. The highest contamination is found for Pb for which 30% of samples show significant or very high enrichment. Most of the soil samples for Cu, Ni, and Zn show minimal and 20–35% moderate enrichment. One hot-spot of very high Pb concentration (999 mg/kg) was located in the south-eastern part of the city at the site close to the low volume traffic road. It was identified that the source of pollution was a small lead accumulator plant located about 50 m from that sampling site. The results of descriptive statistics, correlation analysis, CA and PCA in the study agree with each other. All the results distinguish two groups of metals. The first group includes As, Co, Cr, Mn and Ni, the metals mainly influenced by natural inputs. The second group contains Cu, Pb and Zn which are related to anthropogenic activities.

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REFERENCES

[1] Oprea, C., Multivariate analysis of environmental Data by SPSS, Environment & Progress, pp. 285-290, 2005.
[2] Facchinelli, A., Sacchi, E., Mallen, L., Multivariate statistical and GIS-based approach to identify heavy metal sources in soils, Environmental Pollution, Vol. 114, pp. 313–324, 2001.
[3] Manta, D.S., Angelone, M., Bellanca, A., Neri, R., Sprovieri, M., Heavy metals in urban soils: a case study from the city of Palermo (Sicily), Italy, Science of the Total Environment, Vol. 300, pp. 229–243, 2002.
[4] Gergen I., Harmanescu M., Application of principal component analysis in the pollution assessment with heavy metals of vegetable food chain in the old mining areas, Chemical Central Journal, Vol. 6, p.156. doi: 10.1186/1752-153X-6-156, 2012.
[5] Ahmed,F., Fakhruddin, A.N.M., Imam, M.D.T., Khan N., Khan, T.A., Rahman Md. M., Abdulla, Spatial distribution and source identification of heavy metal pollution in roadside

surface soil: a study of Dhaka Aricha highway, Bangladesh, Ecological Processing, Vol. 5, https://doi.org/10.1186/s13717-016-0045-5, 2016.

[6] Jin, Y., O'Connor, D., Ok, Y.S., Tsang, D.C.W., Liu, A., Hou, D., Assessment of sources of heavy metals in soil and dust at children's playgrounds in Beijing using GIS and multivariate statistical analysis, Environment International, Vol. 124, pp. 320-328, 2019.

[7] https://www.statisticssolutions.com/directory-of-statistical-analyses-cluster-analysis/

[8] Einax, J.W., Ywanyinger, H.W., Geiss, S., Chemometrics in Environmental Analysis, Wiley-VCH Verlag GmbH, Weinheim, 1997.

[9] Ward, J.H., Hierarchical grouping to optimize an objective function. Journal of the American Statistical Association, Vol. 58, pp. 236-244, 1963.

[10] Micó, C., Recatalá, L., Peris, M., Sánchez, J., Assessing heavy metal sources in agricultural soils of an European Mediterranean area by multivariate analysis, Chemosphere, Vol. 65, pp. 863–872, 2006.

[11] Ubavić,M., Bogdanović, D.,Hadžić, V., Basic chemical properties of soil of the Vojvodina province and possibilities of their contamination with heavy metals, Contemporary Agriculture, Vol. 1, pp. 47–51, in Serbian, 1993.

[12] VROM, Circular on Target Values and Intervention Values for Soil Remediation Annex A: Target Values, Soil Remediation Intervention Values and Indicative Levels for Serious Contamination. Dutch Ministry of Housing, Spatial Planning and Environment, (VROM), 2000.

[13] Massas, I., Ehaliotis, C., Kalivas, D., Panagopoulou, G., Concentrations and availability indicators of soil heavy metals; the case of children's playgrounds in the city of Athens (Greece), Water Air & Soil Pollution, Vol. 212, pp. 51–63, 2010.

[14] Lee, C.S., Li, X., Shi, W., Cheung, S.C., Thornton, I., Metal contamination in urban, suburban, and country park soils of Hong Kong: a study based on GIS and multivariate Statistics, Science of the Total Environment, Vol. 356, pp. 45–61, 2006.

[15] Chen, X., Xia, X.H., Zhao, Y., Zhang, P., Heavy metals concentrations in roadside soils and correlation with urban traffic in Beijing, China, Journal of Hazardous. Materials. Vol. 181, pp. 640–646, 2010.

[16] Davis, A.P., Shokouhian, M., Shubei, N., Loading estimates of lead, copper, cadmium, and zinc in urban runoff from specific sources, Chemosphere, Vol. 44, pp. 997–1009, 2001.

THE IMPORTANCE OF RAISING AWARENESS OF ENVIRONMENTAL BEHAVIOR, ENVIRONMENTAL PROTECTION AND CLIMATE CHANGE IN THE APV

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Abstract: In the Republic of Serbia, education on environmental issues in elementary school is very scarce. Environmental protection theme is part of subject's knowledge of nature and/or society, i.e., biology, chemistry, geography, and physics. Also, awareness on the necessity of environment protection among adults should be improved. Thus, the authors of this paper proposed an educational programs on climate change for adolescents that will indirectly transfer their knowledge on their parents or guardians. The educational program will be provided among elementary school children (1-8 grade). The program will cover climate change issues with the focal point on renewable energy resources. The effect of education will be analyzed throughout the survey before and after the program. The effect will be measured both in children and parents. The result should highlight the improvement in knowledge on climate change and raising awareness on this significant issue.
Keywords: climate change, education, renewable energy resources

INTRODUCTION

The Industrial Revolution has ushered in a new era in the history of humanity, not only in terms of progress and development but also in terms of the effects and consequences of the dizzying impact on the human environment. Improved processes have facilitated production processes and made products more diverse and accessible, which has greatly influenced the increase in living standards and, consequently, the multiplication of world half-population. The principles of the production and growing civilization with increasing demands for energy exclusively produced from fossil fuels led to a sharp increase in the concentration of GHG (greenhouse gases), which consequently provoked many adverse effects known under the name of climate change. Surveys show that over the last 200 years, the global atmospheric temperature has increased by 1.1 ℃, with an increase of tentatively and estimates that by 2100 it will increase by 2.7 ℃ [1].
Recognition of global warming issues, expert empowerment seeks to raise awareness of the growing problem by pointing out the complexity of the problem and the need for a multidisciplinary approach. Tackling the issues of global warming is reflected in systematic policy-making and problem-solving strategies. The history of climate change policy development began in the mid-1970s with the Convention on Long-range Transboundary Air Pollution [2], through the Vienna Convention on the Protection of the Ozone Layer [3] and other Significant Protocols [4], [5]. However, the basis of the policy lies in the UN Framework Convention [6] with the Kyoto Protocol [7] defining developed country targets for reducing emissions through three types of carbon dioxide trading mechanisms, as the primary GHG. Continuity of action at the global level is reflected in the last Paris Agreement which establishes the ultimate goal of reducing GHG gas emissions, leading to a reduction in global temperature rise below 2 ℃ during this century [8].
Although the concerns of climate change scientists are serious, reducing catastrophic consequences requires prompt collective action. However, public opinion on climate change as a result of the politicization of this, one of the most significant and real global environmental problems is polarized [9].
On the other hand, the formation of attitudes about environmental problems in adults is guided by the political beliefs and ideals in adolescents it depends most on the views, knowledge, and behavior of adults, that is, parents and educators/teachers [10]. As the perception of climate change in children is not yet formed and it's not influenced by global controversy and discussion, it is possible that adolescents with acquired knowledge of this complex topic affect the awareness-raising in adults, primarily of their parents/guardians [11].

In developed countries, although environmental education occupies an important place in the early childhood education system [12], [13], [14] among teaching staff, there is confusion about the causes of climate change [15].
Environmental education has relatively recently become part of teaching in Serbia. Depending on age, environmental protection education is part of activities in preschool institutions, or subjects knowledge of nature and/or society, i.e. biology, chemistry, geography and physics [16].
The results of a survey conducted in South Backa indicate that only 35% of teachers are ready to introduce environmental-related activities [17].
Previously, a preliminary study conducted in Novi Sad among children aged 6-12 years found that there was a specific awareness of environmental protection, reflected mainly through the waste recycling, water, and energy savings. However, there were no responses in children's free responses regarding wastewater and water pollution, as well as air pollution due to traffic and industry [18].
This indicated the necessity of expanding theoretical and practical activities that would expand the awareness of children in some segments of environment protection, especially concerning the causes of climate changes. The aim of the project, financed by the Autonomous Province of Vojvodina, is to raise awareness of elementary school students about climate changes in order to adopt specific models of environmentally friendly behavior, with the emphasis that their acquired knowledge indirectly affects teachers and parents, as well as others family members.

PARTICIPANTS

The educational program of inter-generational learning will be provided among elementary school children. The size of the sample will be determined after the consultation with the teachers. Schools that are willing to take part in education are located in different regions of the province of Vojvodina (South Backa county, North Banat county, and Middle Banat County). During a preliminary survey on interest in participating the education, we encounter a great deal of attention.

CONCEPT OF THE RESEARCH

The research would be conducted in several stages. The first phase will cover preliminary activities, such as consultation with the teaching staff about the content of the program and the selection of training groups. In order to determine the effects of the implemented project activities, two groups will be set: a reference group and an experimental group. Both groups will include school children, their parents/guardians, and senior family members, as well as teachers/teachers.
The preliminary survey, which will include both groups of respondents, adults, and students, will contain general questions on age, gender, education, to analyze conceptual approaches to the concept and problem of climate change among groups of different ages. Within the group of students as respondents, these questions play a crucial role in looking at the impact of different ages and genders on older people [19].
For the group of teachers, the questionnaire will pay particular attention to the scientific area that teachers teach, as well as the volume of materials devoted to the topic of climate change under the program, as well as additional activities that teachers self-initiated to address climate change. For adults (parents/guardians and teachers), questions will be raised within this group regarding their personal views on climate change, their religious commitment as well as nationality [9]. Specific questions will include self-evaluation questions as well as questions that will explicitly indicate knowledge of the field and will be specially formulated and adapted for adults and children (Table 1).

Table 1. Questionare concept

General questions	**P**	**K**	**T**
Gender/Age	x	x	x
Education (Field and degree)	x		x
Scientific subjects (no od lectures dedicated to the climate change, personal contribution)			x
Personal attitude to the climate change issue	x		x
Political orientation (liberal, “left”,“right”) /religious (yes or no)	x		x
Nationality		x	
Specific questions			
Self-evaluation concerning knowledge in the field of climate change issues	x	x	x
Specific question concerning climate change issues and alternative energy resources	x	x	x
P stands for Parents, K for kids and T for teacher			

The second phase of the research will cover Theoretical and practical teaching, which will be implemented according to the detailed curricula formed. Classes will be implemented through two thematic units:

1. Climate change: defining the concept of climate change, causes of landfill climate change, industry, thermo-energy plants, consequences as well as the mechanisms of adaptation to climate change..
2. Energy and the environment: personal contribution and environmentally friendly behavior with an emphasis on energy efficiency, energy conservation, and the use of renewable energy.

Theoretic teaching will include educational pedagogical tools to bring the complexity and scope of the problem as clear and detailed as possible to a relatively small amount of lessons.
Practical work will focus on renewable energy sources. The realization will be carried out through workshops in which students will have the opportunity to solve specific problems, design and realize individual projects that accompany theoretical instruction (windmills, digester for the production of biogas, green roof models, etc.). Also, students will have the opportunity to express their views, impressions, and concerns about climate protection change as well as their vision of personal contribution to the advancement of this field through individual creative work, artworks or competitive projects.

CONCLUSION

The results of decades of popularization of environmental behavior in developed countries have yielded results over the last few years. The implementation of the model of intergenerational knowledge transfer can improve the situation in Vojvodina as it affects three generations simultaneously, because adolescent children can adopt environmentally friendly behavior models without prejudice, which adults have, which ensures long-term results. On other hand, adults with their preconceived notions and unwittingly developed bad habits are not ready for the direct acquisition of new environmental and energy-saving knowledge. Intergenerational knowledge transfer will enable indirect action on parents, family members, and teachers taught their kids. Preliminary monitoring of the development of awareness of environmental behavior, environmental protection and climate change in the territory of the APV to take concrete measures and activities for long-term planning and improvement of school programs at the level of the Republic of Serbia.

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REFERENCES

[1] Joshi, M., Hawkins, E., Sutton R., Lowe, J., Frame, D., Projections of when temperature change will exceed 2 °C above pre-industrial levels, Nature Climate Change, Vol. 1, pp. 407–412, 2011.

[2] Sliggers, J., Kakebeeke, W., Clearing The Air, 25 years of the Convention on Long-range Transboundary Air Pollution, Economic Commission for Europe, United Nations, New York and Geneva, 2004.

[3] Ozone Secretariat United Nations Environment Programme, The Vienna Convention for the Protection of the Ozone Layer, 2001.

[4] Montreal Protocol on Substances that Deplete the Ozone Layer, 1987.

[5] Doha Amendment to the Kyoto Protocol, 2012.

[6] United Nations Framework Convention On Climate Change, United Nations, 1992.

[7] Kyoto Protocol To The United Nations Framework Convention on Climate Change, United Nations 1998.

[8] Paris Agreement, United Nations, 2015.

[9] Lee, T.M., Markowitz, E.M., Howe, P.D., Ko, C.Y., Leiserowitz, A.A., Predictors of public climate change awareness and risk perception around the world, Nature Climate Change, Vol. 5, pp.1014–1020, 2015.

[10] Shobeiri, S.M., Alihosseini, S.H., Meiboudi, H., Saradipour, A., Preschool educators qualifications for environmental education of children in Iran, Journal of Educational and Management studies, Vol. 5, No.1, pp. 22-26, 2015.

[11] Lawson, D.F., Stevenson, K.T., Peterson, M.N., Carrier, S.J., Strnad, R.L., Seekamp, E., Children can foster climate change concern among their parents, Nature Climate Change, Vol. 9, pp. 458–462, 2019.

[12] Eames, C., Cowie, B., Bolstad, R., An evaluation of characteristics of environmental education practice in New Zealand schools, Environmental Education Research, Vol. 14, No.1, pp. 35-51, 2008.

[13] Jeronen, E., Jeronen, J., Raustia, H., Environmental Education in Finland- A Case Study of Environmental Education in Nature Schools, International Journal of Environmental and Science Education, Vol. 4, No.1, pp. 1-23, 2009.

[14] Jensen, B.B., Knowledge, Action and Pro-environmental Behaviour, Environmental Education Research, Vol. 8, No.3, pp. 325-334, 2002.

[15] Plutzer, E., Mc Caffrey, M., Lee Hannah, A., Rosenau, J,. Berbeco, M., Reid, A.H., Climate confusion among U.S. teachers, Science, Vol. 351, Issue 6274, pp. 664-665, 2016. DOI: 10.1126/science.aab3907.

[16] Skenderović, I., Fetić, M., Uloga ekološkog obrazovanja u zaštiti i unapređenju životne okoline, Ekonomski izazovi, No.5, pp.123-134, 2014.

[17] Aleksić, D., Stepanov, J., Čurčić, Lj., Štrbac, S., Edukacija o zaštiti životne sredine u predškolskim ustanovama, Šesta regionalna konferencija – Životna sredina ka Evropi EnE10, 2010.

[18] Mićić, J., Vujić, B., Mihajlović, V., Environmental awareness among the children in Novi Sad city, 24th International Symposium on Analytical and Environmental Problems, October 8-9 2018, Szeged, Hungary, ISBN 978-963-306-623-2.

[19] Stevenson, K.T., Peterson, M.N., Bondell, H.D., Mertig, A.G., Moore, S.E., Environmental, Institutional, and Demographic Predictors of Environmental Literacy among Middle School Children, PLoS ONE, Vol. 8, No.3, e59519., 2013. doi:10.1371/journal.pone.0059519.

REVIEW OF EUROPEAN PROJECTS AIMING AT REDUCTION OF NON-EXHAUST PARTICLES' EMISSION WHOSE SOURCE IS VEHICLE BRAKING SYSTEM

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Abstract: The use of internal combustion (IC) engines is one of the major sources of particulate emissions that are generated by the vehicles. However, with the current engine's equipment, and with the increasing use of electric vehicles, the engine has become a smaller source of particles on the vehicle. Today, one of the most dominant particles' sources on the vehicle is the braking system that produces the particles with its wear during braking process. Based on this, large European companies, universities and research institutes have launched various projects aimed at improving vehicle braking systems, all in order to reduce the particulate emission that occurs during braking, or by this system. These projects aim to develop braking systems in terms of modern technologies that could reduce particulate emissions by controlling the braking process, using modern materials for the production of friction pads that have a lower wear rate and the formation of ultra-fine particles, but also laying the basis for the introduction of legislation in these authorities. This paper represents the review and analysis of European projects aimed at reducing the particulate emission generated by the braking system, as well as a comparative analysis of their objectives that should be achieved through the realization of these projects. As the basis for all these projects implemented by the largest companies in the world, environmental protection is provided by means of technologies and the way of creating friction elements that were the ideas of the project participants, but on the other hand, and most importantly, the introduction of legal norms that would apply in Europe in relation to non-combustion particles (non-exhaust particles).
Key words: Braking system, particles, non-exhaust emission, reduction, European projects.

INTRODUCTION

The problem of environmental pollution can pose a major problem in the near future both for human health and human quality of life. Up to now, environmental pollution caused by vehicles in terms of combustion in the engine has been largely discussed. By improving the engine and upgrading the equipment in order to minimize environmental pollution, the engine or combustion in the engine does not represent the largest source of the environmental pollution. Today the problem of environmental pollution by particulates is a very significant problem. Particles that are not generated by combustion in an engine, but by wear or otherwise are called non-exhaust particles. As the brakes, or the vehicle's braking system, are one of the pollutants of the particulate matter generated by their wear, many social organizations are aware of this fact. Increasing the number of vehicles also increases the amount of particulate matter generated, so that the largest manufacturers of brakes or brake system elements are involved in various projects related to the reduction of particulate emissions from braking. This part of the paper presents some projects and regulations aimed at controlling particulate matter by the wear of brakes or generally reducing the emission of particulate matter.
The problem of particle formation by wearing some elements on the vehicle is assumed to be a leading problem in the coming years and decades, which can greatly affect human health, which is explained in more detail in the source [1,2].
Despite the lack of legislation and research conducted in recent years, researchers have conclude that this is indeed a major problem, both today and in the future. One of the systems that have the greatest

influence on the formation of particles of different sizes is the braking system of the vehicle. The world's largest manufacturers of braking systems and various institutes have launched various projects aimed at reducing both the amount of particulate matter and the harmfulness of particulate matter. The particle size is primarily divided into PM_{10}, $PM_{2.5}$ and PM_1 particles. All these particles have a very negative effect considering that they contain harmful substances and heavy metals. The aforementioned projects aim to reduce the amount of such particles. Some of the most significant projects in Europe, whose preferred focus is to reduce particle matter, whose source is the vehicle or specifically the braking system, are analysed in this paper. The braking system generated particles by wearing of friction elements that brake the vehicle [2,3].
The aim of this paper is to review some of the most well-known projects that analyse and study how non-exhaust particles are generated by the braking system. Such a goal is set for the purpose of considering opportunities, plans and guidelines for further research, which could result in the introduction of legislation in this area.

REBRAKE project

Based on research on the generation of brake wear particles, it has been concluded that brake is among the three most significant sources of non-combustion particulate matter. For this reason, many global manufacturers of brake systems or components are aware of this issue and are developing various projects related to testing brake influence on the environmental and particulate matter emission [2,3]. One of those projects is the REBRAKE project, which includes one of the largest manufacturers of brake systems - Brembo. This project has been active since 2014, and this project has two main goals:

- Reduction of the total amount of PM10 brake-producing particles by at least 50% in line with the EU2020 strategy aimed at reducing total particulates by 47% by 2020;
- A deeper understanding of the physical and chemical phenomena underlying the brake wear process, including greater understanding and analysis of the characteristics of course, fine and ultra-fine particles [4].

The project is designed in four phases that are certainly correlated with each other. As all phases are interconnected and relevant to the final result expected from this project, it is important to define and describe what each phase is characterized and what it represents:

- The first phase is the phase where experimental brake tests are performed. Also, at this stage, a methodology for collecting particulates generated by brake wear is established;
- The second phase of the project is related to the identification of particulate matter collected, i.e. all the particles collected in the first phase are compared with the available literature or results in the literature related to the influence of particulates on human health. Of course, the particles collected are bound to conventional and newly manufactured materials used in the braking system. The collected particles can be characterized both in chemical composition and morphological sense, and thus the characterized particles can be easily compared with the literature related to the influence of particles on human health;
- The third stage is related to modelling of the process of brake wear (wear of brake linings). Such a mechanism of wear is related to, or correlated with, the braking systems being tested or investigated;
- The fourth phase of the project is one of the keys to reducing particulate emissions from brake wear. At this stage, based on the previous three phases that is, research in these phases, it is necessary to develop new braking systems to reduce particulate emissions by 50% resulting from braking. Of course, the fourth stage is an interactive set of all these previously mentioned phases, [4].

The foregoing phases can be represented graphically as shown in Fig. 1. However, it is noticeable that there are six phases described in the figure, so based on the previous paragraph where it was stated that there are four phases, illogicality is noticeable. The first two phases shown in Fig. 1 are the management (WP1) and the sixth phase (WP6), which is related to further raising awareness of this emission of particulate matter and their formation.

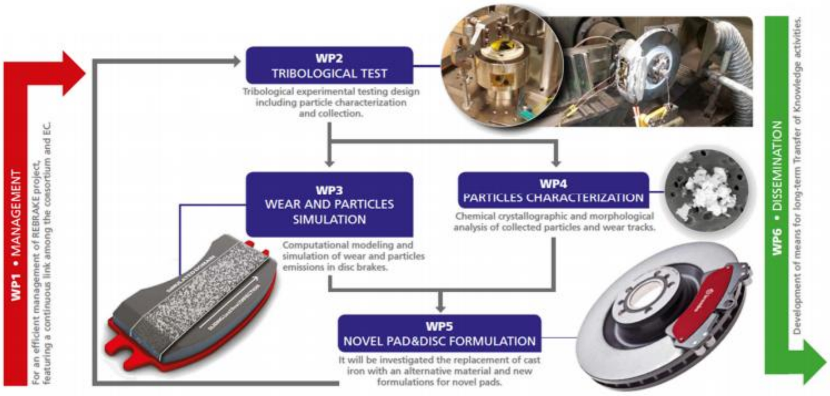

Figure 1. Graphical representation of the REBRAKE project phases [5]

In addition to its main objectives, there are different benefits that would be achieved through this project. First, it would bring different socio-economic benefits, but further application in the development of brake systems is possible.

As the study of the effect of brakes on particle formation is a rather unexplored area, this project would make it possible to characterize the particles generated by different elements in the braking system. However, this project also enables the development of knowledge related to the development of the brake system to reduce the number of particles generated from the brakes as one of the systems in which non-combustion particles are generated. In addition to the aforementioned benefits of this project, there is also the possibility that a standard methodology could be introduced through this project to test brake wear and particle formation of different sizes. According to a report from the European Commission specifically on CORDIS, the knowledge gained from this project and such standardization of particulate matter testing methodology would raise awareness for manufacturers of both brakes and other products, and thus encourage further industrial research to develop perhaps their own methodologies, [6].

The development of engine equipment has led to the reduction of particulate matter generated by combustion in the engine, so that today it is less than the level of particles generated by the brakes and therefore, the brakes are the primary source of these particles today. As one of the primary goals of the REBRAKE project is to reduce these particles by 50 percent, it would come to a level to equalize this percentage of particle formation by the brakes with the particle formation by the engine. Since 2014, researchers participating in the REBRAKE project have also participated in the Particle Measurement Program (PMP), managed by UNECE, where particulate matter experts are working on research related to the development of ECE standards that is related to the emission of particles generated by the brakes, [6].

One of the main goals of this project is to see the possibility of reducing particulate emissions during braking, which would reduce particulate matter in Europe from 4 to 14%. The following section presents some of the results of the research that show that by changing the composition of the friction pads, but also by different treatment of the brake disc, the desired result of reducing the emission of particulate matter can be achieved. One of the drawbacks of this study is that the particle reduction focuses on the reduction of PM_{10} particles, while particles of other sizes have not been analysed, e.g. $PM_{2.5}$ ultra-fine particles, [6].

LOWBRA

Relying on the REBRAKE project, a project has been started that also incorporates modern technologies, that is, the application of sensors to reduce particulate emissions using modern technologies. This system allows the driver to be alerted to the amount of particles created. This project is called the LOWBRASYS project (short for LOW environmental impact BRAke SYStem), [7], [8].

The LOWBRASYS project has the main objective to develop a new generation of technologies used in road traffic, which may encourage the development of innovations that will lead to cleaner and more efficient road transport and will improve air quality. At the same time, LOWBRASYS meets the requirement to comply with possible future stricter emission regulations (both for emissions from combustion in the engine and non-exhaust one, generated by the wear and tear of some elements-in this case, brakes) and better air quality in Europe. The aim of this project is to present a new reduced environmental impact of a brake system that will reduce emissions of micro and nanoparticles by at least 50%, [8]. Measurement and understanding of micrometre and ultra-fine particles and their impact on health and environment will be enhanced with recommendations to organizations to formulate regulations and standards in this area. However, this project sets out three main goals that this project aims for and, which are important factors in reducing particulate emissions, namely:

- New and modern materials from which friction pads would be produced;
- Development of environmentally friendly means or strategies of vehicle braking (control systems) that influence reducing particulate emissions;
- Development of state-of-the-art technologies that can collect particles near the source of origin, all with the aim of drastically reducing the particles generated from that source (in this project, these are the brakes);
- Integration of friction pads, as well as other components in the braking system with vehicle control systems;
- Improvement of techniques for measuring and understanding the health and environmental effects of particles through state-of-the-art techniques and recommendations in relation to them [8], [9].

Based on the goals of this project, it can be graphically depicted in Fig. 2, which describes the stages and processes in each of the stages that the goals can be achieved, [10]. In this way, Fig. 2 also defines the basic phases and objectives that were expected to be achieved by this project.

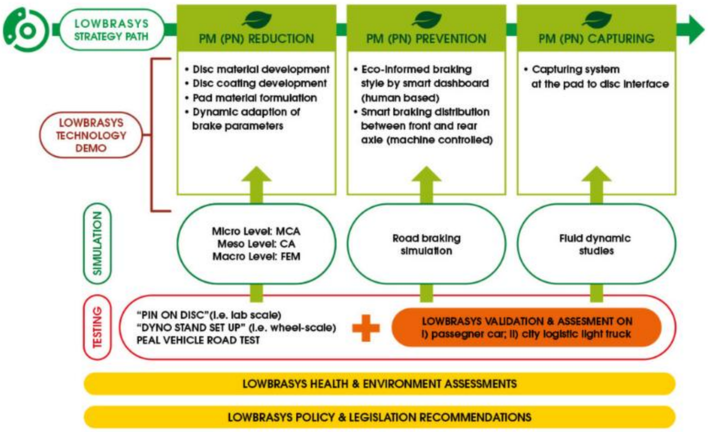

Figure 2. Objectives presented through the stages of the LOWBRASYS project, [10]

This project involves several world-class companies and universities known as the largest manufacturers or research centres related to motor vehicles or other areas of expertise that may have an impact on vehicle development components. This project involves several significant institutions in the world dealing with motor vehicles or materials, some of these companies and universities are *Brembo, Continental, FEDER-MOGUL motor parts, Ford, Flame Spray, Degli Studi Di Trento University (Departmento indedneria industriale), European Commission, KTH Vetenskap och Konst, Instituto di recherché farmacologiche Mario Negri, Nanotechnology Center VSB-TUO Ostrava*. Each of these companies has its own role in this project and its task of research and testing, so that the project itself consists of several phases, but the tests are entrusted with the development of certain companies participating in this project, and yet are related to their field of activity. For example, *Brembo*, *Flame Spray* and *Continenta*l are aiming to develop new brake disc technology with disc torque sensors. *FEDER-MOGUL*, in cooperation with the *Nanotechnology Center VSB-TUO Ostrava*, is tasked with developing new friction pads made of new materials, i.e. composite materials of different composition compare to existing materials used in the production of friction pads. However, despite all new materials and modern technologies, this project is based on modern vehicle systems, so *Brembo* and *Continental*, in collaboration, are responsible of designing and writing of modern IT brake algorithms, as well as the development of an application that would alert the driver about created particulate emissions. In addition to the previous, *KTH Vetenskap och Konst*, in cooperation with *Brembo*, aim to test and determine the synergy between the brake disc and the friction pads, but also to develop a system or technology for collecting particles generated by the wear of the brakes. *Instituto di recherché farmacologiche Mario Negri* has a role in the project to examine the influence of particles on organisms that exist in nature, which means that they examine not only the effects on humans but also on other living organisms. The *University of Degli Studi Di Trento (Departmento di indedneria industriale*) has the role to test the new materials used, as well as the composition of newly formed particles of these modern materials that can be applied to vehicles, or to the braking system. Ford, as one of the world's largest vehicle manufacturing companies, has a role in this project to integrate modern braking systems that reduce particulate emissions, into newly manufactured vehicles. However, as newly manufactured vehicles and the integration of those systems need to be tested to see the effect of implementing such systems, Ford in collaboration with the European Commission is studying, or testing, vehicles with that new system, and specifically testing the efficiency and environmental safety of vehicles with such integrated system, [11]. The official project assignment also defines the task of each company or institution in this project, so just stated above, and taking into account all the phases of the project, Fig. 3 defines the schedule of actions and each company or institution on which each project phase relies.

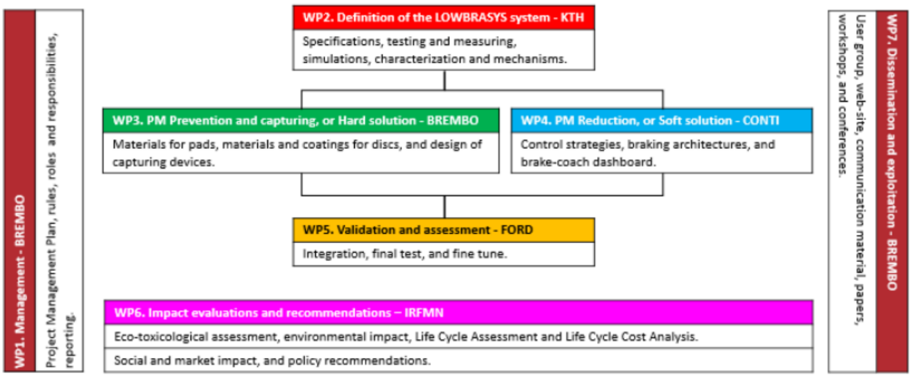

Figure 3. LOWBRASYS project by phases and leading companies or institutions for a particular phase, [12]

This project has multiple roles, i.e. there is a benefit from its development and the goals that have been set in this project. So, in addition to the goals that have been set and the benefits of these projects, various socioeconomic benefits can be obtained, as well as other benefits that the whole world can benefit from. This project can have a radical impact on changes related to the automotive industry. These changes would be reflected primarily in the reduction of particulate emissions and in the conservation of the environment. On the other hand, the application of modern vehicle systems, or in this case modern brake systems, would lead to the vehicles not only having better environmental performance, but also a better vehicle braking performance, higher reliability, but also a longer service life of this system.

This project enables, first and foremost, the development of innovative braking systems that can contain innovative elements that have not been applied or have not existed in current vehicle technologies, as well as some innovative materials. However, innovation must not only be reflected in modern technologies, but also in the development of new knowledge in various fields such as tribology, material science, complex phenomena, and the influence of particles on human health. This is not the only benefit of this project; of course, this project as a result can have an impact on the market as well as competitiveness between different vehicle manufacturers. Thus, this project can lead to increase competitiveness between companies with its innovations related to the braking system, as well as to the environmental performance of the vehicle. However, technology development and thus increasing competitiveness would not only apply to vehicle manufacturers, but also to companies that are suppliers to vehicle companies, and therefore, all suppliers or companies developing technologies or elements of those technologies would seek to develop better components. Therefore, such a competitive development would affect all companies involved in the vehicle production chain. This

means that the EU industry will be able to sustain and improve the production of high-quality products in the EU and ultimately recover some of its production from other competitive regions (especially Asia), [13].
Perhaps one of the main results achieved with this project is the development and prescribing of directives in the field of brake systems, but also, most importantly, the manufacturing technology and materials that can be used in production. This project enables the development of modern technologies that can be one of the standard technologies on some future vehicles by developing the technology of measuring the quantity and types of particles generated, [13].

COBRA

Another project that has been part of European projects in the field of brake systems, and environmental protection is the COBRA project. This project has been active for four years from 2014 to 2018. The aim of this project is to ensure the production of friction pads using modern technologies. This project aims to develop a completely new technology for the production of brake pads, which will be based on the innovative variety of hydro bonding materials that are integral materials of brake pads. In this case, this type of bonding may be applied instead of the use of phenolic resins as a binder, and of course, there must be no change in the brake performance, resulting in similar braking characteristics. In addition, the application of modern friction pad manufacturing technologies can also reduce the emission of aerosols and secondary ultra-fine particles ($PM_{0.1}$) that occur during braking by using traditional made friction pads made using phenolic resins as a binder. Since the brake linings contain 1-14% copper, this makes wear of a vehicle brake an important source of copper concentration in the atmosphere. It is the dominant source of copper when it comes to ambient air in Western Europe [14], [15].
According to [14], [15] which is also one of the official documents of this project, the process of making modern friction pads is shown in Figure 4. It shows a schematic representation of this project that is, the way of making and testing friction pads that are in production under this project. This project apparently develops its technology by applying hydro-bonding materials that can certainly reduce the influence of particulate matter produced by brake wear, however, this emission is primarily based on the reduction of hazardous and harmful substances that may contain heavy materials.

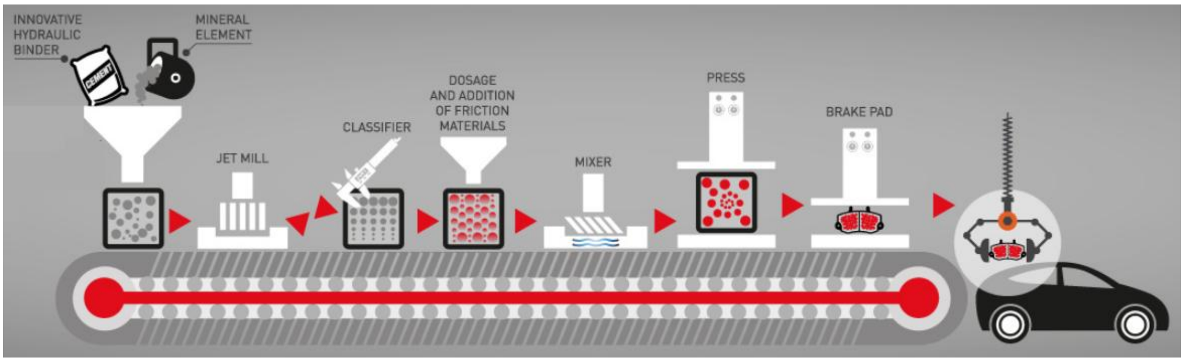

Figure 4. Production process of innovative friction pads developed during the COBRA project [15]

The ultrafine particles, or $PM_{0.1}$ particles, are one of the very dangerous categories of particles that can be created by wearing. The problem is also the frequent evaporation into the atmosphere and the formation of ultra-fine particles by organic compounds. However, it is possible to compare the volatile organic compounds of materials used for the production of friction pads, which are produced using the technology and materials defined in this project, that is, the COBRA project, and standard materials used by other manufacturers. In fact, in the laboratory tests of the project, using the technology of friction pad manufacturing, a dramatic or even complete decrease of COBRA-released volatile organic compounds was observed relative to standard phenol-based materials (M1). It is important to note that the emission of particles generated by friction pads made with COBRA 1 technology is lower than that in material M1, as can be seen in Fig. 5, [16], [17].

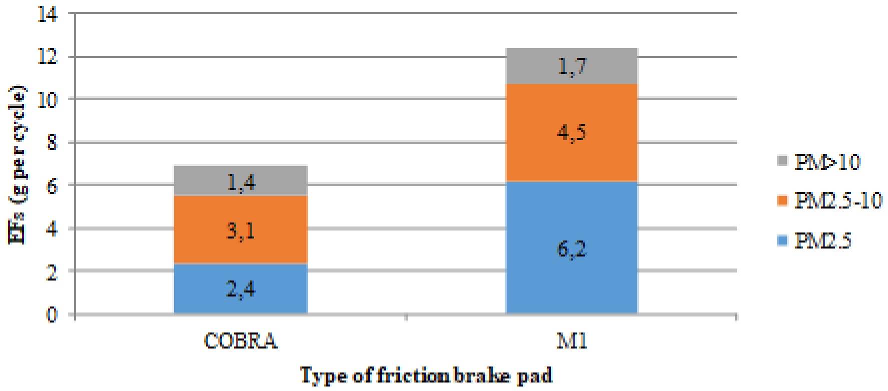

Figure 5. Generated emission of particles depending on the type of friction brake pad [17]

Research has shown that the model of the application of the friction materials used in this project has proven to be a positive measure to reduce the harmfulness of the resulting particles, that is, to have a reduced impact on the risk of developing cancer. Furthermore, this project found that overall toxicity was reduced by the application of this technology and the method of making friction pads. Thus, the effects of PM_{10} particles on various organisms (algae, crustaceans, plant seeds and earthworms) were investigated with various influential parameters such as vitality and reproduction rate. One example of particle toxicity testing is the analysis of particle influence on soil contamination and the effect on seed germination of cress lettuce (Lepidium sativum), whose seeds were exposed for 72 hours to soil contaminated with classic friction pad and particles from COBRA project friction pads. Seeds and their germination and root elongation were evaluated using the Germination Index (hereinafter referred to as IK), on the basis of which the effect of particulate toxicity in comparison with pure soil was evaluated. At the end of the study, it was found that there were no significant differences in germination effects between seed grown in soil contaminated by particulate friction pads developed in the COBRA project and those with the standard production formula (M1), however, this only applies to soil with a small percentage of soil pollution by particles, while in the case of higher pollution, a significant difference in seed germination was observed, as shown in Fig. 6, [17].

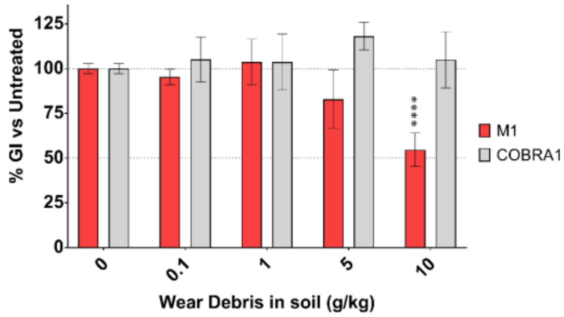

Figure 6. The effect of particle pollution on the seed germination index of plant Lepidium sativum [17]

CONCLUSION

The problem of the formation of non-exhaust particles is one of the problems seen by many automotive companies worldwide, as well as by many authors dealing with this issue. The aim of this paper is to review some of the most well-known European projects that have been initiated with the aim of reducing the particles generated by brake wear and their harmfulness. Such projects give a clear picture of the process that can lead to the reduction and even elimination of particle damage. Now, in all countries, friction substances in the asbestos-containing brake system have been eliminated. However, the metals contained in them are also a problem. Display in some projects with a change in the composition of the friction linings can achieve a reduction in particulate matter and reduce the impact of the negative environmental impact. Special vehicle manufacturing and application technologies can also reduce the number of particulate matter generated. Measurement and understanding of micrometre and ultra-fine particles and their impact on health and environment will be enhanced with recommendations to organizations to formulate regulations and standards in this area.

REFERENCES

[1] Glišović, J., Pešić, R., Vasiljević, S., Stojanović, N., Grujić, I., Road vehicle as a source of non-exhaust particulate matter, Proceedings of 14th International Conference on Accomplishments in Mechanical and Industrial Engineering, Banja Luka, 24 - 25 May, pp. 585-590, 2019.

[2] Denier van der Gon, H., Hulskotte, J., Jozwicka, M., Kranenburg, R., Kuenen, J., Visschedijk, A., European Emission Inventories and Projections for Road Transport Non-Exhaust Emissions. Non-Exhaust Emissions, pp.101–121, 2018.

[3] Wakeling, D., Passant, N., Murrells, TP., Pang, Y., Thistlethwaite, G., Walker, C., Brown, P., Del Vento, S., Hunter, R., Wiltshire, J., Broomfield, M., Watterson, J., Pearson, B.,, Rushton, K., Hobson, M., Smith, H., Misselbrook, T., 2017, UK Informative Inventory Report (1990 to 2015), available on: https://uk-air.defra.gov.uk/assets/documents/reports/cat07/1703161205_GB_IIR_2017_Final_v1.0.pdf, accessed: 15.06.2019.

[4] Aim of the Rebrake http://www.rebrake-project.eu/about/Pages/Aim.aspx, accessed: 06.04.2019.

[5] Phases of the Rebrake project, https://wiki.unece.org/download/attachments/54428767/PMP-45-12BREMBO.pdf?api=v2, accessed: 05.03.2019

[6] CORDIS, https://cordis.europa.eu/project/rcn/106170/reporting/en, accessed: 05.03.2019

[7] Perricone, G., Matějka, V., Alemani, M., Valota, G., Bonfanti, A., Ciotti, A., Ibrahim, M. (2018). A concept for reducing PM 10 emissions for car brakes by 50%. Wear, 396-397, 135–145.

[8] Lowbrasys, https://ec.europa.eu/inea/en/horizon-2020/projects/h2020-transport/road/lowbrasys, accessed: 12.03.2019

[9] Mission and vision of the project,, http://www.lowbrasys.eu/en/the-project/the_lowbrasys_project_mission, accessed: 12.03.2019

[10] Phases of the Lowbrasys Project, http://www.lowbrasys.eu/en/the-project/the_lowbrasys_project, accessed: 15.03.2019

[11] Lowbrasys Project Participants, http://www.lowbrasys.eu/en/media/news/lowbrasys_launches_the_lowbrasys_project_official_video, accessed: 15.03.2019

[12] Project plan, https://ec.europa.eu/research/participants/documents/downloadPublic?documentIds=080166e5a42143b7&appId=PPGMS, accessed: 19.03.2019

[13] Lowbrasys project reports, https://cordis.europa.eu/project/rcn/193410/reporting/en, accessed: 19.03.2019

[14] Glišović, J., Lukić, J., Stojanović, B., Stojanović, N., Airborne wear particles from automotive brake systems in urban and rural areas, 13th International Conference on Accomplishments in Mechanical and Industrial Engineering-DEMI 2017, Banja Luka, Repubika Srpska, pp. 26-26 Maj, pp. 717-722, 2017.

[15] Cobra project, http://www.cobralifeproject.eu/en/the-project/titolo_di_prova, accessed: 23.03.2019

[16] Cobra brochure, http://www.cobralifeproject.eu/en/file/8, accessed: 14.03.2019

[17] Lyman Report about the Cobra Project, http://www.cobralifeproject.eu/en/file/46, accessed: 23.03.2019

RADIATION OF ELECTROMAGNETIC FIELDS OF INDUSTRIAL FREQUENCIES. ELECTROMAGNETIC RADIATION OF ELECTRICAL APPLIANCES IN HOUSEHOLDS

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Abstract: This paper analyzes the sources of time-varying electrical and magnetic fields of industrial frequency. Therefore, very low frequency electromagnetic fields in our environment are analyzed. This refers to the power system, overhead power lines, transformer stations, electrical installations and household electrical appliances. The results of magnetic induction measurements of electrical household appliances (hair dryer, vacuum cleaner, water heater, electric cooker, aspirator, mixer, coffee grinder, mobile charger) are given, depending on the distance from the device.
Key words: fields of industrial frequency, measurements of electrical household appliances

INTRODUCTION

The human environment comprises various sources of non-ionizing radiation. These consider: power lines, cable and satellite communications, power stations, electric transportation vehicles (electric trains, trams and trolleybuses), TV, radio repeaters, etc.. As a result there is an interaction between the electromagnetic fields and biological tissue. The effects of these fields can be harmful to humans if the field strength exceeds certain threshold values which are defined by the corresponding regulations and defined based on harmful effects. In order to analyze the biological effects of electromagnetic radiation and to make assess of the associated hazards in a particular situation, it is necessary to know strength of the field in frequency domain. The same has to be compared with the corresponding allowed value. The field strength values can be reached by applying analytical calculations, numerical methods, or by using the appropriate measurement equipment. Despite the fact that the non-ionizing electromagnetic phenomena have been well studied, interactions between electromagnetic fields and organic matter, and especially human body, are still not fully clarified [1-3].

ELECTROMAGNETIC FIELDS AT VERY LOW FREQUENCIES IN OUR ENVIRONMENT

Time-varying electromagnetic fields generated by time varying AC (Alternating Current) electricity during transmission, distribution and use of electricity. The main sources of time varying electric fields in the work area are electric cables. The strength of these fields is in the range from 1 to 100 V/m. Flow of electrical current through a conductor produces a magnetic field. These fields always form a closed loop around the conductor which caused them. As the basic unit of magnetic flux density Tesla [T] is very large, it is the practice of using smaller units: microtesla [μT] and nanotesla [nT]. Under normal conditions in the workplace time-varying magnetic fields caused by electric grid ranging from 10 nT to 1 mT [2].

Frequency of a VLF field depends on the field sources. Although the dominant frequency of 50 Hz and 60, people are generally exposed to a mixture of frequencies, some of which may be much larger. For example, the frequency of certain parts of electronic equipment or TV monitor can go up to 120 kHz.

In addition, during turning may occur sudden peak in the waveforms of current and voltage, leading to a high-frequency transient conditions that can cause the radiation frequency of a few MHz. Also, the non-linear characteristics of electrical devices can cause the creation of significant harmonics at frequencies of a few kHz. Electric and magnetic fields are components of the EM field. Electric fields are generated in apparatus involved in network installation, ah, these devices do not have to be in operation [4].

Given that the above sources of device components in our environment, we'll just consider these devices as sources of electromagnetic fields of very low frequency VLF. In this sense, we are exposed to VLF magnetic and electric fields originating from many sources: the transmission lines connecting power plants and households through distribution lines and cables that distribute energy into our homes, schools and workplaces, substations, transformers, installation of our homes and buildings, and various other electronic devices.

Electric power system

An electric power system is a network of electrical components used to supply, transmit and use electric power. An example of an electric power system is the network that supplies a region's homes and industry with power - for sizable regions, this power system is known as the grid and can be broadly divided into the generators that supply the power, the transmission system that carries the power from the generating centres to the load centres and the distribution system that feeds the power to nearby homes and industries. Smaller power systems are also found in industry, hospitals, commercial buildings and homes. The majority of these systems rely upon three-phase AC power - the standard for large-scale power transmission and distribution across the modern world [4,5].
If you look at the picture of a typical power system, (Fig.1) you will recognize come to the conclusion that the transmission system (transmission line) is the main source of the electric and magnetic fields, because of the great length of the conductor and the high voltage line.
But other elements, such as electrical device in industry and households, electrical installations and distribution part of the system, are very important sources of electromagnetic fields in our environment.

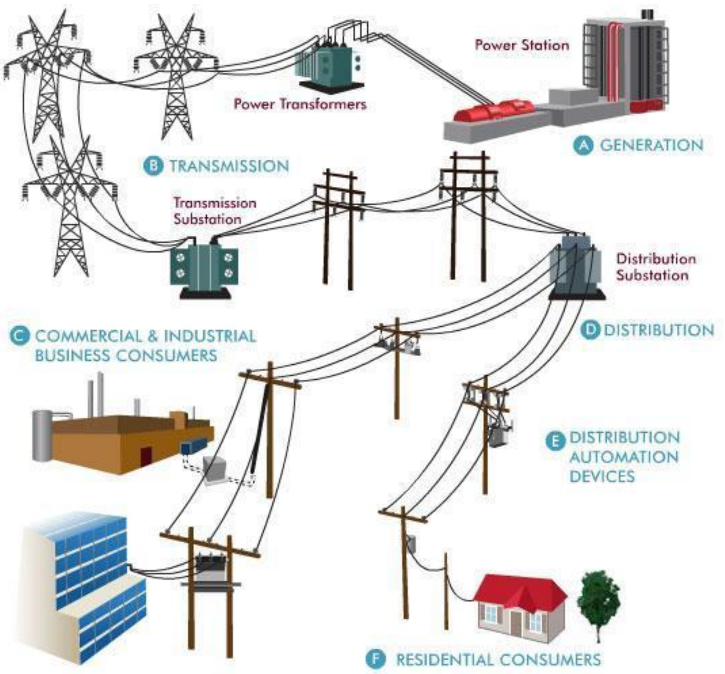


Figure.1. Basic structure of the electric system

Electrical energy produced in power plants is distributed to consumer areas via high voltage power lines from 35 kV to 400 kV. The voltage is reduced by transformers to 400/230 V for local distribution. The general population is exposed to magnetic fields at the network frequency, 50 Hz in as, via three individual sources: high voltage transmission power lines, the local system for the distribution and low voltage electricity at home and at work, and electrical household appliances. The first two sources create basic, so-called background magnetic radiation, known as the magnetic flux density of the environment [4],[5].

Overhead power lines

Transmission and distribution lines can be called by one name - power lines. Overhead power lines (Fig.2.) are the less expensive way to transfer electricity. Usually consist of parallel conductors, which carry most of the energy with very few losses or small radiated energy. Field between the conductors is intense, but it is usually closed between them. The strength of the magnetic field line is determined by the rate of electricity, the proximity of the transmission line, the transmission line height above ground, distance between phases, column geometry and distance from other lines [4],[5].
Highest levels of electric and magnetic field lines are located in the area where the conductors are closest to the earth, and it is midway between the two pillars. Because of the ambient temperature, the height of the lowest conductor was flying lower and higher in the winter, because the levels of the fields in the area flying higher and lower in winter.
Lately, most take account of the distribution and geometry of the column conductors to significantly reduced magnetic field.
At any point the field can be determined by superimposing fields of each wire. If, for example. the three-phase line, then the voltages and currents of each phase conductor to move in, and the resultant field vector calculated based on the sum of the fields of each of the conductors. The only point fields are added which produces a relatively high field strength, while the other points may cancel each other. Conductor fields can thus have a very complex spatial distribution.

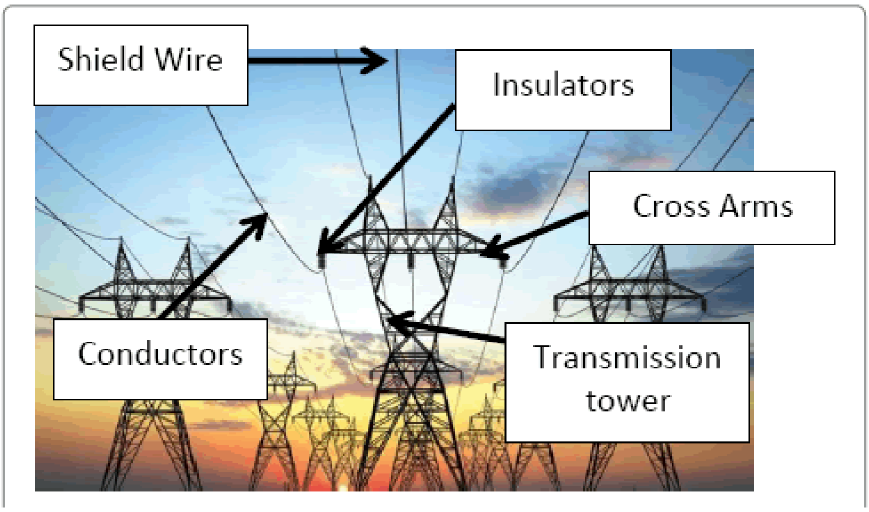


Figure 2. Overhead power lines

Addition to these normal variations in field strength electric field under the conductor is changing depending on their surroundings. In the Fig.3 shown is phenomenon of concentration of the electric field above the person's head beneath the conductors.

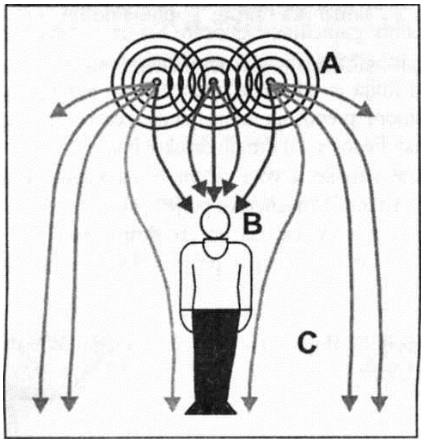


Figure 3. Concentration of the electric field above the person's head beneath the conductors

Because the electric field tends to end up in (or shift to) a grounded object, and because the human body is electrically conductive and near potential electrical field surrounding the Earth is directed toward human head (B). Urinary areas (C) with a weakened electric field strength. All over the world there are vast energy network. That means that almost complete human populations exposed to various fields of power system components. The only difference is in the degree of exposure that varies in the day, days in the week, the season, and depending on the ambient temperature. Most fields are usually located beneath high voltage transmission lines, however, the field strength depends on the strength of the current [4,5].

Transformer stations

Transformer stations (Fig.4) are one of the most important parts of the energy system, which is used to change the voltage level, and perform other functions in the transfer of control and flow of electrical energy. There are several ways to build substations in order to achieve a reliable electricity system. In essence, they are complex equipment such as circuit breakers, high voltage switches, grounding, transformers intended course with the changing voltage control. Since the substations are often located near schools and homes, must be considered as sources close to the electric and magnetic fields.

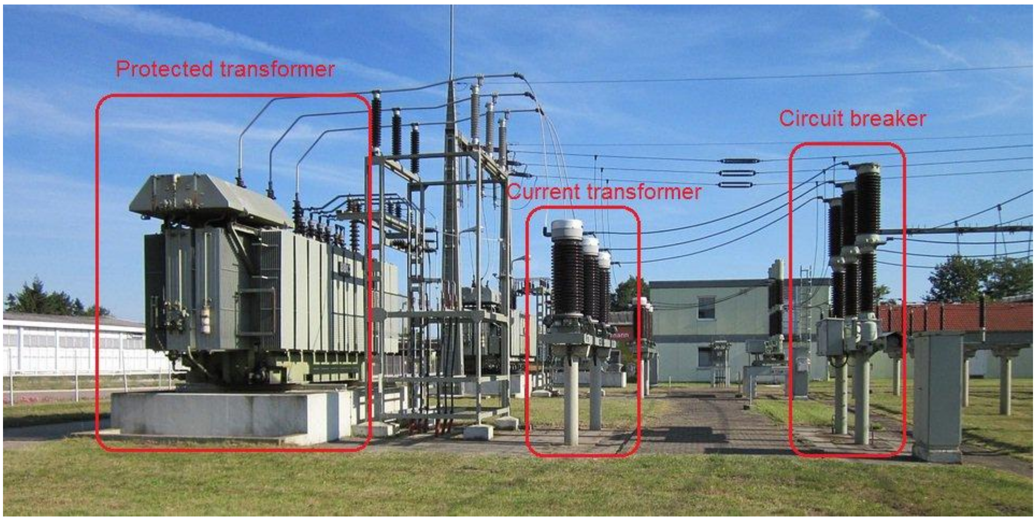


Figure 4. Transformer station

Transformers are sources of strong magnetic fields because their principle of operation is based on a time-varying magnetic fields. The problem of the magnetic field near cells is more complex, since the current entering or leaving the station, in the general case are not symmetric. Field produced by equipment weaks with distance and do not spread outside the physical boundaries stations. However, the magnetic field near the station is stronger than in other parts. Approximate values that can be found near the fence transformer cells depends on the level of voltage: 10 µT for 275-400 kV cells and 1.6 µT station for 11 kV

Transformer as standalone devices found in rural areas (Column transformers), and in urban areas, mostly inside residential buildings. Transformers in buildings adversely affect the people in the apartments above them. These transformers, create an extremely strong electric and magnetic fields. Unfortunately, to enable lower expenses of their installation, they are frequently installed in the buildings. That is not in line with technical recommendation which allowed that kind of installation in exceptional cases, only. This radiation is stronger than transmission radiation [5].

Vehicles on electric power

Electric trams and trains (Fig.5) are also sources of static and VLF fields. For traction they somewhere use direct current somewhere alternating current. Near the coaches floor the static magnetic fields can reach 0.2 mT, and time-varying magnetic fields can reach several hundred µT. At the headquarters of passengers, electric fields can reach up to 300 V / m and magnetic field reaches values of a few tens µT [5].

Figure 5. Radiation Sources in the traffic.

ELECTROMAGNETIC RADIATION ELECTRICAL HOUSE APPLIANCES

Staying in our apartments significantly contributes to the exposure to electromagnetic radiation. All electrical devices, during operation, create a magnetic field. Such fields generally fall inversely with the third degree of distance and are therefore significant at short distances from the device.
In the case of low-frequency radiation measured in the " near zone ", separate measurement of the electric and magnetic fields is required.
At lower frequencies, the magnetic field is more dominant and more harmful to the organism. Therefore, the measurement of the magnetic field H was carried out, depending on the distance from the device.

Figure 6a shows a magnetic dependence diagram of the distance from a mobile charger obtained by measurement, and Figure 6b shows a magnetic dependence diagram of the distance at a coffee mill obtained by measurement. The same results are given in Tables 1 and 2.

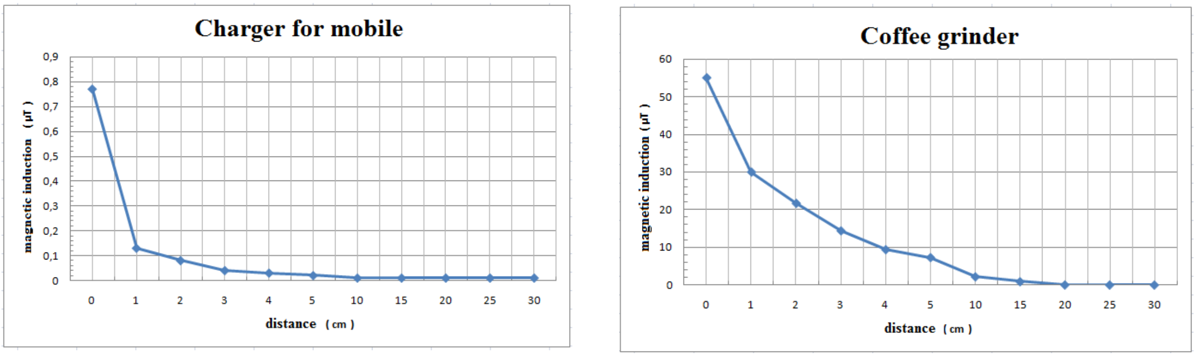


Figure 6. Measured magnetic induction versus distance at a) mobile charger and b) coffee grinder [6].

Table 1. Measured magnetic induction versus distance at mobile charger

Distance (cm)	0	1	2	3	4	5	10	15	20	25	30
Magnetic induction (μT)	0,77	0,13	0,08	0,04	0,03	0,02	0,01	0,01	0,01	0,01	0,01

Table 2. Measured magnetic induction versus distance at coffee grinder

Distance (cm)	0	1	2	3	4	5	10	15	20	25	30
Magnetic induction (μT)	55	30	21,7	14,4	9,4	7,3	2,2	0,9	0,04	0,02	0,01

Figure 7a shows a magnetic dependence diagram of the distance from a mixer obtained by measurement, and Figure 7b shows a magnetic dependence diagram of the distance at a aspirator obtained by measurement. The same results are given in Tables 3 and 4.

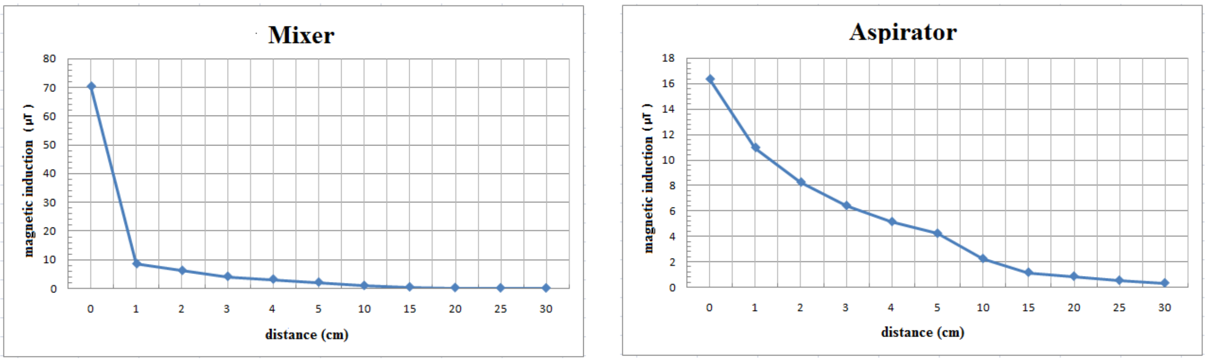


Figure 7. Measured magnetic induction versus distance at a) mixer and b) aspirator [6].

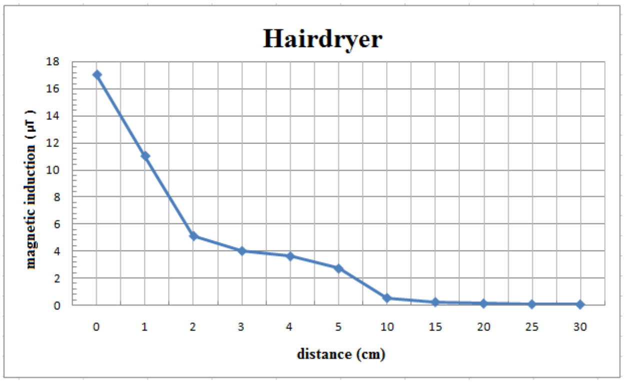
Table 3. Measured magnetic induction versus distance at mixer

Distance (cm)	0	1	2	3	4	5	10	15	20	25	30
Magnetic induction (μT)	70,3	8,5	6,15	4,07	3,12	2,07	0,91	0,41	0,17	0,07	0,03

Table 4. Measured magnetic induction versus distance at aspirator

Distance (cm)	0	1	2	3	4	5	10	15	20	25	30
Magnetic induction (μT)	16,33	10,95	8,23	6,39	5,13	4,21	2,23	1,15	0,84	0,52	0,31

Figure 8a shows a magnetic dependence diagram of the distance from a hairdryer obtained by measurement, and Figure 8b shows a magnetic dependence diagram of the distance at a vacuum cleaner obtained by measurement. The same results are given in Tables 5 and 6.



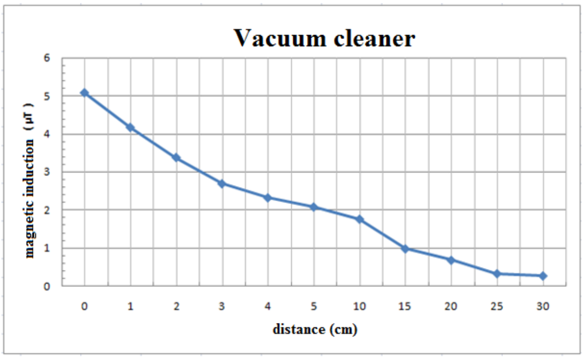


Figure 8. Measured magnetic induction versus distance at a) hairdryer and b) vacuum cleaner [6].

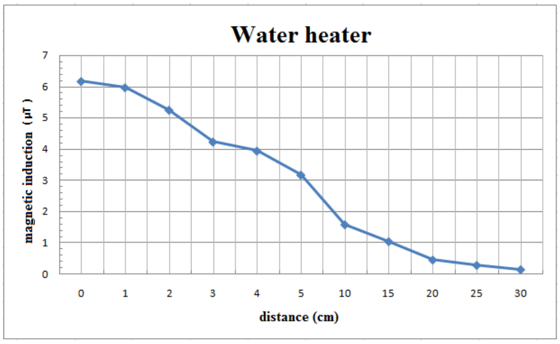
Table 5. Measured magnetic induction versus distance at hairdryer

Distance(cm)	0	1	2	3	4	5	10	15	20	25	30
Magnetic induction (μT)	17	11	5,1	4	3,6	2,7	0,53	0,23	0,12	0,07	0,05

Table 6. Measured magnetic induction versus distance at vacuum cleaner

Distance(cm)	0	1	2	3	4	5	10	15	20	25	30
Magnetic induction (μT)	5,07	4,16	3,37	2,68	2,31	2,07	1,75	0,97	0,67	0,32	0,26

Figure 9a shows a magnetic dependence diagram of the distance from a water heater obtained by measurement, and Figure 9b shows a magnetic dependence diagram of the distance at a electric stove cleaner obtained by measurement.



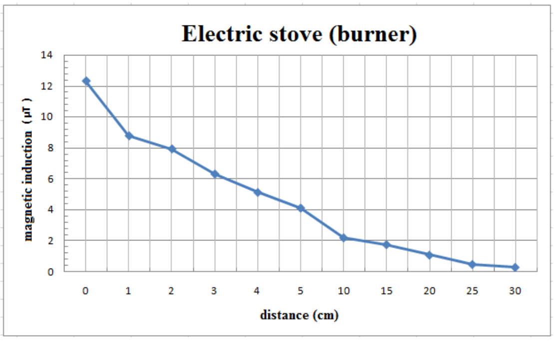


Figure 9. Measured magnetic induction versus distance at a water heater and b) electric stove [6].

Table 7. Measured magnetic induction versus distance at water heater

Distance(cm)	0	1	2	3	4	5	10	15	20	25	30
Magnetic induction (μT)	6,17	5,97	5,25	4,23	3,94	3,14	1,58	1,04	0,45	0,28	0,14

Table 8. Measured magnetic induction versus distance at electric stove

Distance (cm)	0	1	2	3	4	5	10	15	20	25	30
Magnetic induction (μT)	12,32	8,78	7,93	6,31	5,12	4,11	2,19	1,75	1,07	0,47	0,28

Many workers are more exposed to electromagnetic fields in the workplace than at home, although they spend less time there. Workplace fields are usually larger because of the higher concentration of the device. Electrical devices such as photocopiers can emit strong fields even when in standby mode, while in-use radiation can double.
Some industrial plants have equipment that produces large magnetic fields. In power systems, these are generator buses and some reactive elements in the station.

CONCLUSION

The impact of the electromagnetic field on the health of the broadest population and professionally exposed persons is a problem that has been attracting public attention for over thirty years. Scientists around the world are conducting intensive research into the effects of the electromagnetic field on humans and their environment. So far, the results of studies have not reliably confirmed the direct relationship between low-frequency low-intensity electromagnetic radiation exposure and the number of affected post-mortem populations. However, it is evident that adverse effects exist and depend on field strength, frequency and exposure time, etc. The overall conclusion is that, where possible, unnecessary exposure to these fields should be avoided, necessary safeguards should be taken and the regulations and regulations governing it should be adhered to. The development of technology has led to the application of a large number of devices and systems whose operation is based on the use of electromagnetic fields, so that the density and frequency of radiation in the space in which we live is multiplied. Now the human body is exposed to far higher doses of radiation than was the case with natural sources. Of course, this has some effect on the human body and its health..

REFERENCES

[1] International Commision on Non-Ionising Radiation Protection (ICNIRP) Guidelines: Guidelines for Limiting Exposure to Time Varying Electric, Magnetic and Electromagnetic Fields (up to 300 GHz), Health Physics, Vol. 74,4 (1998) 494-522
[2] International Commision on Non-Ionising Radiation Protection (ICNIRP) Guidelines: Guidelines for Limiting Exposure to Time Varying Electric, Magnetic and Electromagnetic Fields (up to 300 GHz), Health Physics, Vol. 74,4 (1998) 494-522
[3] Directive 2004/40/EC of the European Parliament and of the Council of 29 April 2004 on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (electromagnetic fields),Official Journal of the European Union L 159 of 30 April 2004
[4] Kemal Dervić, Slobodan Janković, Željko Despotović, Vladimir Šinik, Vojin Kerleta, THE RADIATION OF ELECTROMAGNETIC FIELDS OF VERY LOW FREQUENCY, International conference „Ecology of urban areas 2012“ **,** Hunting Manor**,** Kaštel – Ečka, Zrenjanin, Pg 348-365
[5] Kemal Dervic“ Man in the Middle radio frequency field“ Transparency Montenegro, Podgorica,2008
[6] Branko Radović, Electromagnetic radiation electrical home appliances, Graduate thesis, Technical Faculty “Mihajlo Pupin”, Zrenjanin, 2016

BASICS OF ELECTROMAGNETIC RADIATION

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Abstract : The basics of electromagnetic radiation are given at the beginning of the paper. The interdependence of the electric and magnetic fields is given. The interdependence of the electric and magnetic fields is pointed out. The concept of near and far zones of electromagnetic field is presented. The electrical characteristics of the electromagnetic field are presented as the characteristic impedance of the free space. Expressions for the power density of electromagnetic waves are given.
Key words: electromagnetic radiation, near and far zones

INTRODUCTION

As a result of the rapid development of electrodynamics in the 19th century, the theory of electromagnetic waves emerged as a special form of electromagnetic field.
At the beginning of the 19th century, the Danish physicist Hans Cristian Oersted (1777-1851) and the English physicist Michael Faraday (1791-1867) came up with the theory about the indivisibility of the electric and magnetic fields. In 1846 the English scientist James Clarc Maxwell (1831- 1879) published a complete theory of the electromagnetic field, explaining in its entirety the basics of electrical and magnetic phenomena. He presented mathematically the theory of the electromagnetic field mathematically in the form of the later called Maxwell's equations, which can also be expressed in words in the form of the following short sentences:

- The electric field force lines have their origin and end in electrical charges.
- The magnetic field force lines are closed curves.
- A variable magnetic field causes an electric field to form
- Variable electric field and electric charges in motion magnetic fields are the cause.

From Maxwell's equations it follows that electricity and magnetism are different manifestations of a single electromagnetic force. Neither the electric field nor the magnetic field will go anywhere for themselves, but as Maxwell described, a change in the magnetic field creates a change in the electric field and vice versa. Changes in these fields in the space around some distribution of electric charges can, if certain conditions are fulfilled, also manifest as electromagnetic waves that propagate at a constant speed of light through space. Maxwell concludes that light waves are also electromagnetic waves. Experimental confirmation of Maxwell's postulates was given in 1887 by the German physicist Heinrich Hertz (1857-1894). In his honor, the unit for measuring the frequency of electromagnetic waves (one oscillation per second) was called Hertz (Hz).In his experiment, Hertz was able to transmit a genuinely strong electrical charge from one copper wire to another copper wire that was a few meters away from each other. In Figure 1. 1, the sheath and construction of the first Hertz oscillator are shown [1].

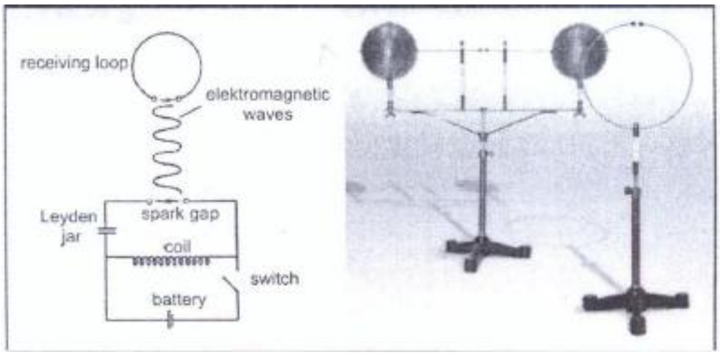

Figure 1. Scheme and construction of the first Hertz oscillator.

Hertz proved what Maxwell had just theorized: that electromagnetic waves move at the speed of light (which confirms that EM waves are a type of light and vice versa) and found a way to produce an electric and magnetic field "hooked" one in. second in the space around the antenna, thus producing an electromagnetic wave that moves just as Maxwell assumed.

The electromagnetic waves obtained in the Hertz experiment had a wavelength of approximately 1 meter, which is one million times greater than the wavelengths of visible light, and the properties of these waves (reflection, deflection, interference) corresponded to the properties of light.

BASIC TERMS OF ELECTROMAGNETIC RADIATION

An electromagnetic (EM) field is a physical field produced by of charged objects and theoretically extends to infinity. It acts by the Lorenz force on the charged objects found in it.

An electromagnetic field is a combination of an electric and a magnetic field, with the electric field being produced by stationary charges and magnetic charges in motion (electric currents). In the past, theories of electric and magnetic fields were considered separately, and later it was understood that electric and magnetic fields were only two parts of one larger whole of the electromagnetic field.

From the standpoint of classical theory, the EM field can be considered as a smooth continuous field propagating in the form of waves, while from the point of view of quantum mechanics it can be viewed as being made up of individual corpuscle photons. Accordingly, the EM field can be seen as: continuous structure or discrete structure.

Electromagnetic radiation is a self-propagating wave in space or through matter, and it has both electrical and magnetic components that oscillate in phase normally (at an angle of 90 °) to each other and in the direction of the propagation of the wave or energy. Given the frequency of this oscillation, a spectrum of EM radiation was formed containing RF, MT, THz, infra red, visible, ultraviolet, X, and gamma radiation.

Otherwise, the term "radiation" means energy in the form of waves or subatomic particles in motion emitted by atoms or other bodies, when it changes from a higher energy state to a lower energy state. It can be classified as ionizing or non-ionizing, depending on its effects on the atom.

The term "radiation" usually refers to ionizing radiation that has enough energy to ionize atoms or molecules, while non-ionizing radiation does not have enough energy. In nature, there is radioactive material that emits ionizing radiation, and so far it has been relatively well researched, from all aspects including its effect on living organisms. However, in recent years, increasing attention has been paid to the study of non-ionizing radiation due to the fact that the environment is increasingly becoming "polluted" by this radiation, and the question is justified: What is the extent of the harmfulness of this radiation on living beings?

If there is an EM field in some space, this is still not enough to form an EM wave, as this requires some additional conditions. For this reason, the term radiation often refers only to states that allow the emission of EM waves, although the state of EM field itself in some space can be considered as the state of energy radiation from the charge system created by that field.

With this in mind, electromagnetic radiation can be divided into two groups: natural and technical radiation, as follows:

Natural radiation includes:

- Earth's magnetic field (approx. 45 μT),

- neutral electric air field,
- Earth's resonant frequency (approx. 10 Hz),
- variable atmospheric field (O - 30 Hz),
- cosmic and terrestrial microwaves,
- radio waves from the sun and from space,
- infrared radiation,
- light radiation,
- X-ray and gamma radiation and
- radiation corpuscles.

For natural radiation, which, like all, is part of the unique electromagnetic spectrum, the simple term "radiation" is used.
In everyday communication, the term electromagnetic radiation refers to technically produced electric and magnetic fields.
The main sources of technical radiation are:

- electrostatic fields,
- power plants and appliances,
- radio and television transmitters,
- electrical appliances in industry and households,
- railway and tram electrical network,
- telecommunication network,
- radar installations,
- infrared radiation,
- ultrasonic radiation and
- X-rays.

In physics, there is a term that clearly defines the specifics of electromagnetic radiation, called the electromagnetic radiation spectrum (Figure 2).

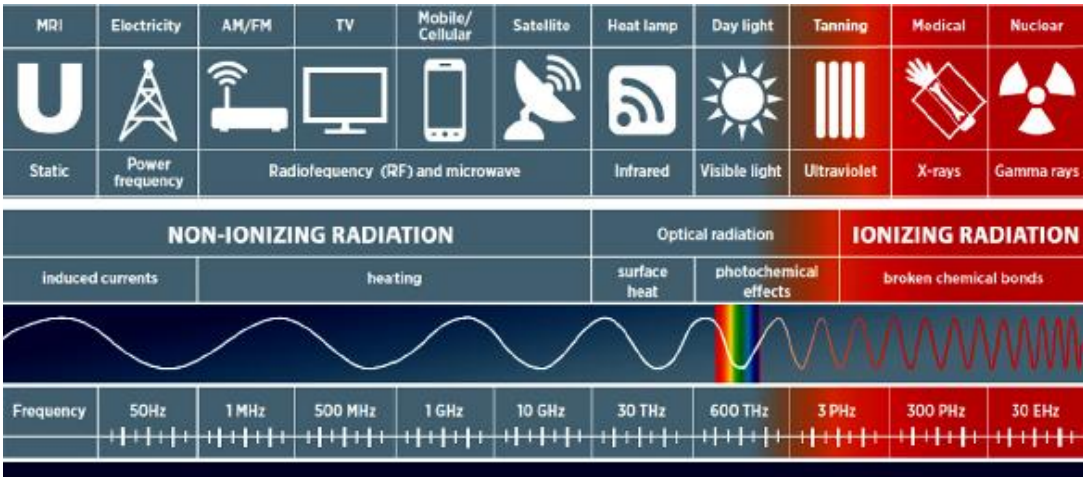

Figure 2. Electromagnetic wave spectrum

This spectrum classifies radiation by wavelength, or frequency, of electromagnetic waves into groups that have similar properties. All types of electromagnetic radiation have the same physical properties in terms of divergence, interference, coupling and polarization, and differ in the amount of energy.
In general, the non-ionizing part of the electromagnetic spectrum can be divided into three broad areas:

- EM radiation of electric and magnetic fields of extremely low frequency
- (Extremely low frequency-ELF)
- Radio frequency radiation
- Optical radiation

THE INTERDEPENDENCE OF ELECTRICAL AND MAGNETIC FIELDS

Each variable magnetic field creates a variable electric field whose forces are closed and encompasses the magnetic field forces that create it (Figure 3-a).
The intensity of the induced electric field is proportional to the rate of change of the magnetic field [2].
This law of electromagnetic induction can be formulated as follows: each variable electric field creates a variable magnetic field whose forces are closed and encompasses the forces of the electric field that creates it (Figure 3-b).
The intensity of the induced magnetic field is proportional to the rate of change of the electric field. This most important property of the mutual induction of electric and magnetic fields explains the nature of wave propagation in free space, i. where there are neither conduction currents nor electrical loads.

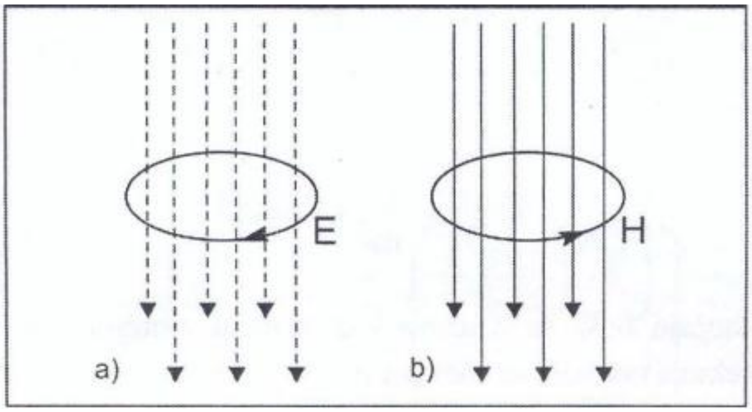

Figure 3. Each variable magnetic field creates a variable electric field whose forces are closed and encompasses the magnetic field forces that create it

Time-varying electromagnetic field

The radiation of electromagnetic waves can be explained by the behavior of the electromagnetic field produced by time-varying current.
Each field has energy that comes from a power generator. Sometime after the generator is switched on, the conductor begins to radiate energy to its environment. This means that an electromagnetic field has been created ("a certain time after" because electricity does not spread infinitely fast but "only" at a speed light). When the generator shuts off, the electromagnetic field disappears, ie. the field energy is returned through the conductor to the generator. This feedback process also requires some time. Therefore, the parts of the field farthest from the conductor return the last. The disappearance of the magnetic field creates a voltage in the conductor which again causes the electric field to form.
The electromagnetic field does not change when a direct current flows through the conductor. It changes only when you turn on (create a field) and turn off (disappear a field) a source.
If a time-varying current flows through the conductor, then the processes of switching on and off are constantly repeated in the frequency rhythm.

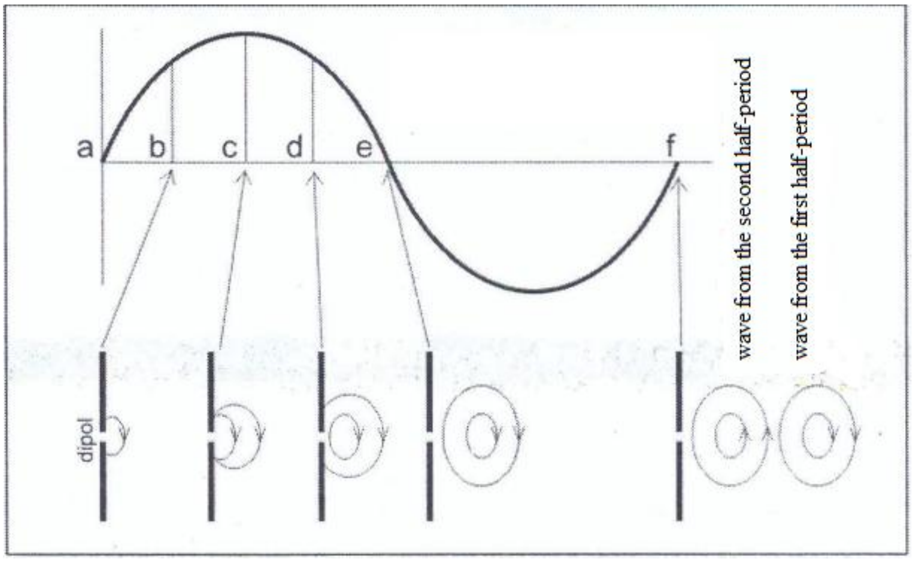

Figure 4. Generation of an electromagnetic wave on a dipole

Using Figure 4, we consider events on an open radiator-dipole that is powered by a time-varying current, through the time of change of one half-period of voltage at the ends of that dipole.
The image begins with the condition shown at (a) when the voltage is zero. Since there is no voltage, so does the force of the electric field. In point {b) we have an increase in voltage so a small force occurs, the number of forces increases with increasing voltage (c).
Particularly interesting is the moment (d) when one force no longer closes over the dipole, but "detaches" and closes to itself. Later this happens to the other force (e).

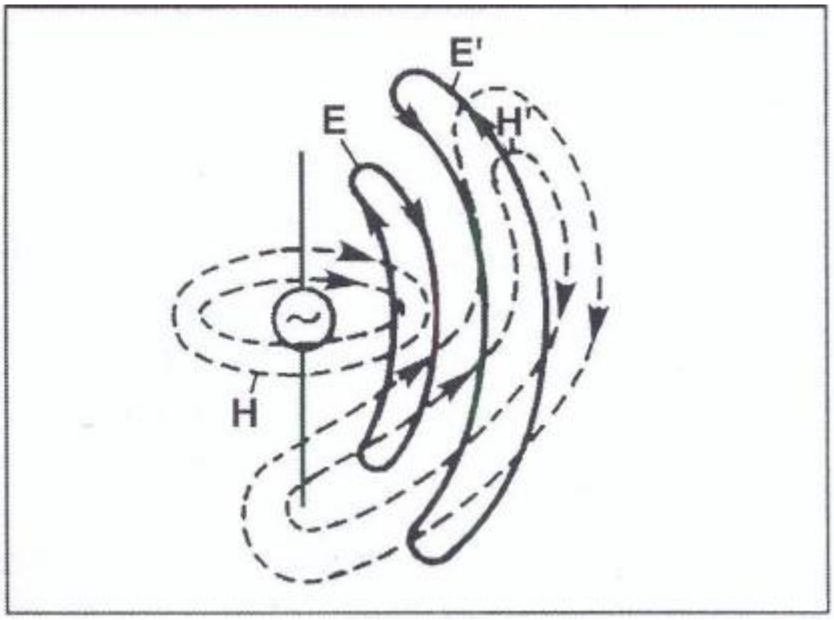

Figure 5. Time-varying electromagnetic field near dipoles

In the second half period, the force from the dipole, but now in the opposite direction, reappears, and the previously produced forces that have "broken off" propagate through space.
The magnetic field forces behave in the same way, except that they belong to a plane normal to the plane in which the electric field forces are located (see Figure 6).

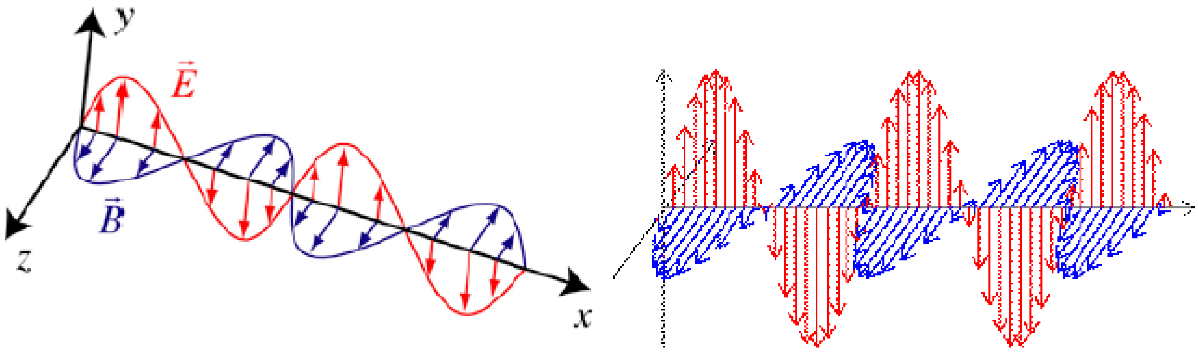

Figure 6. Electromagnetic wave

Given the repetition of this process in accordance with its periodicity, a time-varying current flowing through the conductors produces in space a time-varying magnetic field H, which, according to the law of electromagnetic induction, creates a time-varying electric field E at distant points.
The field E is connected to the field H and at further distant points creates a time-varying magnetic field H ', which again creates an electric field E', etc. (Figure 5).
These periodically changing fields expand in space at the speed of light.

The creation of an electromagnetic wave in free space is conditioned by the assumption that the generator constantly changes the direction of flow of current and that the distribution and time of flow of current are of a different direction. This prevents residual field lines from returning to the conductor and forces them to expand into space.
In the homogeneous medium, the radiation field extends perpendicularly and such a line represents the line of propagation of the electromagnetic wave (Figure 6).
Along the wave propagation line, the electric and magnetic fields are arranged in a sinusoidal manner and coincide with each other in phase. At any point in the space through which an electromagnetic wave passes, the electric and magnetic fields change according to sine law. The electromagnetic field phases at different points are different. As a result, the field image of the electromagnetic wave is constantly changing.

The term "near" and "far" zones of EM fields

Electromagnetic waves generated by man-made technical devices (transmitters) are fed by a coaxial cable or waveguide to the appropriate antenna through which electromagnetic energy is transmitted to free space.
If the conditions are met that the antenna is well adapted on the one hand to the electrical impedance of the cable and on the other hand to the characteristic impedance of the free space, the charged particles on the surface of the antenna generally extend outward (out of the antenna), thus forming an electromagnetic wave traveling through the free space.
Electric and magnetic fields do not have the same characteristics near a radiation source and at a certain distance. If we could freeze the motion of an electromagnetic wave traveling in free space, it would look like Figure 7.

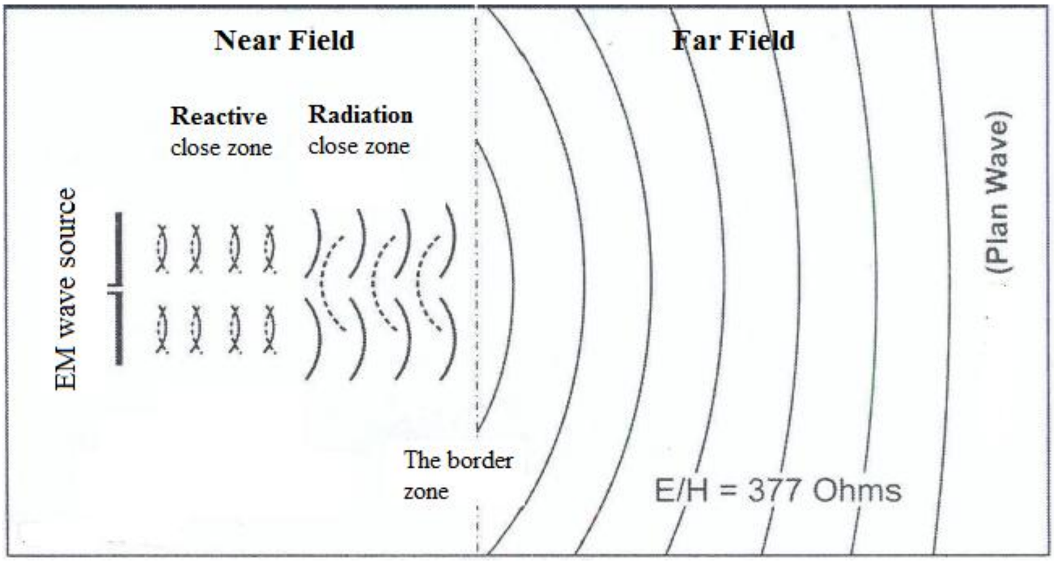

Figure 7. Near and far field

Within the close zone, there are: a reactive close zone and a radiant close zone in the immediate vicinity of the antenna. In a reactive close zone, energy is not radiated but is renewed and re-emitted during successive oscillations. The reactive close zone is very important when analyzing the EM fields of the frequency range on which handheld radios and mobile phones operate, at energy levels of just a few watts. In the radiant close zone, both energy accumulation and radiation are performed [3,4,5].
While the strength in the far area dissipates with distance, it may increase or even remain in the near zone until the distance from the antenna is closer to the far zone. In the near zone, the relationships between electric and magnetic fields are neither constant nor proportional, and therefore need to be measured separately.
The electromagnetic field in the far zone is very consistent and the basic rules apply here are that the electric field is always normal to the propagation direction, while the magnetic field is always normal to both the electric field and the propagation direction. In the far field of the electromagnetic field, where the relations between the electric and magnetic fields are constant, it is possible to measure only the electric field and to calculate it from the magnetic field (which is not possible in the near field). How close the source is, the "closer field" is determined by the wavelength, or frequency, of the individual radiation source. There is talk of a ‘far field’.
The higher the frequency, the shorter the wavelength and vice versa.
From this it can be concluded that the wavelength at the frequencies of the voltage grids is very large (6000 km for 50 Hz and 5000 km for 60 Hz).
The electric and magnetic fields in this range act independently and are thus measured. Since the 6000/5000 - kilometer wavelength, 50/60 Hz radiation is much greater than the relevant distances from the field source, the intensity of the so - called. The "near field" is matte higher than the so-called radiation field. At a 10-kilometer 60 Hz, 500 MW (megawatt) transmission line, radiation is measured at only 1 mW, which is a very small fraction of the transmitted energy.

ELECTRICAL CHARACTERISTICS ELECTROMAGNETIC FIELD

When considering the propagation and radiation of electromagnetic waves, it is necessary to wash their basic electrical characteristics in order to obtain a realistic assessment of the effect of electromagnetic radiation on the human body.

Characteristic impedance of free space

The characteristic impedance of the space implies the relationship of the transwave components of the electric and magnetic fields. In our case, we start from the assumption that this is a "far zone" where the vectors of electric and magnetic fields are non-zero.

The magnitude of the energy density in a wave can be calculated from a vector product.

$$\vec{E}\times\vec{H} = E\cdot H\cdot\sin\theta \tag{1}$$

When we look at our electromagnetic wave in free space (see Figure 7), where the quotient of electric and magnetic fields is equal to the impedance in free space, we can say that:

$$Z_0 = \sqrt{\frac{E}{H}} \tag{2}$$

Z_0 is the impedance and is equal to the quotient of E and H, and does not depend on the magnitudes of these fields [10]. Free space provides resistance to electromagnetic radiation. It has permeability (the ratio of the magnetic flux density generated in an environment and the strength of the magnetic field that produced it) and the dielectric constant - the transmittance (the ratio of the electric flux density generated in an environment and the strength of the electric field that produced it). For free space, these two sizes have the following value:

$$\mu_0 = 1,257\cdot 10^{-6}\left[\frac{H}{m}\right]\cdots\varepsilon_0 = 8,853\cdot 10^{-12}\left[\frac{F}{m}\right] \tag{3}$$

so using Maxwell's equations we get:

$$Z_0 = \sqrt{\frac{\mu_0}{\varepsilon_0}} = \sqrt{\frac{1,257\cdot 10^{-6}\, F/m}{8,855\cdot 10^{-12}\, H/m}} = \sqrt{141953,6985}$$
$$Z_0 = 376,767 \approx 377\Omega \tag{4}$$

Electromagnetic wave power density

Electromagnetic waves transmit electromagnetic energy whose quantity is characterized by a power density (S) or a Pointing vector [1].

Pointing vector or power density of EM field is the amount of energy that passes through the surface of 1 m^2, normal to the direction of wave propagation.

The power density of EM waves is a very small magnitude which characterizes the power of the electromagnetic wave and is a direct indicator of the radiation exposure of EM waves.

The electric (E) field is usually expressed in volts per meter (V / m). Similarly, the magnetic (H) field is determined in A / m. The product of these two values is the energy density (the voltage times the stntja equals the power, according to Om's law). The resulting units are watts per square meter (W/m^2), or more often milliwatts per centimeter square (mW/cm^2).

The magnitude of the power density of the EM wave (S) is determined by the expression:

$$S\left[W/m^2\right] = E\left[V/m\right]\cdot H\left[A/m\right] \tag{5}$$

The magnitudes of the intensity of the electric (E) and magnetic (H) fields of the electromagnetic wave in the free space are related to each other by the expression:

$$E\left[V/m\right] = 377\Omega\cdot H\left[A/m\right] \tag{6}$$

where: $377\,\Omega$ - characteristic impedance of free space.

Therefore, the magnitude of the Pointing vector or the power density of the electromagnetic wave (S) is:

$$S\left[W/m^2\right] = 377\Omega \cdot H^2\left[A/m\right], \tag{7}$$

expressed over the intensity of the magnetic field, or

$$S\left[W/m^2\right] = \frac{E^2}{377} = 0.00265 \cdot E^2\left[V/m\right], \tag{8}$$

expressed over the intensity of the electric field.

CONCLUSION

In order to understand the effects of electromagnetic radiation on humans, it is necessary to know the basics of electromagnetic radiation. The theory of inseparability of electric and magnetic fields is presented in the paper. Neither the electric field nor the magnetic field will go anywhere for themselves, but as Maxwell described, a change in the magnetic field creates a change in the electric field and vice versa. Changes in these fields in the space around some distribution of electric charges can, if certain conditions are fulfilled, also manifest as electromagnetic waves that propagate at a constant speed of light through space. Maxwell concludes that light waves are also electromagnetic waves.

REFERENCES

[1] Kemal Dervic“ Man in the Middle radio frequency field“ Transparency Montenegro, Podgorica, 2008. http://www.foti.co.rs/
[2] Bozo Metzger: " Radio Manual for Amateurs and Technicians ", Technical Book, Belgrade, 1985
[3] Hubert Trzaska.: "Electromagnetic Field Measurements in the Near Field", Hardcover-Mar 2000.
[4] Pawel Bienkowski.: ″Accuracy limitation factors in near field, emf metrology″. EM Environrnent Protection Lab., Technical University of Wroclaw, Poland
[5] Wu,K., Parekh,S.: ″Method oj Transjorming Fresnel Field to Far Field jor, Circular Aperture Antennas″, IEEE 1990, pp. 216-219.

SESSION 7. ENVIRONMENTAL MANAGEMENT AND OCCUPATIONAL SAFETY

THE IMPORTANCE OF YOUTH ENTREPRENEURSHIP FOR ACHIEVING COMPETITIVENESS AND ITS ROLE IN SUSTAINABLE DEVELOPMENT

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Abstract: The sustainable development agenda focuses on the preservation of natural resources alongside improving the quality of peoples' lives. Entrepreneurial behavior has a significant role in economic development. Further, youth entrepreneurship affects economic prosperity in several ways. It increases productivity, reduces unemployment rates, increases the standard of living etc. This paper analyzes the role and importance of entrepreneurial behavior of young people for achieving competitiveness, sustainable development, and sustainability entrepreneurship. The paper discusses guidelines for improving competitiveness with youth entrepreneurship within the frameworks of sustainable development. In addition, the paper analyses data on youth entrepreneurship in Serbia. Sustainable development is discussed through the "The 2030 Agenda for sustainable development". Overall, the paper provides significant insight for future research.
Key words: sustainability entrepreneurship, youth entrepreneurship, sustainable development, competitiveness

INTRODUCTION

Entrepreneurship can be observed as a process that aims at creating and implementing innovations in the company with the function to solve and manage problems and challenges of consumers. In addition, entrepreneurship has a large impact on society. In the modern business environment companies have to apply the concept of entrepreneurship in order to achieve a more competitive position on the market. Certainly, entrepreneurship and entrepreneurial behavior is a crucial factor for achieving competitiveness. This implies entrepreneurial behavior of individuals as well. Small and medium-sized enterprises, which operate on the basis of entrepreneurship, are a strong force which drives economic growth and it is an effective creator of new jobs [1]. Further, entrepreneurs can be viewed as innovators who seek out opportunities on the market. Entrepreneurship diversifies and distributes knowledge between groups and individuals. It also plays and important role in the economy as it contributes to the increase of employment rates, utilizes innovations and other resources to create value, increases productivity, and all this opens doors for positioning on regional markets [2].
Within the framework of achieving competitiveness, another important concept arises. Sustainable development can be viewed as concept of conducting and developing business activities with the goal to reduce or completely erase the negative effects of conducting business on natural resources. A more objective view on sustainable development includes every aspect of society (education, poverty, employment, health etc.) and nature (water, sustainable agriculture, sustainable energy, air pollution etc.) on a global scale [3]. Solutions which would tackle the challenges of sustainable development goals are innovative in nature. Entrepreneurship is a source of innovation, thus innovation-based entrepreneurship is an imperative in the process of achieving sustainable development. Now, companies have to motivate their employees to act in accordance with the entrepreneurial concept. This means that the company should provide an adequate organizational structure which will allow systematic development of innovations among employees. The entrepreneurial process includes motivational, intentional and developmental factors which form the activities of individuals and groups. It is evident that entrepreneurship, and more precisely, youth entrepreneurship is an important factor when it comes to not only achieving competitiveness, but also to conduct business within the framework of sustainable development.
In this paper the importance of youth entrepreneurship for achieving competitiveness and its role in sustainable development are analyzed. In addition, the concept of sustainability entrepreneurship is addressed. The aim is to discuss how can youth entrepreneurship affect competitiveness on a national

level, and on the level of enterprises. Sustainable development is addressed as an concept which is important in the modern business environment. Namely, conducting business in the midst of globalization, requires goals towards sustainability as a measure to prevent future over-exploitation of natural resources. The paper includes three main sections. The first section analyzes the sustainable development agenda and competitiveness. The second section addresses the importance of youth entrepreneurship. Finally, the third section discusses guidelines for competitiveness improvement through youth entrepreneurship in accordance with the concept of sustainability.

THE SUSTAINABLE DEVELOPMENT AGENDA AND COMPETITIVENESS

In the modern business environment, where the globalization of markets puts a strain on enterprises, one more concept emerges as a necessity for preserving natural resources. This concept is sustainable development. According to the 2030 agenda for sustainable development published by the UN, sustainable development was segmented into 17 goals [3]. For this present research the following goals are target of interest:

- Goal 8: Promoting sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all;
- Goal 9: Building resilient infrastructure, promoting inclusive and sustainable industrialization and foster innovation;

In more detail, Goal 8 includes:

- sustainable economic growth per capita by 7% in the least developed countries;
- higher economic productivity through innovation, diversification and technological upgrades;
- focusing on adding higher-values and on the labor sectors;
- promoting development-oriented policies that will support entrepreneurship, innovation, creativity, decent job creation;
- developing policies that will support and encourage the formation and growth of micro, small, and medium-sized enterprises (MSMMEs);
- financial support for developing and starting MSMMEs;
- decoupling production from environmental degradation;
- achieving full productive employment;
- reducing youth unemployment
- eradicating forced labor of children, migrants, and others;
- developing and operationalizing a global strategy for increasing youth employment [3].

Further, Goal 9 includes the following sub-goals:

- Developing reliable, quality, and resilient infrastructure (regional and trans-border) which will enhance economic development;
- Promoting sustainable and inclusive industrialization and raising industries' share of employment;
- Increasing the access of small scale industries to affordable loans, financial services and the integration of business activities into value chains and markets;
- Upgrading the infrastructure in order to make them sustainable, to increase their efficiency, and to increase adoption rates of clean, environment-friendly technologies;
- Improving scientific research, technological capabilities, industrial sectors, and enhancing and supporting innovation and sustainability;
- Supporting domestic technology development, innovation and research;
- Increasing the access to information and communication technologies (ICTs) and providing universal Internet access to the least developed countries [3].

It was noted [4] that sustainable development, economic growth and competitiveness have developed relationships, where continuous competitive ability, economic growth and prosperity are essential for establishing adequate living standards and overall wellbeing. Strong competitiveness on an international level results in wellbeing of individuals and groups and enhances national competitiveness. Further, innovation as a result of research and development activities, also represents an important factor which affects competitive ability on a national level but also on the level of enterprises. This effect comes from the innovation's capacity to create value for customers, and to create wealth for stakeholders [5]. In the same study it was noted that sustainable development comes from knowledge-based and knowledge-creating enterprises, and that sustainability comes from corporate governance. Now, based on the goals of the UN 2030 Agenda and the previously conducted studies in the domain of sustainable development, it is evident that sustainability, innovation, competitiveness, and other mentioned factors, are interconnected. Further, it can be argued that entrepreneurship, or more precisely, youth entrepreneurship has an important role in achieving sustainable development.

THE IMPORTANCE OF YOUTH ENTREPRENEURSHIP AND SUSTAINABILITY ENTREPRENEURSHIP

Entrepreneurship can be viewed as a source of innovation and as a process of creating value. Even though entrepreneurial activities are regarded as catalysts to economic growth and competitiveness, the situation in Serbia is not the best when it comes to youth entrepreneurship. The main problems are lack of encouragement, support and motivation of young people to start their own business. The statistics don't end there. It was also reported that in Serbia youth unemployment rates were significantly higher compared to general unemployment. These issues have to addressed, as youth entrepreneurship is important for strengthening competitiveness, enhancing economic prosperity, reducing unemployment rates, and increasing the standard of living [6]. It was previously mentioned that entrepreneurship, amongst other factors, has an important role in sustainable development. Thus, in accordance with this, we have the concept of sustainability entrepreneurship which relates to sustainable development [7].

Further, the concept of sustainability entrepreneurship implies the ability to seek out opportunities on the market, and to create social, economic and ecological value. The difference between sustainability youth entrepreneurship and "just" youth entrepreneurship is in meeting the minimum requirements of socio-ecological conditions which were defined by government laws and policies. Namely, sustainability youth entrepreneurship aims at achieving higher sustainability, whereas youth entrepreneurship focuses primarily on business performance and meeting the minimum social-ecological conditions [7]. Further, sustainability entrepreneurship can only exist if entrepreneurs, beside values and motives for success, have the right practical expertise when it comes to conducting business in accordance with the socio-ecological aspects of sustainable development [8]. In the same study it was concluded that the success of sustainability entrepreneurship depends on the successfulness of entrepreneurs in designing an organization that will comply with conditions of sustainable development.

Beside this, quality, or more precisely, institutional quality, and innovation also have a key role in achieving sustainability [9]. This implies that sustainable development through sustainability entrepreneurship is achievable, however, factors such as quality, innovation, compliance with policies and laws are inevitable influencing factors. Before guidelines for improvement in the domain of sustainable development and youth entrepreneurship are discussed, a brief overview of youth entrepreneurship in Serbia is presented.

A study conducted in Serbia in the Central Banat Region, in 2018, included 350 students. Some of the key opinions of the participants include that the government should stimulate and motivate youth entrepreneurship through more affordable loans (51%), education (46%), adequate laws and policies (25%), market regulations (28%), and through promotion of the entrepreneurship concept (31%). It is important to note, that the participants could choose one or more of the mentioned factors (hence, the higher percentages). Further, the participants noted that innovativeness and competitiveness of enterprises are a crucial part of economic development. As expected, a staggering 81.73% of the participants evaluated the competitive ability of domestic enterprises as unsatisfactory. Similarly, 77% of the participants think that domestic enterprises are not adequately innovative. Further, the participants pointed out that investments in marketing are important for achieving competitiveness (29%), and modern management methods and techniques are also necessary for achieving competitiveness (35%). Participants (29%) pointed out that modern technology application and

modern equipment application are necessary for developing competitiveness. Additionally, other important factors of domestic enterprises development were pointed out such as financial support (41%), new technology application (50%), education (43%), and motivation of employees (34%).
Now, based on the conducted research, and the literature overview in the domain of sustainable development and entrepreneurship, it is evident that in order to increase competitiveness of domestic enterprises and national competitiveness as well, in Serbia, in accordance with sustainable development, there are a lot of factors that need to be addressed. These are, but not limited to, innovation, education, quality, modern management, knowledge etc. Guidelines for improving competitiveness through youth entrepreneurship are presented in the next section.

GUIDELINES FOR IMPROVING THE COMPETITIVENESS

In the process of ensuring sustainable development it is important to develop a systematic infrastructure, and to provide and apply technologically sound solutions in domestic enterprises. Technological procedures and the equipment have to be modernized. As mentioned in the previous sections youth entrepreneurship as a concept has its role in the sustainable development agenda. Thus the following should be conducted in order to increase the potential of youth entrepreneurship and sustainability entrepreneurship:

- Expanding the infrastructure for a systematic financial support for young entrepreneurs;
- Providing support for sustainability entrepreneurship;
- Increasing the minimum conditions for conducting business regarding socio-ecological impact of the enterprise;
- Expanding policies regarding sustainable development, and reducing the release frequency of new laws and policies;
- Increasing the promotion of entrepreneurship in IT and in non-IT sectors as well;
- Reducing taxes and implementing “no-revenue, no tax” policies;
- Introducing entrepreneurship in high-schools and elementary schools;
- Introducing flexible taxation options for various types of entrepreneurial activities;
- Providing support from governmental agencies;
- Providing support for existing enterprises to reduce their negative socio-ecological impact;
- Promoting sustainability as an imperative for long-term success;
- Increasing the awareness of consumers of the importance of sustainable development in order to “force” companies to focus on long-term sustainability;
- Forming cluster-like cooperation between new enterprises.

The above noted guidelines and suggestions can be further developed in accordance with the goals of sustainable development and improving competitiveness. Policies and laws are necessary to define the framework within which young entrepreneurs, and entrepreneurs overall, can conduct business. Certainly, there is room for expanding these guidelines, or to put it better, it is important to expand them in future research.

CONCLUSION

Sustainable development slowly becomes an imperative for long-term success on the global market. Due to various socio-ecological issues that emerged from the extensive exploitation of natural resources, enterprises and new start-ups have to tackle challenges of sustainability. The minimum conditions that enterprises have to meet, need to be increased. Further, the sustainable development agenda noted that one of the sub-goals is to improve and support youth entrepreneurship, and entrepreneurship overall. Now, in this paper, the concept of sustainability entrepreneurship was also presented. Here, the concept of entrepreneurship is enhanced by the notion that conducting business shouldn’t just comply with minimal socio-ecological policies, but rather it should focus on developing a sustainable business model which will further expand on society. The positive effect of sustainability entrepreneurship is observed on preservation of natural resources and its rational exploitation. This paper addressed the goals of the sustainable development agenda, and analyzed youth entrepreneurship and the concept of sustainability entrepreneurship. It can be concluded that in order to achieve national competitiveness and sustainable development, it is necessary to enhance the potential of youth entrepreneurship and at the same time these new enterprises (and existing enterprises as well) should focus on sustainability entrepreneurship. Policies, laws, financial support and other stimulating actions should be introduced as means of sustainability entrepreneurship. National economies are focused on supporting, enhancing and encouraging entrepreneurial behavior, and this approach is one of the main long-term strategies for sustainable economic development. This is even more applicable in emerging economies.

The main limitation of this paper is the lack of meta-analytic data from several countries. However, given the aim of the paper, this limitation is not severe. For future research it is recommended to analyze sustainability entrepreneurship in more detail. Also, it is advised to compare sustainability entrepreneurship with social entrepreneurship. Additionally, another survey could be conducted regarding youth entrepreneurship. This would broaden the view on how youth entrepreneurship factors affect competitiveness and how sustainability entrepreneurship is the way to go when it comes to conducting business on globalized markets. This present paper provides a significant insight and a solid basis for future research in the domain of sustainable development, youth entrepreneurship and sustainability entrepreneurship.

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REFERENCES

[1] Bollingtoft A., Ulhoi J., The networked business incubators – leveraging entrepreneurial agency, Journal of Business Venturing, Vol 20 No 2 2005, str. 165–290.
[2] Minniti M., Lévesque M., Recent developments in the economics of entrepreneurship, Journal of Business Venturing, Vol 23 No 6 2008, str. 603-612.
[3] Assembly, UN General. The 2030 Agenda for Sustainable Development. Resolution A/RES/70/1, 2015.
[4] Balkyte A., Tvaronavičiene M., Perception of competitiveness in the context of sustainable development: Facets of "sustainable competitiveness, Journal of Business Economics and Management, Vol 11 No 2 2010, str. 341–365. doi:10.3846/jbem.2010.17
[5] Rodriguez M. A., Ricart J. E., Sanchez P., Sustainable Development and the Sustainability of Competitive Advantage: A Dynamic and Sustainable View of the Firm, Creativity and Innovation Management, Vol 11 No 3 2002, str. 135–146. doi:10.1111/1467-8691.00246.
[6] Bakator M., Đorđević D., Ćoćkalo D., Nikolić M., Vorkapić M., Lean startups with industry 4.0 technologies: Overcoming the challenges of youth entrepreneurship in Serbia, Journal of Engineering Management and Competitiveness (JEMC), Vol 8 No 2 2018, str. 89-101.
[7] Dzemyda I., Raudelia J., Sustainable youth entrepreneurship in conditions of global economy toward energy security, Entrepreneurship and Sustainability Issues Vol 1 No 4 2014, str. 247-256.
[8] Parrish, B. D., Sustainability-driven entrepreneurship: Principles of organization design, Journal of Business Venturing, Vol 25 No 5 2010, str. 510–523. doi:10.1016/j.jbusvent.2009.05.005
[9] Ben Youssef A., Boubaker S., Omri A., Entrepreneurship and sustainability: The need for innovative and institutional solutions, Technological Forecasting and Social Change, Vol 129 2018, str. 232–241. doi:10.1016/j.techfore.2017.11.003

CIRCULAR ECONOMY AND THE DOMESTIC ECONOMY - CHALLENGES AND LIMITATIONS

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Abstract: In the domain of sustainable development, the application of the circular economy concept plays an important role. The current way of manufacturing is based on a linear model where the exploitation of natural resources is the main way of acquiring resources for manufacturing. In contrast, the circular economy concept is based on the reuse and recycle approach, which dramatically reduces the exploitation rates of natural resources. This way, higher savings in energy are achieved. Thus, waste management within the circular economy concept is important for the preservation of natural resources and the overall environment. In this paper the basic indicators of waste management in Serbia are presented. In addition, the concept of circular economy is reviewed. Finally, guidelines for improvement in the domain of circular economy are discussed.
Key words: business model, circular economy, management, waste management.

INTRODUCTION

In the process of achieving sustainable development in the upcoming years, resource management and material management plays an important role on the overall global economy. In that sense, the process of waste management becomes an important part of economic development. The current main way of manufacturing implies that the manufacturing process is based on exploiting natural resources. In this process, the products are distributed to the market, and after exploitation the products ends up in the landfill. This type of economy is also known as a linear model of conducting business. Further, this type of linear business over the past decades has led to over-exploitation of natural resources and waste agglomeration. These are basically the limits of this linear model. In contrast to this model, there is an often mentioned alternative, a model that focuses on the reusability of resources and recycling. This model is called circular economy (CE). According to some beliefs [1], CE implies the circling of materials and its reuse, with the goal to reduce energy and water consumption (in some cases there is over 90% energy and water saved). The concept of CE has found its way to affect policymakers, and it also affects government and intergovernmental agencies on multiple levels [2]. Often, environmental sciences, CE and sustainable development are interchangeably used. However, even though they have similarities, they certainly are not synonyms. The main common ground on which these concepts exist is solving environmental challenges with the main goal of preserving natural resources for future generations [3]. Therefore, it can be noted that CE includes social, economic and ecological objectives. These objectives, or better say, goals, can be achieved through intervention on a national level and on the level of companies. Furthermore, the CE concept is mainly economical and technical, and innovation is an important driver of CE initiatives [4]. This includes the application of specific value chains and the flow of materials. Next, when it comes to biological systems like agricultural industries, chemical and biochemical industries, CE is not fully investigated. Certainly, there is room for improvement in the domain of CE concept application. Based on the mentioned studies, it is almost evident that the CE is an important element for achieving competitiveness. Even more so, in Serbia, the application of CE has the potential to increase the competitive ability of domestic enterprises and to increase the competitiveness of the overall economy. However, the application of CE has its challenges and limitations.

In this paper the CE concept and the competitiveness of the domestic economy is analyzed. The main goal is to provide a concise overview of CE and waste management indicators in Serbia. Based on the analyzed literature and data, guidelines for improvement are discussed. The paper consists of three main sections. The first section analyzes the basic concept of CE, as this is important for further discussions. In the second section waste management indicators in Serbia are presented. Finally, in the third section, guidelines for improvement in the domain of CE are discussed.

ANALYZING THE BASIC CONCEPT OF CIRCULAR ECONOMY

Economic development, environment protection, and the development of social community are interconnected on the basis of organization, technological development and the development of human resources. If a successful enterprise wants to maintain its competitive position on the market, it has to synchronize its economic development with the requirements of environmental protection and its improvement. This includes the production of ecologically acceptable products, integrated waste management and the conservation and protection of natural resources (soil, water, air etc.). Also, an enterprise has to positively affect the development of social communities, on the basis of improving human resources.

On a global scale, there are guidelines for sustainable development, which can establish balance between economic development on one side, and the development of social communities on the other. In addition, the need for improving the environment has to be considered. The modern society increasingly demands from enterprises to be more socially responsible. The process of industrialized spending and consumerism, especially in the XX century, has dramatically affected the environment. People are starting to become aware of the danger which is brought by excessive consumerism, and modern manufacturing. Even though there is a collective rise of social awareness when it comes to environment protection, which started in the 60s, the effort which are put into conserving natural resources on a global level are not sufficient. One of the main conclusions of Agenda 21, which represents the guideline for applying and conducting the concept of sustainable development in every developing sector, is the necessity for waste recycling, as one of the most rational ways of managing waste.

The CE concept offers a new model which implies a relation of product-waste-product. In order to create adequate conditions for economic growth, with the reduction of waste and the reduction of natural resource exploitation, it is necessary to recycle as much waste as possible. This way, products are reused, and savings in energy and water are achieved. Products have to be designed in a fashion which will make it possible to recycle them. It is necessary to point out that in the recycling process it is advisable to use energy from reusable sources.

The benefits of applying the circular economy concept are numerous, and the most important are: protection of natural resources and the environment, energy savings, employment increase, as well as improving the innovativeness and competitiveness of the economy. Responsible consumption and production are one of the goals of sustainable development. Indicators related to the measurement of this goal of sustainable development are: the reduction of environmental pollution in relation to the impact of economic development, the sustainable use of energy, and the generation and management of waste. By using various recycling processes, the consumption of natural resources is reduced through reusing useful materials and increased energy savings. Recycling has a double effect on society:

1. a part of the ecological problems are solved more efficiently which were caused by the pollution of the environment with waste materials;
2. conditions are created for the realization of production at lower costs, while simultaneously reducing the use of primary raw materials.

In order for recycling to achieve maximum effects on both mentioned aspects (both ecologically and economically), it needs to be institutionalized, which implies precise program orientation and legal regulations, as well as a modern approach to waste management. In addition to the accompanying activities at the state and the economy level, a more comprehensive and complex action at the level of the entire social community is needed. This includes education at all levels, promotional activities in the economy and educational institutions, as well as a proactive approach of all participants in the process (citizens, communal organizations, local government, state administration, etc.).

According to some perceptions [5], the waste treatment strategy is designated as the "3R Program: Waste **R**educe, **R**euse and **R**ecycle". The 3R Program presupposes legal, organizational and educational frameworks, as well as concrete mechanisms and instruments for waste management.

In the field of industrial production, special attention is paid to ecological efficiency (in relation to pollution). There is a significant impact of ecological taxes and good-value agreements aimed at reducing the amount of waste generated through manufacturing. EU waste management policy is targeted by a document called the "Waste Management Strategy", and whose main goal is the establishment of a waste management policy at the EU level. The strategy is based on the hierarchy of principles, giving priority to the prevention of waste generation, then the reuse and recycling of materials and the regeneration of energy and the final disposal of waste. According to the EU report, the rate of reused materials in the EU is 11.4%, and the recycling rate is 55% of the total created waste [6].

ANALYZING WASTE MANAGEMENT INDICATORS IN SERBIA

The situation is not adequate when it comes to the implementation of an integrated waste management concept in the function of developing a circular economy. As a result of the long-term application of the concept of linear economy, Serbia has a large number of non-controlled landfills and a small recycling rate. According to the data, in Serbia there are about 3,500 non-controlled landfills and only 8 sanitary landfills, and only 5-7% of waste is recycled per year [1]. Waste is also organized on non-sanitary landfills that are located in inadequate locations, and where their remediation and closure are necessary. Today, the number of sanitary landfills is increased to ten [1].
According to the data of the Republic Institute for Statistics [7], in 2017 an extraction of 107,949,000 tons of resources was conducted. The largest amount of extracted resources are fossil fuels - 40,730 thousand tons, and then biomass - 29,245 thousand tons. Total environmental protection costs in 2017 amounted to 34,400 million dinars, which is 2.7% less than in 2016 [8]. The share of investments in the cost structure for environmental protection was 19.2%, while current expenditures amounted to 80.8% of the amount spent. The largest share in the structure of investments for environmental protection in 2017 was related to the waste management sector and amounted to 37.5% of the total amount of investments. The largest share in the structure of current expenditures for the environment was related to waste management and amounted to 63.9% [8].
Based on data provided by 303 operators with a permit for re-utilization waste, during 2017, it was subjected to treatment of 1.74 million tons of waste, of which approximately 90 thousand tons was hazardous waste and 1.67 million tons was non-hazardous waste, [9].
Based on the label of the treatment provided by the operators in the annual report, it can be seen that 257,459 tons of the presented amount have been submitted to procedures that involve preparation for treatment and storage prior to treatment, after which this amount is handed over to the other operators again for treatment. Of the total amount of processed waste, waste metal containing iron, and waste from thermal processes are the most present, followed by paper and cardboard packaging [9].

Table 1. Number of waste management facilities

Year	Reuse of waste	Waste disposal	Waste import	Waste export
2011	157	14	18	57
2012	134	17	23	79
2013	253	24	30	90
2014	274	29	40	92
2015	291	28	45	90
2016	306	33	48	93
2017	305	33	46	94

Source: Waste management in the Republic of Serbia in the period 2011-2017, SEPA, Belgrade, 2018. www.sepa.gov.rs

The presented numbers refer only to operators who sent in their annual reports. Therefore, it can be seen that over the years, there is an increase in waste management. For example the United Nations Development Programme in Serbia is managing a project under the title "A platform for circular economy and sustainable development in Serbia". The focus of this project is to involve the private sector in support programs regarding CE in the plastic, textile, furniture a food sectors [10].
Further, in order to present a broader view on waste management in Serbia, data from the Republic Statistical Office is given in Table 2 [11].

Table 2. Waste management (treatment in 2018)

	2018		
	t	hazardous waste, %	non-hazardous waste, %
Waste treatment (total)	**48 873 746**	**31,4**	**68,6**
Use of waste as fuel for energy production	135 328	8,6	91,4
Incineration on ground	-	-	-
Recycled	1 507 740	4,1	95,9
Waste for filling in landfills	437 897	-	100,0
Disposal above ground	46 662 638	32,7	67,3
Other types of treatment and disposal	130 142	-	100,0

Source: Waste treatment in 2018. Republic Statistical Office of Serbia

Based on the data in Table 2 it is evident that only a small portion of the total generated waste is recycled. This indicates that improvements are still necessary in the domain of waste management in order to adequately apply the CE concept. Other problems which limit the potential of CE in Serbia is water treatment. Based on the data from the Republic Statistical Office of Serbia, in 2018 only 2% from the released industrial water was purified [12].

GUIDELINES FOR IMPROVEMENTS

In order to ensure the smooth development of a circular economy, it is necessary to create a systemic infrastructure, as well as to improve technological processes in domestic enterprises. Regarding the legislation, it has to be in line with EU requirements, especially in the part dealing with the imperative part of the legal infrastructure. The Law on Waste Management stipulates that waste is deposited in landfills only if there is no other solution for its treatment. This implies that waste must be sorted before disposal and that all usable components must be separated from it. In this and other legal acts that are compliant with EU requirements, waste reduction in landfills is prescribed. However, the problem is in the part concerning the stimulus for the environmental improvement process, such as the financial incentives of companies that are in favor of protecting and improving the environment (fiscal expansion for the amount of investment in environmental improvement, or obtaining financial resources at more favorable ports for future investments in environmental improvement etc.).

When it comes to technological procedures and their innovations, it is considered [13] that the most rational production is the one in which there is no waste, that is, the one in which the raw materials and energy are fully used. The road to achieving these technological solutions leads through “closed” technologies that are already achievable in many industries. The problem with domestic enterprises is that technological procedures, and primary equipment are relatively outdated. The average age of equipment on the domestic market is around 30 years [14]. Old equipment and inadequate technological procedures based on the principles of liner economy are an important obstacle which hinders the realization of the circular economy concept. It is necessary to emphasize that domestic enterprises face chronic problems with insolvency problems, which additionally hinders access to sources of investment. Therefore, the problem of insufficient investments in the protection of the environment is even more complicated. Companies, when they procure equipment for their business, buy mainly repaired machines that can achieve a certain new productivity in business, but represent the previous technological generation.

One of the main conclusions of Agenda 21 is that the inclusion of organized recycling into waste management system is a necessity. The importance of recycling is reflected in the following:

- Conditions are created for the conservation of natural resources;
- Energy savings;
- Disposition of smaller amount of waste leads to reduction of environmental pollution.

The development of recycling processes also enables:

- Decrease in the price of basic raw materials;

- Reduction of costs arising from the removal of waste;
- Reducing strategic dependence on production - the import of defective materials adversely affects economic development.

In order for the recycling activity to have maximum effects on both aspects (ecologic and economic), it needs to be institutionalized, which implies precise program orientation and legal regulations, as well as a modern approach to management. In addition to the accompanying activities at the state and the economy level, a more comprehensive and complex action at the level of the entire social community is needed. This includes education at all levels, promotional activities in the economy and educational institutions, as well as proactive approach of all participants in this process (citizens, communal organizations, local government, state administration, etc.). Further, when it comes to financial and credit analysis of companies regarding CE, the data indicates that the situation in Serbia is optimistic for CE development [15]. In contrast, another study revealed that in 2016, the data collected from 12 municipalities in Serbia, showed that the majority of generated waste ends up in landfills as mixed waste [16]. Thus, it is necessary to develop a better approach for collecting waste.
According to the research conducted by the World Economic Forum [17], four steps can be noted that shape the development of circular economy. These are: the key role of leadership, the role and potential of the fourth industrial revolution, the establishment of value chains of the circular materials and the key role of cooperation. In relation to the stated problem of domestic enterprises, it is a fact that most of them are not ready for the challenges of the fourth technological revolution.

CONCLUSION

By applying the circular economy concept, the domestic economy would be given a chance for development, and the society and citizens would get the improvement of environmental protection, primarily in the domain of waste reduction, as well as new jobs that would be created in the waste processing sector. It is believed that the social capital of a nation is an investment without which there is no future. Estimates are that around 30,000 jobs can be created using the concept of circulatory economy. On the other hand, the level of recycling in our country, according to the volume of collected and processed waste materials and assortment, does not correspond to the needs of the domestic industry, nor is it harmonized with the available potentials. The recycling sector is crucial for the implementation of the circular economy concept. This implies that in order to effectively apply the circular economy concept it is necessary to have an adequate recycling infrastructure. One of the main challenges for recycling facilities is to effectively collect waste from various sources. Therefore, we can conclude that the concept of circular economy is indeed complex and it includes the application of ecological, technological, industrial and social constructs.
Taken this into consideration, it is further concluded that in order to develop recycling as an important waste management strategy that defines the circular economy, actions are needed in the field of education, communication, institutional operation, cooperation with foreign partners, infrastructure construction and more efficient application of knowledge. The application of these guidelines would bridge the discrepancy between conceptual understanding and the possibility of recycling.
For future research it is recommended to comparatively analyze several sets of data in the domain of circular economy circles from industries. This would include the analysis of circular economy indicators on a national level but also on the level of enterprises and existing recycling facilities. In addition, a meta-analysis of existing studies in this domain should be conducted in order to create a broad overview of circular economy application in Serbia.

REFERENCES

[1] Cirkularna ekonomija kao šansa za razvoj Srbije, OEBS Misija u Srbiji, Beograd.
[2] Geissdoerfer, M., Savaget, P., Bocken, N. M. P., Hultink, E. J., The Circular Economy – A new sustainability paradigm?, Journal of Cleaner Production, 143, 2017, 757–768.
[3] Sauvé, S., Bernard, S., Sloan, P., Environmental sciences, sustainable development and circular economy: Alternative concepts for trans-disciplinary research, Environmental Development, 17, 2016, 48–56.

[4] Winans, K., Kendall, A., Deng, H., The history and current applications of the circular economy concept, Renewable and Sustainable Energy Reviews, 68, 2017, 825–833.

[5] Đorđević Lj., Bijelović S., Unapređenje procesa reciklaže u domaćoj privredi, Međunarodna konferecnija o upravljanju zaštitom životne sredine u elektropriovredi "ELECTRA V",, EPS, EPCG i EPRS i Forum za kvalitet Beograd, Divčibare 12-14 novembar 2008.

[6] Sustainable development in the European Union – Overview of progress towards the SDGs in an EU context, Eurostat, Luxembourg, 2018.

[7] Indeksi materijalnih tokova u 2017., RZS, Beograd, 05.12.2018.

[8] Troškovi za zaštitu životne sredine u 2017. RZS, Beograd, 20.11.2018.

[9] Upravljanje otpadom u Republici Srbiji u periodu 2011-2017, SEPA, Beograd, 2018., www.sepa.gov.rs

[10] UNDP Srbija (2018). Platforma za cirkularnu ekonomiju i održivi razvoj u Srbiji. Available at: http://www.undp.org.rs/FactSheets/Circular%20Economy%20SRP.pdf (Accessed 10th July 2019).

[11] Stvoreni i tretirani otpad u 2018. godini, RZS, Beograd, Available at: http://www.stat.gov.rs/sr-Latn/oblasti/zivotna-sredina/otpad-i-opasne-hemikalije (Accessed 10th July 2019).

[12] Korišćenje i zaštita voda od zagađivanja u 2018.godini, Beograd, Available at: http://publikacije.stat.gov.rs/G2019/Pdf/G20191153.pdf (Accessed 10th July 2019).

[13] Đorđević D., Ćoćkalo D., Poslovna etika i pravo, TF Mihajlo Pupin, Zrenjanin, 2007., str. 33.

[14] Đorđević D., Ćoćkalo D., Bešić C., Bogetić S., The role of quality in process of improving competitiveness of domestic economy, International Journal of Advance Quality, Vol 46, No 1 2018. Beograd: JUSK. pp. 21-26.

[15] Vukadinović, P., Cerović, S., Matović, V., Stevanović, G., Financial position and credit rating of companies in circular economy in Serbia, Industrija, 46, 2018, 77-98.

[16] Ilić, M., Nikolić, M. Drivers for development of circular economy – A case study of Serbia, Habitat International, 56, 2016, 191–200.

[17] Key steps towards a circular economy, WEF, 2019., www.weforum.org/agenda/2019/02/4-key-staps-towards-a--circular-economy/

TRANSPORT OF CRUDE OIL ACCORDING TO THE PROVISIONS OF THE EUROPEAN AGREEMENT CONCERNING THE INTERNATIONAL CARRIAGE OF DANGEROUS GOODS BY ROAD

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Abstract: This work aims to analyze the data for crude oil in Table A: Dangerous Goods List from the European Agreement Concerning the International Carriage of Dangerous Goods by Road - ADR to determine differences. It is assumed that when a substance (crude oil) belonging to the same UN number have different chemical properties, physical properties and/or carriage conditions, several consecutive rows are used for that UN number [3]. Table A contains crude oils with different names and/or descriptions belonging to the same UN number. In Table A data are classified into 20 columns. The results confirmed the expectations. Crude oils belonging to the same UN number have different properties and carriage conditions which are determined by special provisions given in Table A. Based on the information in Table A, the proper selection of safe crude oil carriage conditions within the same UN number can be made.
Key words: crude oil, dangerous goods list, ADR, carriage conditions, safe transport

INTRODUCTION

Crude oil consists predominantly of hydrocarbon compounds which, under normal conditions of temperature and pressure, are in a gaseous, liquid and solid state depending on the complexity of the composition of their molecules [1]. One way to transport previously prepared and stabilized oil from oilfields to refineries is by road. Crude oil transport by road is a more expensive mode of transport than other commercial modes of transport and is used mainly for short distances (or for smaller quantities) when no oil pipelines exist [1]. The transport of crude oil (as dangerous goods) by applicable regulations is very important for the safe operation of refining processes. According to the Law on the Transport of Dangerous Goods [2] and the accompanying by-laws, the transport of dangerous goods by road in the territory of the Republic of Serbia is carried out in accordance with the provisions of a confirmed international agreement (adopted by UNECE) called the European Agreement Concerning the International Carriage of Dangerous Goods by Road-ADR (EU Directive ECE/TRANS/275) [3]. As of 1th January, 2019 a new version of the ADR is in force [3]. The Republic of Serbia, as a candidate for EU accession, has implemented ADR into national legislation but has allowed certain and time-varying derogations to protect certain groups of transporters [4]. Domestic regulations in the field of the carriage of dangerous goods by road are also in line with EU Directive 94/55 / EC and subsequent Directives.

This work aims to analyze the data for crude oil in Table A: Dangerous Goods List from the European Agreement Concerning the International Carriage of Dangerous Goods by Road - ADR to determine differences. It is assumed that when a substance (crude oil) belonging to the same UN number have different chemical properties, physical properties and/or carriage conditions, several consecutive rows are used for that UN number [3]. Crude oils with different names and/or descriptions belonging to the same UN number have different properties and carriage conditions which are determined by special provisions given in Table A. The choice of the topic of work is further justified by the fact that the use of the ADR provisions in practice is one of the key parameters to increase safety in the transport of dangerous goods, but also an important segment in the sphere of transport planning/transport operations and marking of vehicles for the transport of dangerous goods to oil refineries.

TABLE A: DANGEROUS GOODS LIST

Table A: The list of dangerous goods for ADR transport is located in chapter 3.2 (Annex A, Vol.1) of the ADR (ECE / TRANS / 275) [3,5]. Dangerous Goods List in practice, it makes basic guidance on the application of the ADR. Table A, contains the dangerous goods list in numerical order by UN numbers. As soon as the UN number of a particular hazardous substance is determined (in this paper crude oil) Table A, which has 20 columns of data, provides cross-linking to the specific requirements that must be met for the transport of that substance [3].

DATA ANALYSIS FOR CRUDE OIL CONTAINED IN TABLE A: DANGEROUS GOODS LIST

In this chapter, the data for crude oil will be analyzed. Data is given in 20 columns of Table A: Dangerous Goods List. Obtained results will be discussed. Each column of Table A will be interpreted individually, for the selected subject of work.
Column 1 UN number [5]. The UN number for crude oil is 1267. As a rule, each row of Table A deals with the substance covered by a specific UN number.
Column 2 Name i description [5]. Refers to the information in section 3.1.2. [3]. Contains, in upper case characters, the name of the substance because the substance has been assigned its own specific UN number. This name shall be used as the proper shipping name. A descriptive text in lower case characters is added after the proper shipping name to clarify the scope of the entry if the classification and/or carriage conditions of the substance or article may be different under certain conditions.
It is noted that UN number 1267 contains crude oil under the following names and descriptions (given in four lines):

1. PETROLEUM CRUDE OIL. In this paper referred: PETROLEUM CRUDE OIL in column 2, row 1;
2. PETROLEUM CRUDE OIL (vapor pressure of 50 °C more than 110 kPa);
3. PETROLEUM CRUDE OIL (vapor pressure of 50 °C not more than 110 kPa);
4. PETROLEUM CRUDE OIL. In this paper referred: PETROLEUM CRUDE OIL in column 2, row 4.

Based on the data in column 2, PETROLEUM CRUDE OIL in column 2, row 1; and PETROLEUM CRUDE OIL in column 2, row 4; do not differ in name and description.
Column 3a Class [5]. The crude oils listed in column 2, irrespective of their name and description (or physical, chemical and/or technical properties) are classified in Class 3 dangerous goods - Flammable liquids.
Column 3b Classification code [5]. The crude oils listed in column 2, regardless of their name and description, have a classification code of F1 - Flammable liquids having a flashpoint of or below 60 °C. Classification code is very important general information for the choice of carriage conditions. (general, code F - Flammable liquids, without subsidiary risk and articles containing such substances).
Column 4 Packing group [5]. Refers to the information in section 2.1.1.3. [3]. PETROLEUM CRUDE OIL in column 2, row 1; has been assigned the packing group number I: Substances presenting high danger. Petroleum crude oil (vapor pressure at 50 ° C more than 110 kPa) and Petroleum crude oil (vapor pressure at 50 ° C not more than 110 kPa) have been assigned the packing group number II: Substances presenting medium danger. PETROLEUM CRUDE OIL in column 2, row 4; has been assigned the packing group number III: Substances presenting low danger. The crude oils under the same UN number are different according to the value of the vapor pressure or volatility, which causes differences in the packing group number. Different packing groups have crude oils that differ from each other according to the degree of physical danger (a consequence of physical properties, e.g. vapor pressure). Differences in physical hazards will cause mutual differences in data on column 7a.
Column 5 Labels [5]. Contains the model number of the labels/placards (per section 5.2.2.2 and section 5.3.1.7 [3]) that have to be affixed to packages, containers, tank containers, portable tanks, MEGCs, and vehicles. The general provisions on labeling/placarding (e.g. the number of labels, their location) for packages are to be found in section 5.2.2. [3]. Labels shall satisfy the provisions below and confirm, in terms of color, symbols and general format, to the models shown in section 5.2.2.2.2.

[3]. Corresponding models required for other modes of transport, with minor variations which do not affect the obvious meaning of the label, are also acceptable. Crude oil of the names and descriptions given in column 2 (Table A [3,7]) belongs to Class 3 dangerous goods. Class 3 is marked with a label – Flammable liquids (symbol: flame, black/white; background: red; in the figure, number 3 in the bottom corner).

Column 6 Special provisions [5]. Refers to the information in chapter 3.3. [3]. PETROLEUM CRUDE OIL in column 2, row 1; PETROLEUM CRUDE OIL in column 2, row 4; has numeric code 357-Petroleum crude oil containing hydrogen sulfide in sufficient concentration that vapors evolved from the crude oil can present an inhalation hazard shall be consigned under the entry UN 3494 PETROLEUM SOUR CRUDE OIL, FLAMMABLE, TOXIC (in various limited and exceptional quantities according to column 7a). Petroleum crude oil (vapor pressure at 50 ° C more than 110 kPa) has numeric codes 357 and 640C while Petroleum crude oil (vapor pressure at 50 ° C not more than 110 kPa) has numeric code 357 and tank numeric 640D. In addition to the special provisions for numeric code 357 explained, special conditions are required, covered by numeric code 640. The physical and technical characteristics mentioned in column 2 of Table A [5] determine different numeric codes.

Column 7a Limited and excepted quantities [5]. Provides the maximum quantity per inner packaging or article for carrying dangerous goods as limited quantities per chapter 3.4. [3].

Column 7a Limited and excepted quantities [5]. Provides the maximum quantity per inner packaging or article for carrying dangerous goods as limited quantities in accordance with chapter 3.4. ADR [3]. The crude oils of the names and descriptions in column 2 (Table A [5]) have different maximum quantities per inner packaging. The differences between the two observed crude oil of the same name (PETROLEUM CRUDE OIL in column 2, row 1; PETROLEUM CRUDE OIL in column 2, row 4;) will be expressed through limited quantities for transport, depending on their physical and chemical properties. PETROLEUM CRUDE OIL in column 2, row 1; can be transported in a quantity limited to a maximum of 500 ml per inner packaging, which specifies a different packing group number and tank numeric code relative to PETROLEUM CRUDE OIL in column 2, row 4. PETROLEUM CRUDE OIL in column 2, row 4; can be transported in a maximum amount of 5 liters per inner packaging. Petroleum crude oil (vapor pressure at 50 ° C more than 110 kPa) and Petroleum crude oil (vapor pressure at 50 ° C not more than 110 kPa) have the same maximum amount per inner packaging, regardless of differences in e.g. the vapor pressure. They are also transported in the same packing group.

Column 7b Limited and excepted quantities [5]. Refers to the information in section 3.5.1.2. [3]. PETROLEUM CRUDE OIL in column 2, row 1; as dangerous goods can be transported in exceptional quantities in according to alphanumeric code E3: maximum net quantity per outer packaging is 300 ml and maximum net quantity per inner packaging is 30 ml for liquids [3]. 1. PETROLEUM CRUDE OIL in column 2, row 4; as dangerous goods can be transported in exceptional quantities in according to alphanumeric code E1: maximum net quantity per outer packaging is 1000 ml and maximum net quantity per inner packaging is 30 ml for liquids. Petroleum crude oil (vapor pressure at 50 ° C more than 110 kPa) and Petroleum crude oil (vapor pressure at 50 ° C not more than 110 kPa) as dangerous goods can be transported in exceptional quantities in according to alphanumeric code E2 : maximum net quantity per outer packaging is 500 ml and maximum net quantity per inner packaging is 30 ml for liquids [3]. Without the implementation of the special provisions defined by the E alphanumeric codes, ADR carriage of crude oil is not allowed. The definition of limited quantities for the transport of crude oil (by inner or outer packaging), as well as the conditions for applying exceptional quantities for transport, therefore, depends on the name and description of the crude oil.

Column 8 Packing instruction [5]. In accordance with the provisions of section 4.1.4. [3]. PETROLEUM CRUDE OIL in column 2, row 1; and Petroleum crude oil (vapor pressure at 50 ° C more than 110 kPa) have alphanumeric code P001 of applicable packing instruction for liquids (in composite packaging of different types of materials). Petroleum crude oil (vapor pressure at 50 °C not more than 110 kPa) has alphanumeric code P001 of applicable packing instruction for liquids, alphanumeric code IBC02 (metal, rigid plastics, composite materials) and alphanumeric code R001 (refers to packing instructions for light gauge metal packaging). [3]. PETROLEUM CRUDE OIL in column 2, row 4; has alphanumeric code of applicable packing instruction for liquids, alphanumeric code IBC03 (metal, rigid plastics), alphanumeric code LP01 (refer to packing instructions for large packaging) and alphanumeric code R001. Packing instructions depend on the name and description of the crude oil.

Column 9a Special packing provisions [5]. According to the provisions of section 4.1.4. ADR [3] have no special packing provisions for the crude oil observed in column 2, regardless of their physical, chemical and technical properties.

Column 9b Mixed packing provisions [5]. Conditions are defined in section 4.1.10. [3]. PETROLEUM CRUDE OIL in column 2, row 1; has alphanumeric codes MP7 and MP17. Alphanumeric code MP7: combination packaging conforming to: with goods of the same class covered by other classification codes when mixed packing is also permitted for these; or with goods which are not subject to the requirements of ADR. Alphanumeric code MP7 provided they do not react dangerously with one another. Alphanumeric code MP17: May - in quantities not exceeding 0.5 liters per inner packaging and 1 liter per package - be packed together in a combination packaging; or with goods which are not subject to the requirements of ADR [3]. Petroleum crude oil (vapor pressure at 50 ° C more than 110 kPa), Petroleum crude oil (vapor pressure at 50 °C not more than 110 kPa) and PETROLEUM CRUDE OIL in column 2, row 4; have alphanumeric code MP19: May - in quantities not exceeding 5 liters per inner packaging – be packed together in a combination packaging conforming to 6.1.4.2.1 [3] with goods of the same class covered by other classification codes or with goods of other classes, when mixed packing is also permitted for these; or with goods which are not subject to the requirements of ADR, provided they do not react dangerously with one another. The name and description of the crude oil respectively, the physical and technical characteristics predetermine mixed packing provisions.

Column 10 Portable tanks and bulk containers – Instructions [5]. Column 10 contains an alphanumeric code assigned to a portable tank instruction, in accordance with 4.2.5.2.1, to 4.2.5.2.4 and 4.2.5.2.6. [3]. This portable tank instruction corresponds to the least stringent provisions that are acceptable for the carriage of the substance in portable tanks. The codes identifying the other portable tank instructions that are also permitted for the carriage of the substance are to be found in 4.2.5.2.5. [3]. The general requirements for the design, construction, equipment, type approval, testing and marking of portable tanks are to be found in section 6.7. [3]. The general requirements for the use (e.g. filling) are to be found in 4.2.1 to 4.2.4. [3].

When a specific portable tank instruction is specified in column 10 of Table A [5] for a specific dangerous goods (crude oil) entry additional portable tanks which possess higher minimum test pressures, greater shell thicknesses, more stringent bottom opening, and pressure-relief device arrangements may be used. The guidelines [3] apply to determine the appropriate portable.

Column 11 Portable tanks and bulk containers - Special provisions [5]. According to section 4.2.5.3. [3] for PETROLEUM CRUDE OIL in column 2, row 1; Petroleum crude oil (vapor pressure at 50 ° C more than 110 kPa) and Petroleum crude oil (vapor pressure at 50 °C not more than 110 kPa) have alphanumeric codes TP1 (degree of filling) and TP8 (the test pressure may be reduced to 1.5 bar when the flashpoint of the substances carried is greater than 0 °C) [3]. PETROLEUM CRUDE OIL in column 2, row 4; has alphanumeric code TP1 (degree of filling). Physical and technical properties of crude oil predetermine the special provisions.

Column 12 ADR tank code [5]. Contains an alphanumeric code describing a tank type, in accordance with 4.3.4.1.1 [3] (for substances of Classes 3). This tank type corresponds to the least stringent tank provisions that are acceptable for the carriage of the relevant substance (crude oil) in ADR tanks. The codes describing the other permitted tank types are to be found in 4.3.4.1.2 (for substances of Classes 3). A tank code for liquids (L) is indicated that crude oil may be offered for carriage in tanks in the liquid state. The general requirements for the construction, equipment, type approval, testing and marking that are not indicated in the tank code are to be found in 6.8.1, 6.8.2, 6.8.3 and 6.8.5. [3]. The crude oils discussed in this paper have different tank code and the hierarchy of tanks [3].

Column 13 ADR tank - Special provisions [5]. According to the provisions of section 4.3.5. and section 6.8.4. [3] do not provide special provisions for crude oil discussed in this paper.

Column 14 Vehicle for tank carriage [5]. Column 14 contains a code designating the vehicle in accordance with chapter 9.1.1[3] to be used for the carriage of the substance in the tank in accordance with section 7.4.2. [3]. The requirements concerning the construction and approval of vehicles are to be found in chapters 9.1, 9.2 and 9.7.[3]. Crude oil discussed in this paper has code designating the vehicle – FL in accordance with section 9.1.1.2. [3]. Code designating the vehicle - FL: A vehicle

intended for the carriage of liquids having a flash-point of not more than 60°C in fixed tanks or demountable tanks with a capacity exceeding 1 m3; or in tank-containers or portable tanks with an individual capacity exceeding 3 m3.
Column 15 Transport category (Tunnel restriction code) [5]. PETROLEUM CRUDE OIL in column 2, row 1; transport category 1, maximum total quantity per transport unit is 20 l. Petroleum crude oil (vapor pressure at 50 ° C more than 110 kPa) and Petroleum crude oil (vapor pressure at 50 °C not more than 110 kPa), transport category 2, maximum total quantity per transport unit is 333 liters. PETROLEUM CRUDE OIL in column 2, row 4; transport category 3, maximum total quantity per transport unit is 1000 l. [3]. The crude oil discussed in this paper has a tunnel restriction code D/E: bulk or tank carriage - passage forbidden through tunnels of category D and E [3]. Different transport categories of crude oil may have the same tunnel restriction code. The degree of physical danger of crude oil discussed in this paper influences the choice of transport category.
Column 16 Special provisions for carriage - Packages [5]. In accordance with section 7.2.4. ADR [3], the crude oil discussed in this paper does not have special provisions for carriage - Packages.
Column 17 Special provisions for carriage - Bulk [6]. In accordance with section 7.3.3. ADR [3], the crude oil discussed in this paper does not have a special provision for carriage - Bulk.
Column 18 Special provisions for carriage - Loading, unloading, and handling [5]. In accordance with section 7.5.11. ADR [3], the crude oil discussed in this paper does not have a special provision for carriage - Loading, unloading, and handling.
Column 19 Special provisions - Operation [5]. In accordance with chapters 8.4. and 8.5. [3], PETROLEUM CRUDE OIL in column 2, row 1; Petroleum crude oil (vapor pressure at 50 ° C more than 110 kPa) and Petroleum crude oil (vapor pressure at 50 °C not more than 110 kPa) have alphanumeric codes S2 and S20. Alphanumeric code S2: Additional requirements concerning the carriage of flammable liquids. Portable lighting apparatus - The load compartment of closed vehicles carrying liquids having a flash-point of not more than 60 °C shall not be entered by persons carrying portable lighting apparatus other than those so designed and constructed that they cannot ignite any flammable vapors or gases which may have penetrated into the interior of the vehicle. Operation of combustion heaters during loading or unloading - The operation of combustion heaters of vehicles of type FL is forbidden during loading and unloading and at loading sites. Precautions against electrostatic charges - In the case of vehicles of type FL, a good electrical connection from the vehicle chassis to earth shall be established before tanks are filled or emptied. In addition, the rate of filling shall be limited [3]. Alphanumeric code S20: The provisions of Chapter 8.4 [3] concerning the supervision of vehicles shall apply when the total volume of crude oil in the vehicle exceeds 3000 l in tanks. Thus, transport operations and vehicles require constant monitoring according to the defined provisions.
Column 20 Hazard identification number [5]. In accordance with section 5.3.2.3. [3] PETROLEUM CRUDE OIL in column 2, row 1; Petroleum crude oil (vapor pressure at 50 ° C more than 110 kPa) and Petroleum crude oil (vapor pressure at 50 °C not more than 110 kPa) have a hazard identification number 33: Highly flammable liquid (flash-point below 23 °C). PETROLEUM CRUDE OIL in column 2, row 4; has a hazard identification number 30: Flammable liquid (flash-point between 23 °C and 60 °C, inclusive) [3]. PETROLEUM CRUDE OIL in column 2, row 1; Petroleum crude oil (vapor pressure at 50 ° C more than 110 kPa) and Petroleum crude oil (vapor pressure at 50 °C not more than 110 kPa) have a higher degree of flammability and thus, present a greater physical risk from fire and explosion than PETROLEUM CRUDE OIL in column 2, row 4. In this paper used current data for hazard identification number [3] in comparison to the previous version of ADR.

CONCLUSION

Crude oil transport may only be carried out if the general and special provisions of the ADR have been completed. Table A: Dangerous Goods List is used to selecting the general and special carriage conditions of crude oil according to their characteristics. Table A may be used as a practical guide for choosing safe carriage conditions of crude oil. An analysis of the crude oil data from Table A revealed that the belonging to the same UN number is four crude oils with different names and/or descriptions, in accordance with assumption of this work: when substance belonging to the same UN number have different chemical properties, physical properties and/or carriage conditions, several consecutive rows are used for that UN number [3].

In Table A, the first four columns identify the substance belonging to those rows. The following columns give the applicable special provisions, either in the form of complete information or in coded form. An empty column means either that there is no special provision and that only the general requirements apply, or that the carriage restriction indicated in the explanatory notes is in force.

For the crude oils discussed in this paper, no differences were observed with the following provisions for ADR transport: class, classification code, labels, a vehicle for tank carriage. Results are explained by the fact that crude oils cause similar physical hazards (physical properties) which classifies them into the same class of dangerous goods for ADR transport. Consequently, are assigned the same classification code. Similarities in physical and chemical properties require the same type of construction of a transport vehicle, so-called FL vehicle. Data analysis for crude oil (from Table A) indicates differences related to: packing group, special provisions, limited and excepted quantities, packing instructions, special and mixed packing provisions, portable tanks and bulk containers (instructions and special provisions), ADR tank code, ADR tank special provisions, transport category (tunnel restriction code), special provisions for carriage, hazard identification number. Crude oils with different names and/or descriptions belonging to the same UN number have different properties and carriage conditions which are determined by special provisions given in Table A.

Based on the information in Table A, the proper selection of safe crude oil carriage conditions within the same UN number can be made.

Further work could include analysis of the mutual similarities of crude oil according to the data in the same columns, elaboration of individual transport conditions, etc.

REFERENCES

[1] Cerić, E.: Sirova nafta, procesi i proizvodi, IBC d.o.o., Sarajevo, 2012.
[2] Zakon o transportu opasne robe, "Sl. glasnik RS", br. 104/2016, 83/2018, 95/2018, 10/2019.
[3] Directive ECE/TRANS/275: European Agreement Concerning the International Carriage of Dangerous Goods by Road (ADR), Volume 1 and Volume 2, Economic Commission for Europe of UNECE, Inland Transport Committee, edition 2019. Available at https://www.unece.org/trans/danger/publi/adr/adr2019/track.html
[4] Lazić, M., Nikolin, T., Hajdu, M.: Zakon o transportu opasne robe - Klauzule odstupanja od primene Evropskog sporazuma o međunarodnom drumskom prevozu opasne robe, Zbornik radova VII Naučno-stručni skup Preduzetništvo, Inženjerstvo, Menadžment, str. 247-255, Visoka tehnička škola strukovnih studija u Zrenjaninu, Zrenjanin, 2018.
[5] Table A: Dangerous Goods List from European Agreement Concerning the International Carriage of Dangerous Goods by Road (ADR). Available at www.unece.org/trans/danger/publi/adr/adr2019/track.html

A BRIEF STUDY ON FIRE PROTECTION SYSTEMS

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Abstract: Fire is a process of uncontrolled combustion that endangers the lives and health of humans, as well as material goods and the environment. Therefore, the basic idea of installing a fire protection system is to protect the lives of people and objects in the event of a fire. When it comes to fire protection, there are three types of fire protection: preventive, in the form of education, passive, fireproof walls, smoke duct etc. and active, which includes automatic fire detection, alarm and fire extinguishing systems. These systems are designed to detect smoke, heat or fire, activate and extinguish fires. By basic division, fire extinguishing systems can use: water, carbon dioxide, foam or powder.
Key words: fire, protection, detection, extinguishing

INTRODUCTION

Ever since the birth of mankind, man has admired the fire, endeavored to observe it from a safe distance, until he found a way to tame it and use its power to create new goods. Fires are an extremely common occurrence, especially due to the widespread use and utilization of fire. Not every burning is considered a fire, but even the smallest burning, which represents a danger to flora and fauna and can cause material damage, can be characterized as a fire. Therefore, fire is a process of uncontrolled combustion that endangers the life and health of people, material goods and the environment. The conditions required for a fire are[1]:

- fuels,
- continuous flow of oxygen into the fire zone and
- energy required to extinguish fires.

Initially, the fight against fire was spontaneous, in order to understand over time that the business needed to be approached in an organized manner and with the appropriate equipment [2]. Fire protection involves the detailed analysis and study of fires and associated effects, as well as the development and production, testing and implementation of adequate protection systems. In various facilities, whether on land or at sea or in the means of transportation, owners and users of the system are responsible for maintaining it in accordance with the basic safety regulations [3].
Today, very large and expensive objects are built in the world, in which a large number of people live, work or inhabit temporarily. Therefore, such objects require special safety precautions. With the size and cost of the facility, as well as the number of people, the risk of accidents increases, and the risk of casualties and damage increases. For this reason, more and more is being invested in the development of more efficient fire protection systems.

FIRE PROTECTION

Fire protection is a set of preventive and repressive measures and activities aimed at preventing the occurrence of a fire and its spreading, minimizing the consequences, effectively extinguishing the fire, determining the cause of its occurrence, and eventual liability for not taking the prescribed fire protection measures. as well as the detection of possible elements of criminal offenses, all with a view to protecting the lives of people and material possessions [4].
Fire protection methods are divided into:

- preventive and educational protection,
- passive protection and
- active protection.

Prevention and education are probably the most important fire protection factor. Users of certain facilities need to be educated about hazards, as well as the services responsible for suppressing fires and assisting the injured. Users should be familiar with the features of the building, the structure of the building, the fire protection system, if any, fire procedures, as well as details that enhance safety and minimize potential damage [5]. Posters placed in conspicuous and busy places in all municipalities, settlements and local communities are cited as an example of educational and preventive protection measures, and in this manner warn residents of the risk of fire and the spread of fire.

Passive fire protection involves the use of passive components such as firewalls, the implementation of special types of doors or bulkheads to prevent further spread of fire, etc. [6] Thus, passive fire protection is based on protection of structures against fire and division into fire sectors, which enables safe evacuation of persons from the facilities and entry of fire crews into the facility [7]. Division into fire sectors requires that walls, ceilings and structural elements have proven fire resistance characteristics. It is important that these elements have the required performance in real situations, not just in simpler configurations for fire testing. All openings, joints, ducts for pipes and cables must be adequately protected, as these can become pathways for the spread of fire and smoke. One of the most important factors of passive fire protection is the inclusion of more evacuation routes, and in the case of tall buildings, at least two staircases placed far from each other. In stairways and evacuation routes in general, combustible materials should never be present and they should be made, as far as possible, of non-combustible materials. Also, key passive protection measures include safety zones or extremely efficient fire sectors, that is, vacant floors or rooms designed to withstand the spread of fires for much longer than usual [8].

Fire ducts are a very important segment of passive fire protection in buildings. Depending on their role, there are two main types of these channels [9].

- Smoke exhaust ducts - used to remove smoke from rooms to allow emergency evacuation of attendees, advance fire suppression and prevent flashover. These channels are mainly used in large fire sectors, hotspots, high-rise buildings, commercial and residential buildings. From the point of view of effective smoke extraction, it is essential that the room in question be thoroughly analyzed with respect to the rate of spread of fire, floor area and height;
- Ventilation ducts - used to provide division into fire sectors, More specifically, fire ventilation ducts can prevent the spread of fire and heat from one fire sector to another. These ducts must have some fire resistance, since typical tin ducts do not meet fire requirements, heat up and warp quickly, and under certain circumstances can accelerate the spread of fire and smoke.

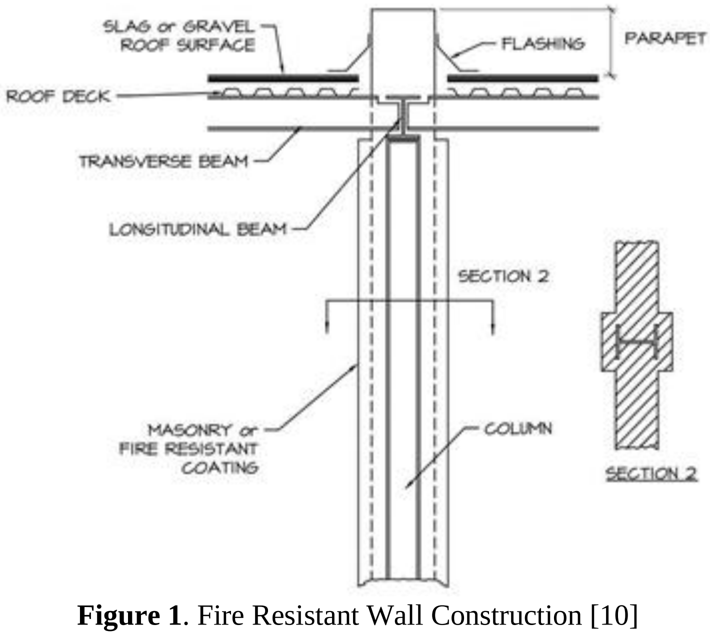

Figure 1. Fire Resistant Wall Construction [10]

Active fire protection involves automated fire detection and suppression. Active protection such as fire alarms, sprinklers, fire extinguishers can help localize fires, protect property and life. These systems require automation to operate effectively, so that when a fire and smoke is detected in the building, an alarm alerts people inside the building and starts a fire extinguishing system[8].

Figure 1. Fire sprinkler

Lastly, active systems cannot work without passive fire protection materials and these two approaches should work in conjunction.
In the Republic of Serbia, fire protection is regulated by the Law on Fire Protection (Official Gazette RS 111/2009, 87/2018), as well as by-laws - Decree on the Basics, criteria, and conditions for classifying organizations into the appropriate categories of fire hazard, The Rulebook on the minimum content of the general part of the worker training program in the field of fire protection. According to the law, the subjects of fire protection are: state bodies, autonomous province bodies, local self-government bodies, companies, other legal and regular individuals. Fire protection is achieved [11]:

- organizing and preparing fire protection entities for the implementation of fire protection,
- providing conditions for the implementation of fire protection,
- taking measures and actions to save people, material goods and the environment in the event of a fire,
- supervising the application of fire protection.

FIRE PROTECTION SYSTEMS

Fire can smolder for hours without causing major material damage. However, when it bursts, it causes lots of direct and indirect material damage. The time of fire detection and the beginning of its extinguishing is directly related to the damage that will result from the fire. Design and execution of works on stable fire alarm systems, based on legal regulations, is performed by experts and companies licensed for the design and construction of stable installations for fire alarms.
Fire systems are systems for automatic reporting or extinguishing of fire, systems for the detection of explosive gases and systems for smoke and heat removal. The basic division of these systems is at [12]:

- stable fire alarm and water fire extinguishing systems,
- stable fire alarm and carbon dioxide fire extinguishing systems,
- stable fire alarm and foam fire extinguishing systems and
- stable fire alarm and powder fire extinguishing systems.

Depending on the type of material in the room and the amount of oxygen, a different amount of gases are released at the outbreak of fire (e.g. CO, CO_2, hydrocarbons with large and small smoke particles),

which leads to an increase in temperature and light. Automatic systems then detect one of these manifestations of fire, pass the information to a specific place and then take specific action.
Each fire alarm system consists of:

- automatic fire alarm systems - specially designed for early detection and extinguishing of fires in all economic areas, especially in industrial processes where there is a high fire risk. They have a large number of features, some of which are: the ability to manage a large number of extinguishing zones from one place, the ability to control web applications from remote positions, the ability to integrate multiple panels.
- fire detectors - they are considered the most important part of the system, because they are the first to recognize, i.e. detect smoke, temperature increase or react to light.
- signaling devices - these rusts include sirens, i.e. alarms, bells and light panels
- devices for managing executive functions - executive functions include: lowering the elevators to the ground floor, switching on the overpressure in the stairs, switching on the smoke system, switching off the ventilation systems and closing the fire sheds. These functions are realized through relay contacts that are controlled via the control panel.
- indicators and parallel indicators - represent handheld fire alarms.
- electrical installations for connecting these elements - represents a set of elements used to connect electrical receivers to the network.

Stable fire extinguishing systems can be automatic and semi-automatic. These systems are installed because of the following requirements: [4]

- high speeds of fire spread and possible high damage,
- the absence of a fire unit or its long distance,
- severe conditions with mobile firefighting equipment and
- large quantities of extinguishing water required in the first moments of a fire outbreak.

These systems include sprinkler systems, open and group sprinkler devices, drainers and water curtains.
Sprinkler devices are stable fire extinguishers with water spray. Sprinklers are closed and open at a certain elevated temperature. The pipelines that lead the water to the sprinkler are under constant pressure. If the pipeline, from its valve station, is pressurized, then we have a dry sprinkler system, and if the piping is filled with pressurized water, then it is a wet sprinkler system.

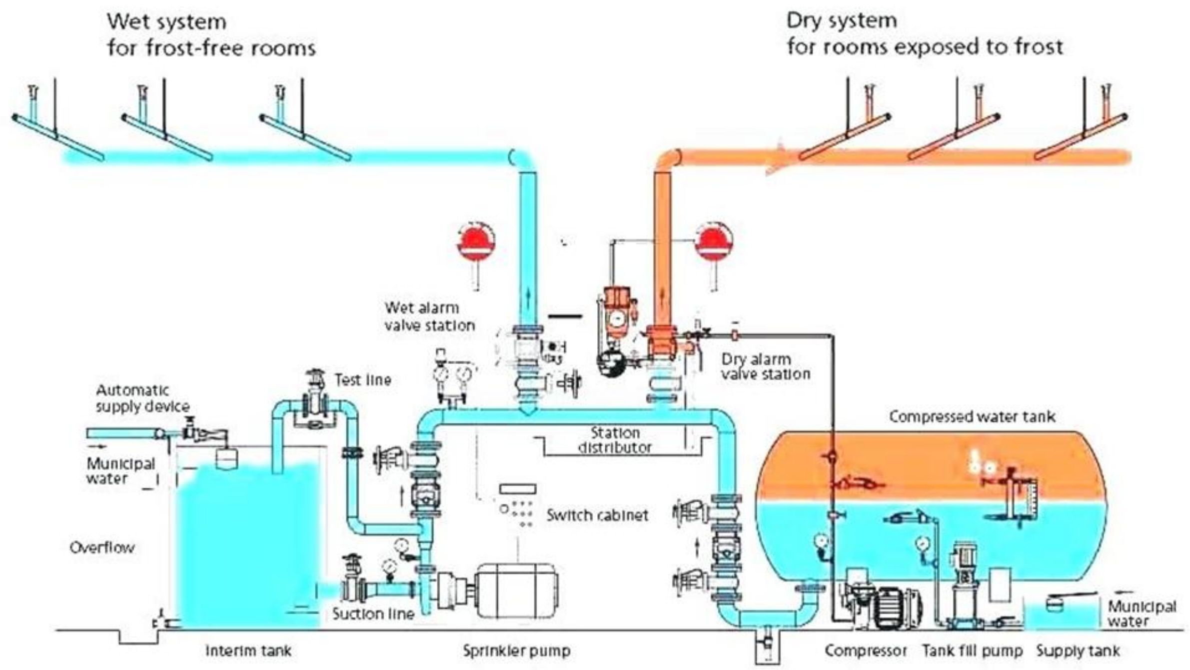

Figure 3. Wet and dry sprinkler system

A wet and dry sprinkler system consists of the following elements: [4]

1. air pressure tank for initial quenching, usually up to 10 minutes;
2. supply of water from the water supply network or auxiliary pump;
3. a compressor that maintains constant air pressure above water;
4. sprinkler pump which takes over the quench, after emptying the tank, under pressure for one hour;
5. pool with water;
6. dry check-valve-valve station at dry system;
7. wet check-valve-valve station for wet system;
8. electrical-signaling device;
9. mechanical signaling device;
10. fire hose connections;
11. the main pipeline for the supply of water to the dry system;
12. the main pipeline for the supply of wet system water;
13. branches of a sprinkler net and
14. pulverizers-sprinklers.

Stable carbon dioxide fire extinguishing installations are fire-fighting installations for three-dimensional CO_2 gas extinguishing. CO_2 is delivered to the fire site via the installed nozzles in the room or above the firebox. The room creates a spatial concentration of CO_2, and when this concentration is enough to reduce the amount of oxygen in the air to the amount required for the combustion process, the fire is extinguished. Activation of these devices can be manual, semi-automatic - remote and automatic [13].

Stable foam fire extinguishing systems are most commonly used to protect above ground fuel tanks. They stemmed from a request for long distance extinguishing. As a rule, these systems are central, because from one place the fire station, through the distribution system, sends the mixture (or only water) to the inflamed tank. Also, as a rule, these systems are manually activated. Foam as a fire extinguisher may be chemical or mechanical. Mechanical is much more used lately. It consists of bubbles of synthetic and protein extracts filled with air and CO_2. The extinguishing action is partly choking, partially cooling [14].

Stable powder fire extinguishers have not yet been widely used in fire protection, such as water, foam and CO_2. The reason for this probably lies in the economic reason, but also because there is still a technical inexperience in planning and designing. A stable powder dispenser extinguishes the enclosed spaces, and can also be installed in open spaces under limited conditions and in limited places. Given the high powder application capability, as well as the ability of one device to protect multiple rooms or objects, such a stable fire extinguisher can find great use. Although the fixed position of the nozzles does not allow direct control of the nozzle at the point of fire, it should be considered that, if a cloud is created, the powder also has a three-dimensional quenching effect. In this case, its efficiency will be particularly pronounced, especially in the application of extinguishing flammable liquids and gases, as in surface and volume terms so as in three-dimensional terms. [15]

OBLIGATIONS OF FIRE PROTECTION ENTITIES

According to the Law and Fire Protection in the Republic of Serbia, the subjects of fire protection are state bodies, bodies of autonomous province, bodies of local self-government units, companies and other legal and regular individuals [11].

According to Article 6 of the said Law, fire protection entities are obliged to act in accordance with the obligations laid down by this Law and the regulations made thereunder, to ensure the implementation of plans and other acts and are responsible for any activity that changes or may change the state and conditions of protection from the fire.

Fire protection entities are obliged to participate in the firefighting and rescue of people and property endangered by fire by engaging the available human and material resources, if they can do so without danger to themselves or others.

CONCLUSION

Fire has always been something that man has admired and trembled about, and its control and use is considered one of the greatest achievements of the human race. Urbanization of cities and towns, development of infrastructure and industry, as well as the development of technology, in addition to all the positives it carries, has increased the risk of fire. Due to the fact that fire can both endanger human lives and pollute the environment and cause great material damage, a well-designed fire protection system is crucial. Such systems allow for the rapid detection, reporting and extinguishing of fires and also allow for rapid organization and faster and unimpeded exit of fire units into the field. However, it should be emphasized that no matter how developed and effective (and still evolving) these systems are, one of the most important factors is a person, that is, his / her knowledge and ability to prevent fire protection.

REFERENCES

[1] Erić M., Protivpožarna i preventivno tehnička zaštita, Jel&Mil, Čačak, 2003.
[2] Raković J., Jakovljević V., Prostorno i urbanističko planiranje u funkciji zaštite od požara u urbanim sredinama, Godišnjak Fakulteta bezbednosti, Beograd, 2011.
[3] Stojanović D., Zaštita od požara i eksplozija, Savremena administracija, Beograd, 1988.
[4] Almaks - Zakoni i propisi, Stabilne instalacije za gašenje požara vodom tipa sprinkler, https://almaks.rs/wp-content/uploads/stabilni_sistemi_ _stabilne_instalacije_za_gasenje_pozara_vodom_tipa_sprinkler.pdf (10.09.2019.)
[5] Sekulović Z., Bogner M., Pejović S., Preventivna zaštita od požara, Eta, Beograd, 2012.
[6] Benković D., Todorovski Đ., Peretin S., Sprečavanje pojave i širenja požara na informatičkoj opremi, Sigurnost, 2019.
[7] Pasivna zaštita od požara – važan element svake strategije bezbednosti od požara, Promat, Centar znanja – članci, https://www.promat-see.com/sr-latn-rs/centar-znanja/clanci/pasivna-zastita-od-pozara-za-bezbednost-od-pozara , 2019. (10.09.2019.)
[8] Pasivna i aktivna protivpožarna zaštita: postizanje ravnoteže, Promat, Centar znanja – članci, https://www.promat-see.com/sr-latn-rs/centar-znanja/clanci/pasivna-i-aktivna-protivpozarna-zastita-postizanje-ravnoteze , 2018. (10.09.2019.)
[9] Protivpožarni kanali – važan segment pasivne zaštite od požara za upravljanje dimom i vazduhom u zgradi, Promat, Centar znanja – članci, https://www.promat-see.com/sr-latn-rs/centar-znanja/clanci/protivpozarni-kanali-vazan-segment-pasivne-zastite-od-pozara , 2018. (10.09.2019.)
[10] Ivison J., Fire Protection Engineering Bulletin, Design and Construction of Firewalls http://www.johnivison.com/design-and-construction-of-firewalls/ , 2011, (10.09.2019.)
[11] Zakon o zaštiti od požara Republike Srbije http://prezentacije.mup.gov.rs/svs/HTML/ZAKON%20O%20ZP.pdf (10.09.2019.)
[12] Almaks – Zakoni i propisi, Stabilni sistemi zaštite od požara, https://almaks.rs/wp-content/uploads/stabilni_sistemi_-_uvod.pdf (10.09.2019.)
[13] Almaks - Zakoni i propisi, Stabilne instalacije za gašenje požara ugljen dioksidom, https://almaks.rs/wp-content/uploads/stabilni_sistemi_-_stabilne_instalacije_za_gasenje_pozara_ugljen_dioksidom.pdf (10.09.2019.)
[14] Almaks - Zakoni i propisi, Stabilne instalacije za gašenje požara prahom, https://almaks.rs/wp-content/uploads/stabilni_sistemi_-_stabilne_instalacije_za_gasenje_pozara_prahom.pdf (10.09.2019.)
[15] Almaks - Zakoni i propisi, Stabilne instalcije za gašenje požara teškom, srednjom i lakom penom, https://almaks.rs/wp-content/uploads/stabilni_sistemi_-_stabilne_instalacije_za_gasenje_pozara_teskom_srednjom_i_lakom_penom.pdf (10.09.2019.)

ANALYSIS OF CAUSES OF SERIOUS AND FATAL OCCUPATIONAL INJURIES IN THE REPUBLIC OF SERBIA FOR THE PERIOD FROM 2016 TO 2018

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Abstract: Occupational injuries are a regular and following occurrence of every human activity and one of the major health and economic problems of modern society. Their consequences affect not only the injured worker, but also his family, work organization and society as a whole. This paper analyzes the causes of serious and fatal occupational injuries by four criteria: the activity of the employer, source of injury, cause of injury, and age of the injured person. It was concluded that, apart from certain illogicalities contained in the official statistics of the Ministry of Labor, the dominant factor causing serious and fatal occupational injuries in the Republic of Serbia is the human factor.
Keywords: occupational injuries, causes of occupational injuries, hse

INTRODUCTION

Injury at work is an adverse event that results in a violation of the physical integrity of the worker, where each injury carries with it some pain tolerated by the injured. Injury, also referred to as trauma, is violent damage to the body caused by mechanical force (impact, crushing, stabbing, incision), electricity, etc [1,2].
Health damage, impairment or loss of ability to work, material costs due to sickness compensation, treatment, rehabilitation, disability, impairment of life activities, disruptions in the workplace, impaired productivity, and decreased quality of work caused by occupational injuries make the problem of occupational traumatism very topical [3,4].
Otherwise, an injury at work is the last event in the chain whose first link is a potential hazard resulting from the action of human and material factors. Under the influence of activation factors, the potential danger grows into an active one, and this one becomes an accident by the action of immediate factors. If all the factors coincide in time, there are inevitably occupational injuries [5].
Injury is also one of the most serious social problems, due to the incidence rate and the loss of working days due to sick leave, which is the basis for the grading of the severity of occupational injuries [4].
The aim of the paper is a multicriteria analysis of serious and fatal occupational injuries in the Republic of Serbia for the period 2016-2018 to highlight the most significant factors leading to injuries and to point out the illogicalities present in the official reports of the Ministry of Labor of the Republic of Serbia.

MATERIAL AND METHODS

The analysis of the work report of the Directorate for Safety and Health at Work of the Ministry of Labor of the Republic of Serbia concluded that for the period 2016-2018 on average 824 serious and/or fatal occupational injuries, 771 in 2016, 907 in 2017 and 795 in 2018. It should be noted that of this number, fatal injuries accounted for about 1% [6-8].
Occupational injuries can be analyzed according to many criteria, however, the author considered that four criteria play a dominant role in determining more specifically the severity of serious and fatal occupational injuries:

1) The activity of the employer,
2) The source of the injury,
3) Immediate cause of injury, and
4) Age of the injured.

RESULTS AND DISCUSSION

Review of occupational injuries by employer activity

As Table 1 shows, the number of serious and fatal occupational injuries categorized by employer activity averages just over 800 injuries per year. The largest number of occupational injuries was recorded in the following industries: manufacturing (25.9%), wholesale and retail trade, repair of motor vehicles (10.3%), health and social care (9.2%) and transport and storage (8.3%). The number of serious and fatal occupational injuries in these four activities account for more than half (53.7%) of the total injuries. However, it is interesting to note that the construction industry is only in 6th place in the number of serious and fatal occupational injuries, although it is to be expected that injuries are very common in this type of activity. In contrast, in the administrative and support services, where the number of serious and fatal injuries would be expected to be negligible, it is around 5%.

Table 1. Number of serious and fatal occupational injuries by activity of employer [6-8]

Activity of the employer	2016.		2017.		2018.		Average	
	No	%	No	%	No	%	No	%
Construction	49	6,4	67	7,4	59	7,4	58	7,1
Agriculture, forestry and fishing	20	2,6	37	4,1	32	4,0	30	3,6
Mining	26	3,4	36	4,0	27	3,4	30	3,6
Manufacturing industry	205	26,6	216	23,8	216	27,2	212	25,9
Health and social care	65	8,4	94	10,4	70	8,8	76	9,2
Traffic and storage	61	7,9	79	8,7	65	8,2	68	8,3
Electricity, gas, steam and air conditioning supply	56	7,3	71	7,8	62	7,8	63	7,6
Water Supply, Wastewater Management, Controlling Waste Disposal	35	4,5	34	3,8	47	5,9	39	4,7
Wholesale and retail trade, repair of motor vehicles	91	11,8	94	10,4	69	8,7	85	10,3
Accommodation and catering services	9	1,2	14	1,5	7	0,9	10	1,2
Information and communication	9	1,2	15	1,6	9	1,1	11	1,3
Financial activity and insurance	15	1,9	17	1,9	9	1,1	14	1,6
Education	25	3,2	30	3,3	28	3,5	28	3,3
Professional, scientific, innovation and technical activities	14	1,8	14	1,5	19	2,4	16	1,9
Administrative and support service activities	41	5,3	22	2,4	52	6,5	38	4,7
Public administration and defense	12	1,6	42	4,6	14	1,8	23	2,7
No data	38	4,9	25	2,8	10	1,3	24	3,0
In total	**771**	**100**	**907**	**100**	**795**	**100**	**824**	**100**

Review of occupational injuries by source of injury

An analysis of serious and fatal injuries by source of injury is presented in Table 2. Occupational injuries most often occur when employees move in work facilities (slip, trip, etc.), auxiliary rooms, or other sources depending on the work environment (37.3%), using tools when performing work activities (20.5%) and using machines and devices (13.6%).

Table 2. Review of occupational injuries by source of injury [6-8]

Source of the injury	2016.		2017.		2018.		Average	
	No	%	No	%	No	%	No	%
Facilities/Plants	13	1,7	25	2,8	16	2,0	18	2,2
Machines and devices	79	10,2	153	16,9	103	13,0	112	13,6
Passenger transport	47	6,1	69	7,6	46	5,8	54	6,6
Freight transport	42	5,4	49	5,4	44	5,5	45	5,5

Table 2. Review of occupational injuries by source of injury (continuation) [6-8]

Source of the injury	2016.		2017.		2018.		Average	
	No	%	No	%	No	%	No	%
Electrical devices, tools and installations	15	1,9	4	0,4	5	0,6	8	1,0
Scaffolding	2	0,3	7	0,8	2	0,3	4	0,4
Tools	175	22,7	181	20,0	150	18,9	169	20,5
Sources depending on the work process	73	9,5	60	6,6	26	3,3	53	6,4
Installation	259	33,6	317	35,0	346	43,5	307	37,3
Other sources of employee injury	55	7,1	26	2,9	42	5,3	41	5,0
No data	11	1,4	16	1,8	15	1,9	14	1,7
In total	**771**	**100**	**907**	**100**	**795**	**100**	**824**	**100**

Review of occupational injuries by cause of injury

Table 3 shows that the most common cause of occupational injuries is non-application or non-compliance with special rules on safety at work (31.4%), performing work operations in a manner contrary to the rules of safety at work (20.5%), and non-application or non-compliance with basic rules occupational health and safety (16.6%). These three causes, which together account for 70% of the causes of injuries, are a direct consequence of neglect and non-compliance with safety and health rules at work.

Table 3. Review of occupational injuries by cause of injury [6-8]

Cause of injury	2016.		2017.		2018.		Average	
	No	%	No	%	No	%	No	%
Defective work equipment	31	4,0	7	0,8	15	1,9	18	2,1
Inoperative, slippery and obstructed passageways and surfaces on which workers stand while performing work activities	93	12,1	116	12,8	101	12,7	103	12,5
Inoperative guardrails and other fall protection devices	13	1,7	7	0,8	16	2,0	12	1,5
Inoperative safety devices on operating equipment	9	1,2	5	0,6	10	1,3	8	1,0
Reducing inadequate lighting	2	0,3	2	0,2	5	0,6	3	0,4
Improper protection against accidental electric shock	8	1,0	2	0,2	7	0,9	6	0,7
Inoperative protection against heat radiation	1	0,1	3	0,3	2	0,3	2	0,2
Disorder in the technological process	2	0,3	9	1,0	5	0,6	5	0,6
The basic safety and health rules at work have not been applied	169	21,9	81	8,9	160	20,1	137	16,6
Performing work activities in a practice contrary to the rules of occupational safety	136	17,6	197	21,7	173	21,8	169	20,5
Perform work activities without the use of appropriate personal protective equipment or the use of faulty personal protective equipment	15	1,9	45	5,0	29	3,6	30	3,6
Employee fatigue due to hard work and overtime, insufficient rest, etc	19	2,5	28	3,1	23	2,9	23	2,8

Table 3. Review of occupational injuries by cause of injury (continuation)

Cause of injury	2016.		2017.		2018.		Average	
	No	%	No	%	No	%	No	%
Poor work organization	7	0,9	5	0,6	8	1,0	7	0,8
Not applied specific occupational safety rules	216	28	359	39,6	201	25,3	259	31,4
Unlawful action by a third party	38	4,9	17	1,9	22	2,8	26	3,1
Force Majeure	2	0,3	3	0,3	3	0,4	3	0,3
No data	10	1,3	21	2,3	15	1,9	15	1,9
In total	**771**	**100**	**907**	**100**	**795**	**100**	**824**	**100**

Review of work-related injuries by age of the injured worker

Table 4 shows that according to the age of the injured worker, the highest number of occupational injuries was recorded in employees aged 30 to 49 years (46.9%) and in the elderly over 50 years (39.2%), which accounts for over 85% of the total number of serious and fatal occupational injuries in the Republic of Serbia.

Table 4. Review of work-related injuries by age of the injured worker [6-8]

Age of the injured worker	2016.		2017.		2018.		Average	
	No	%	No	%	No	%	No	%
< 18	0	0,0	0	0,0	1	0,1	0	0,0
18 - 24	33	4,3	38	4,2	33	4,2	35	4,2
25 - 29	69	8,9	81	8,9	68	8,6	73	8,8
30 - 49	372	48,2	432	47,6	356	44,8	387	46,9
>50	297	38,5	344	37,9	329	41,4	323	39,2
No data	0	0,0	12	1,3	8	1,0	7	0,8
In total	**771**	**100**	**907**	**100**	**795**	**100**	**824**	**100**

CONCLUSION

The analysis of statistics on serious and fatal occupational injuries in the Republic of Serbia for the period 2016-2018 has led to several important conclusions.

Although all research shows that construction is the most common occupational accident activity, this was not the case for Serbian companies. On the contrary, construction is only sixth in official statistics in terms of the number of serious and fatal occupational injuries. The explanation for this phenomenon could be that a large number of construction employees do without a contract with the employer, and in the case of injury, they are driven by a private vehicle to the emergency center, explaining that they were injured at home instead of at the construction site.

However, serious occupational injuries also occurred in workplaces not characterized as high-risk workplaces, as in the case of administrative and support services, which, on the other hand, concludes that the possibility of injury at work should not be excluded in any workplace.

When it comes to the source of occupational injuries, the most common injuries occur when employees are moving in work-related facilities due to slipping, tripping, etc. (37.3%), using tools when performing work activities and using machines and devices. Such a high percentage of injuries in work facilities, due to extremely banal reasons, implies poor organization of the workspace, lack or disregard of the lanes, and warnings about slippery movement.

The most common causes of occupational injuries are the failure to apply basic and specific occupational safety rules and perform work operations in a manner contrary to occupational safety rules. The aforementioned causes, which together account for 70% of the causative agents of injuries, are a direct consequence of neglect and non-compliance with safety and health rules at work. However, if you look at the other values shown in Table 3, it is concluded that the human factor is absolutely the dominant cause of serious and fatal occupational injuries.

When it comes to the age of workers who have suffered an injury, the two age groups with the highest percentage of injuries are characteristic. Over 45% of serious and fatal occupational injuries belong to the 30-49 age group. This may be explained by the theory that in this group there are workers with extensive work experience, excellent psycho-physical condition, which can lead to too much self-confidence or the personal conviction that nothing can happen to them, resulting in neglect and disrespect for the occupational safety rules. The second group, with about 40% of serious and fatal occupational injuries, belongs to workers older than 50 years. The explanation would be similar to that of the previous group of workers, noting that workers of this age have significantly less psycho-physical fitness.

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REFERENCES

[1] Heinrich, H.W., Industrial Accident Prevention, a Scientific Approach, McGraw-Hill, New York, US, 1959.
[2] Stout, N.A., Castillo, D.N., Amandus, H.E., Pizatella, T.J., Occupational Injuries and Work Place Violence, International Encyclopedia of Public Health (Second Edition), pp.334-341, 2017.
[3] Macdonald, D., Sanati, K., Macdonald. E., The Costs and Characteristics of Occupational Injuries Admitted to a Trauma Unit, International Journal of Occupational Safety and Ergonomics, Vol. 18, pp.587-590, 2012.
[4] Keogh, P.J., Nuwayhid, I., Gordon, L.J., Gucer, W.P., The impact of occupational injury on injured worker and family: Outcomes of upper extremity cumulative trauma disorders in Maryland workers, American Journal of Industrial Medicine, Vol. 38, pp.498-506, 2000.
[5] Carter, N., Behavior analysis and the primary prevention of occupational injuries, Scandinavian Journal of Behaviour Therapy, vol. 21, pp.89-103
[6] Ministry of Labour, Employment, Veteran and Social Policy of the Republic of Serbia, 2016 Work Report, https://www.minrzs.gov.rs/sr/dokumenti/izvestaji/uprava-za-bezbednost-i-zdravlje-na-radu/izvestaji-o-radu
[7] Ministry of Labour, Employment, Veteran and Social Policy of the Republic of Serbia, 2017 Work Report, https://www.minrzs.gov.rs/sr/dokumenti/izvestaji/uprava-za-bezbednost-i-zdravlje-na-radu/izvestaji-o-radu
[8] Ministry of Labour, Employment, Veteran and Social Policy of the Republic of Serbia, 2018 Work Report, https://www.minrzs.gov.rs/sr/dokumenti/izvestaji/uprava-za-bezbednost-i-zdravlje-na-radu/izvestaji-o-radu

IMPACT OF EXPOSURE TO METALWORKING FLUID AEROSOLS ON EMPLOYEES HEALTH

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Abstract: Metalworking fluids (MWFs) are seen as a mandatory element for simultaneously achieving high quality and high productivity of machining operations. On the other hand, metalworking fluids easily generate aerosols to which employees are exposed. This paper aims to provide a literature review of the possible harmful effects of metalworking fluid aerosols on employees health. The paper presents the possible correlation of different types of acute and chronic diseases with the exposure of employees to MWF aerosols resulting from the use of different types of MWFs in the metalworking process.
Keywords: Metalworking fluid, aerosol, employees health

INTRODUCTION

Metalworking fluids (MWFs) are engineering materials that optimize the metalworking process. The primary role of MWFs is to provide good cooling and lubrication in the contact area of the tool and the metal workpiece. Additionally, they are used to prevent corrosion and to remove (flush) metal shavings [1, 2].

Although MWFs have positive effects on the cost-effectiveness of the process, they represent pollutants of the working environment due to the generation of aerosols in the metalworking zone. MWF aerosols are two-phase systems where the continuous phase is air and the discontinuous phase is in the form of very small droplets [3].

The properties of aerosols depend on the size of the dispersed droplets, their chemical properties, and concentration. Very small aerosol particles penetrate deep into the airways and accumulate there, making them much more dangerous to human health. All particles smaller than 100 µm can be inhaled, called the inhalation fraction. Particles up to 10 µm are retained in the upper airways, while particles smaller than 2,5 µm penetrate deep into the lungs and accumulate in the alveoli [4-6].

Epidemiological studies have shown that exposure to MWF aerosols can cause asthma, bronchial hyperreactivity, lipoid-pneumonia, dermatitis and even lung or pharyngeal cancer [7,8].

Health effects depend on many factors, such as the time and frequency of exposure to the hazardous substance, employee sensitivity, type of chemicals present, and aerosol size distribution [9].

This paper aims to provide a literature review of the possible harmful effects of MWF aerosols on employee health and to present the possible association of different types of acute and chronic diseases with the exposure of employees to MWF aerosols. The paper presents the types of MWFs and the mechanisms of the formation of their aerosols for a better understanding of their negative impacts.

MATERIAL AND METHODS

Metalworking fluids are grouped into four major classes [10-13]:

1) Straight oil (neat oil) MWFs are severely solvent-refined petroleum oils (lubricant-base oils) or other animal, marine, vegetable, or synthetic oils used singly or in combination and with or without additives. Straight oils are not designed to be diluted with water.
2) Soluble oil (emulsifiable oil) MWFs are combinations of 30% to 85% severely refined lubricant-base oils and emulsifiers that may include other performance additives. Soluble oils are diluted with water at ratios of 1 part concentrate to 5 to 40 parts water.
3) Semisynthetic MWFs contain a lower amount of severely refined lubricant-base oil in the concentrate (5% to 30%), a higher proportion of emulsifiers, and 30% to 50% water. The transparent concentrate is diluted with 10 to 40 parts water.

4) Synthetic MWFs contain no petroleum oils and may be water soluble or water dispersible. The synthetic concentrate is diluted with 10 to 40 parts water.

In most cases, the use of MWFs during metalworking leads to the formation of aerosols, Figure 1.

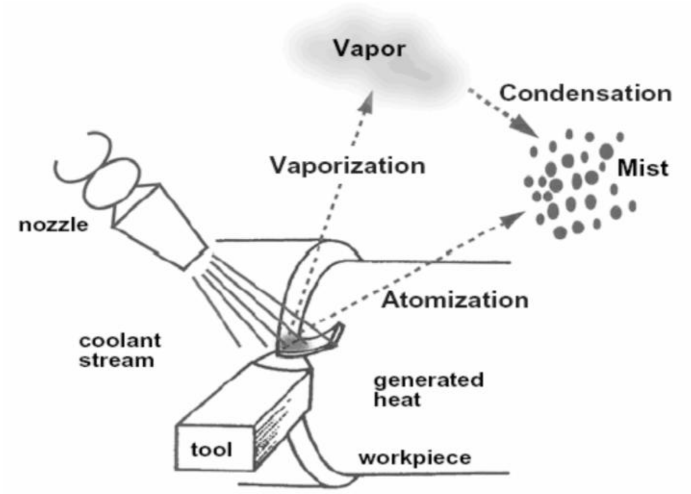

Figure 1: Metalworking fluid aerosols generation mechanisms [14]

Thornburg and Leith are defined three mechanisms of aerosol formation [15,16]:
1) impaction - aerosol is formed when a liquid leaking from nozzle hits the surface, then the liquid is repelled and dispersed in the form of droplets. The formed drops are larger than 10 µm.
2) centrifugal force - aerosol is formed from a liquid that covers the surface of the machine rotor. The formed drops are in size from 10 µm to 1 µm.
3) evaporation/condensation - aerosol is formed by evaporation of MWF in the metalworking zone and then by condensation of MWF in contact with air. The formed drops are in size from 1 µm to 0,1 µm.

The risk of exposure to MWF aerosols is assessed either by the sum of aerosols and water vapor or solely by aerosols. The risk of inhalation of aerosols is caused by exposure to three agents [17]:
1) undiluted processing liquid,
2) microbial contaminants, and
3) other chemical contaminants accrued in MWFs during the process (e. g. toxic or allergenic elements from machined metal: Cr, Pb, Ni, Cd).

NOISH (USA National Institute for Occupational Safety and Health) recommends that exposures to MWF aerosols be limited to 0,4 milligrams per cubic meter of air (thoracic particulate mass) or 0,5 milligrams per cubic meter of air (total particulate mass), as a time-weighted average concentration up to 10 hours per day during a 40-hour workweek. The recommended exposure limit (REL) is intended to prevent or greatly reduce respiratory disorders associated with MWF exposure. Some workers have developed work-related asthma (WRA), hypersensitivity pneumonitis (HP), or other harmful respiratory effects when exposed to MWFs at lower concentrations. This REL is technologically feasible for most metalworking operations. [18].
In 2002, the UK Health and Safety Executive suggested guidance values for MWFs of 3 mg/m^3 for oil-based and 1 mg/m^3 for water-soluble, both measured as inhalable aerosols. The UK occupational exposure standards are not regulated limits but are given as a recommendation to workplaces. Value of 1 mg/m^3 inhalable aerosol for water-soluble fluid would range between approximately 0,3 mg/m^3 and 0,5 mg/m^3 total aerosol, which is similar to the NIOSH REL (0,5 mg/m^3) [19].

RESULTS AND DISCUSSION

Exposure to health risks of employees who have contact with MWF aerosols can lead to acute and chronic diseases. Acute diseases include contact and allergic dermatitis and acute respiratory diseases, and chronic diseases include chronic respiratory diseases and cancers [1].

Exposure to MWF aerosols can lead to inhalation by employees and the deposition of aerosols on employees skin or exposure skin to vapor resulting from the use of MWF [17,20]. Depending on the size of the aerosol particles, they reach different parts of the respiratory system and cause different health risks for employees. Particles in the range from n10 to 100 µm can be inhaled through the nose, reaching the oral cavity from where they are swallowed. Smaller particles (<10 µm) reach the lungs where they are deposited, while particles smaller than 2,5 µm penetrate deep into the lungs and accumulate in the alveoli [2,3].

In the last thirty years or more, many researchers have analyzed the effects of MWF aerosols on employee health and analyzed the possible association of different types of acute and chronic diseases with the exposure of employees to MWF aerosols.

Bennet and Bennet, 1985 consider that workers exposed to MWFs are at risk of pneumonia (Legionnaires - a special form of pneumonia), and also believe that inhalation of oil mist can cause a condition known as lipid pneumonia. One in five employees exposed to oil fog from tandem mill at a concentration of 0,6-0,7 mg/m^3 over 4 years can develop lipid pneumonia [21].

Research by Tolbert et al., 1992 indicates that there is a correlation between exposure to straight oils with rectal, laryngeal and prostate cancer [22].

Massin et al., 1996 concluded that workers exposed to oil mist of soluble oils had significantly more (chronic) respiratory symptoms and hyperreactivity to methacholine than those who are not exposed [23].

The data obtained by the study of Kriebel et al. 1997 indicates that exposure to MWFs can have chronic and acute respiratory effects. Employees exposed to straight oils more likely to suffer from chronic cough than those exposed to soluble oils, while asthma is more common among employees exposed to soluble oils [24].

In the same year, Greaves et al. conducted that there is a correlation between respiratory irritation (cough, phlegm, chronic bronchitis) and machine work when employees are exposed to straight oils and synthetic MWFs. Exposure to straight oils is associated with phlegm and wheezing, and for synthetic oils, there is a significant relationship between current exposure and the occurrence of phlegm, wheezing and chronic bronchitis [25].

Rosenman et al. 1997, in their research, showed that there was a correlation between exposure to emulsified, semi-synthetic and synthetic MWFs with a high percentage of employees who had some unintended consequences, which is not the case with mineral MWFs, and that exposure to MWFs was the second the most common cause of work-related asthma [12].

Kennedy et al. 1999, in their study, indicate that there is a correlation between exposure to water-based MWFs and bronchial response and asthma [26].

Kazerouni et al. 2000, reported that workers with high levels of exposure had an increase in asthma, emphysema, bile and liver cancers, scrotum cancer, lung cancer, and Hodgkin's disease [5].

Byers in his paper [1], found a negative correlation between synthetic MWFs and lung cancer, however, according to a study by Li et al. [13] water-based MWFs are exposed to high levels of contamination, including gram-negative bacteria producing endotoxin, with endotoxin inhalation presumed to have a protective effect against lung cancer.

Agalliu et al. 2005, in the results of their research provide further evidence that exposure to soluble and straight metalworking fluids is associated with prostate cancer among workers [27].

Jaakkola et al., 2009 in their research concluded that employees working on processing machines are at increased risk of upper respiratory tract symptoms, coughs, shortness of breath and acute asthma [28].

In the same year, Zeka et al. [29] examined the correlation between exposure to MWFs and upper respiratory tract cancer. Their study states that there is the greatest correlation between exposure to straight oils and the occurrence of laryngeal cancer.

In a review paper, Rosenman (2009) concluded that exposure to MWFs could lead to asthma and hypersensitive pneumonitis [30].

Sujova induce in 2012 that exposure to MWFs and their aerosols can lead to skin diseases, respiratory diseases (irritation of the lungs, throat, nose, asthma, chronic bronchitis) and various types of cancers (rectum, pancreas, larynx, skin, scrotum, blood) [20].
In the same year, Burton et al. in a review paper reported that exposure to MWFs can lead to asthma, emphasizing that soluble oils are excluded from these fluids. Besides, they state that the contamination of MWFs with microorganisms plays a significant role in the development of certain respiratory diseases [31].
Vasilyev et al. 2013, stated that exposure to MWF aerosols can cause pneumonia, skin diseases, damage to the heart muscle, liver and kidney. [32].
Schwarz et al. 2015, stated that inhaling MWF aerosols could irritate the throat (sore throat), nose (rhinorrhea, bleeding from the nose) and lungs (cough, shortness of breath, increased mucus). They further state that exposure to MWFs is associated with bronchitis, hypersensitivity pneumonitis and asthma, while skin irritations (contact dermatitis) and allergies can occur [17].
In a review paper by Jabbar et al. 2017, they analyzed respiratory diseases at MWFs exposure, stating that hypersensitive pneumonitis, asthma, alveoli disease, impaired lung function, bronchitis, respiratory symptoms such as phlegm, shortness of breath, and chest tightness could occur. Also, the paper states that the percentage of microorganisms in MWFs contributes to the emergence of occupational diseases such as asthma and hypersensitive pneumonitis [11].
Table 1 shows the diseases that may result from exposure to different types of MWF aerosols.

Table 1. Diseases that may result from exposure to MWF aerosols

Disease	Type of MWF associated with the disease	Literature
respiratory irritation	soluble oils	[20, 21, 23]
throat irritation	semisynthetic MWFs, soluble oils	[1, 17, 20]
nose (rihone, nasal obstruction and nosebleeds)	*	[17, 20]
productive and chronic cough	straight oils	[1, 11, 21, 24]
increased mucus secretion	straight oils, synthetic MWFs	[1, 17, 21, 25]
short breath	*	[17]
wheezing	straight oils, synthetic MWFs	[11, 25]
pneumonia	*	[21, 32]
chest pain	synthetic MWFs	[1, 11]
pharyngitis, laryngitis, sinusitis	*	[21]
rhinitis	soluble oils, semisynthetic MWFs, synthetic MWFs	[21, 30]
chronic bronchitis (bronchitis)	soluble oils, semisynthetic MWFs, synthetic MWFs	[17, 11, 20, 25, 26]
hypersensitive pneumonitis	soluble oils, semisynthetic MWFs, synthetic MWFs	[1, 17, 11, 30]
asthma	straight oils, soluble oils, semisynthetic MWFs, synthetic MWFs	[1, 17, 11, 20, 24, 30, 31, 5, 28]
allergic alveolitis	*	[11]
damage of the heart muscle	*	[32]
liver damage	*	[32, 22]
damage of the kidney	*	[32]
leukemia and blood cancer	*	[17, 20, 30]
larynx cancer	straight oils	[17, 20, 30, 22, 29]
esophageal cancer	straight oils, soluble oils	[17,29]
pancreatic cancer	*	[17, 20, 30]
rectal cancer	straight oils, soluble oils	[17, 13, 20, 30, 22]

Table 1. Diseases that may result from exposure to MWF aerosols (continuation)

Disease	Type of MWF associated with the disease	Literature
bladder cancer	synthetic MWFs	[1,17]
prostate cancer	straight oils, soluble oils	[27]
scrotum cancer	straight oils	[1,17, 20, 30]
skin cancer	*	[17, 20, 30]
digestive tract cancer	soluble oils, semisynthetic MWFs, synthetic MWFs	[13]

* no data were found that included an association between MWF type and disease

CONCLUSION

Metalworking fluids are engineering materials that optimize the metalworking process, but they also represent pollutants of the working environment due to the generation of aerosols in the metalworking zone. This review paper provides a list of possible harmful health effects of employees exposed to MWF aerosols. A review of the available literature indicates that there is a correlation between a particular acute and/or chronic disease and the use of a particular type of MWF. Besides, it can be concluded that straight oils, soluble oils, and synthetic MWFs have the highest association with disease, while semisynthetic MWFs have an insignificantly lower health impact.

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REFERENCES

[1] Byers, P.J., Metalworking Fluids, Taylor & Francis Group, Boca Raton, USA, 2006.
[2] Sokolović, D., Höflinger, W., Zavargo, Z., Šećerov-Sokolović, R., Effect of ventilation in enclosure machine system on MWF aerosol properties, Hemijska Industrija, Vol. 66, pp.67-77, 2012.
[3] Sokolović, D., Investigation on the phenomena of aerosols formed from emulsions of mineral and other oils in water (PhD dissertation), University of Novi Sad, Serbia, 2012.
[4] Mzojo, T., Ozabu, T., Nishi, K., Kadoza, C., Tanaka, I., Ono-Ogasawara, M., Sakae, H., Shirai, T., Aerosol generation and measurement of multi-wall carbon nanotubes, Journal of Nanoparticle Research, Vol. 11, pp.91-99, 2009.
[5] Kazerouni, N., Thomas, L.T., Petralia, A.S., Hayes, B.R., Mortality Among Workers Exposed to Cutting Oil Mist: Update of Previous Reports, American Journal of Industrial Medicine, Vol. 38, pp.410-416, 2000.
[6] Eisen, E.A., Smith, T.J., Kriebel, D., Woskie, S.R., Myers, D.J., Kennedy, S.M., Shalat, S., Monson, R.R., Respiratory Health of Automobile Workers and Exposures to Metal-Working Fluid Aerosols: Lung Spirometry, American Journal of Industrial Medicine, Vol 39, pp.443-453, 2001.
[7] Chen, M., Tsai, P.J., Chang, Ch.Ch., Shih, T.-Sh., Lee, W.J., Liao, P.C., Particle size distributions of oil mists in workplace atmospheres and their exposure concentrations to workers in a fastener manufacturing industry, Journal of Hazardous Materials, Vol. 146, pp.393-398, 2007.
[8] Lillienberg, L., Burdorf, A., Mathiasson, L., Thoerneby, L., Exposure to metalworking fluid aerosols and determinants of exposure, Annals of Occupational Hygiene, Vol. 52, pp.597-605, 2008.
[9] Lillienberg, L., Andersson, E.M., Järvholm, B., Torén, K., Respiratory symptoms and exposure-response relations in workers exposed to metalworking fluid aerosols, Annals of Occupational Hygiene, Vol. 54, pp.403-411, 2010.

[10] Park, D., Stewart, A.P, Coble, B.J., Determinants of Exposure to Metalworking Fluid Aerosols: A Literature Review and Analysis of Reported Measurements, Annals of Occupational Hygiene, Vol. 53, pp.271-288, 2009.
[11] Jabbar, A.M., Hashim, Z., Zainuddin, H., Hamat, A.R., Munn-Sann, L., Respiratory Health Effects of Metalworking Fluid among Metal Machining Workers: Review Article, Asia Pacific Environmental and Occupational Health Journal, Vol. 3, pp.15-19, 2017.
[12] Rosenman, D.K., Reilly, J.M., Kalinowski, D., Work-Related Asthma and Respiratory Symptoms Among Workers Exposed to Metal-Working Fluids, American Journal of Industrial Medicine, Vol. 32, pp.325-331, 1997.
[13] Li, K., Aghazadeh, F., Hatipkarasulu, S., Ray, G.T., Health Risks From Exposure to Metal-Working Fluids in Machining and Grinding Operations, International Journal of Occupational Safety and Ergonomics, Vol. 9, pp.75-95, 2003.
[14] Adler, D.P., Hii, W.W-S., Michalek, D.J., Sutherland, J.W., Examining the Role of Cutting Fluids in Machining and Efforts to Address Associated Environmental/Health Concerns, Machining Science and Technology, Vol. 10, pp.23-58, 2006.
[15] Thornburg, J., Leith, D., Size distribution of mist generated during metal machining, Applied Occupational and Environmental Hygiene, Vol. 15, pp.618-628, 2000.
[16] Thornburg, J., Leith, D., Mist generation during metal machining, Journal of Tribology, Vol. 122, pp.544-549, 2000.
[17] Schwarz, M., Dado, M., Hnilica, R., Veverkova, D., Environmental and Health Aspects of Metalworking Fluid Use, Polish Journal of Environmental Studies, Vol. 24, pp.37-45, 2015.
[18] National Institute for Occupational Safety and Health (US), Criteria for a recommended standard occupational exposure to metalworking fluids, https://www.cdc.gov/niosh/docs/98-102/default.html
[19] Park, D., Occupational Exposure Limit for Metalworking Fluids, Safety and Health at Work, Vol. 3, pp.1-10, 2012.
[20] Sujova, E.. Contamination of the working air via metalworking fluids aerosols, Engineering Review, Vol. 32, pp.9-15, 2012.
[21] Bennett, O.E., Bennett, L.D., Occupational airway diseases in the metalworking industry: Part 1: Respiratory infections, pneumonia, chronic bronchitis and emphysema, Tribology International, Vol. 18. pp.169-176, 1985.
[22] Tolbert, P.E., Eisen, E.A., Pothier, L.J., Monson, R.R., Hallock, M.F., Smith, T.J., Mortality studies of machining-fluid exposure in the automobile industry: II. Risks associated with specific fluid types, Scandinavian Journal of Work, Environment & Health, Vol. 18, pp.351-360, 1992.
[23] Massin, N., Bohadana, B.A., Wild, P., Gouter, P., Kirstetter, H., Toamain, P.J., Airway responsiveness, respiratory symptoms, and exposure to soluble oil mist in mechanical workers, Occupational and Environmental Medicine, Vol. 53, pp.748-752, 1996.
[24] Kriebel, D., Sama, S.R., Woskie, S., Christiani, D.C., Eisen, E.A., Hammond, S.K., Milton, K.D., Smith, M., Virji, A.M., A Field Investigation of the Acute Respiratory Effects of Metal Working Fluids. I. Effects of Aerosol Exposures, American Journal of Industrial Medicine, Vol. 31, pp.756-766, 1997.
[25] Greaves, I.A, Eisen, E.A., Smith, T.J., Potheir, J.L., Kriebel, D., Woksie, S.R., Kennedy, S.M., Shalat, S., Monson, R.R., Respiratory Health of Automobile Workers Exposed to Metal-Working Fluid Aerosols: Respiratory Symptoms, American Journal of Industrial Medicine, Vol. 32, pp.450-459, 1997.
[26] Kennedy, S.M., Chan-Yeung, M., Teschke, K., Karlen, B., Change in Airway Responsiveness among Apprentices Exposed to Metalworking Fluids, American Journal of Respiratory and Critical Care Medicine, Vol. 159, pp.87-93, 1999.
[27] Agalliu, I., Kriebel, D., Quinn, M.M., Wegman, D.H., Eisen E.A., Prostate Cancer Incidence in Relation to Time Windows of Exposure to Metalworking Fluids in the Auto Idustry, Epidemiology, Vol. 16, pp.664-671, 2005.
[28] Jaakkola, M.S., Suuronen, K., Luukkonen, R., Jarvela, M., Ruomi, T., Alanko, K., Makela, E.A., Jolanki, R., Respiratory symptoms and conditions related to occupational exposures in machine shops, Scandinavian Journal of Work, Environment & Health, Vol. 35, pp.64-73, 2009.

[29] Zeka, A., Eisen E.A., Kriebel, D., Gore, R., Wegman, D.H., Risk of upper aerodigestive tract cancers in a case-cohot study of autoworkers exposed to metalworking fluids, Occupational and Environmental Medicine, Vol. 61, pp.426-431, 2004.
[30] Rosenman, D.K., Asthma, hypersensitivity pneumonitis and other respiratory diseases caused by metalworking fluids, Current opinion in Allergy and Clinical Immunology, Vol. 9, pp.97-102, 2009.
[31] Burton, M.C., Crook, B., Scaife, H., Evans, S.G., Barber, M.C., Systematic Review of Respiratory Outbrakes Associated with Exposure to Water-Based Metalworking Fluids, Annals of Occupational Hygiene, Vol. 56, pp.374-388, 2012.
[32] Vasilyev, V.A., Gusarova, V.D., Analysis of Lubricating Cooling Liquids Negative Influence to the Human`s Health and the Ways of it Reduction, Safety of Technogenic Environment, Vol. 4, pp.37-40, 2013.

INVESTIGATION OF INHALABLE PARTICLES CHARACTERISTICS GENERATED DURING WELDING OF THE STAINLESS STEEL

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Abstract: Welding is one of the most dangerous industrial processes. Welding processes have potentially hazardous impact on human health, and on the environment as well. The health effects of this process on workers are numerous and very serious, like respiratory diseases, damage to skin, eyes, hearing, or can cause organ problems (stomach, kidneys), and also can be fatal like cancer. The degree of risk depends on the composition, concentration and time exposed to the harmful process/emissions and usage of different welding procedures, basic material and electrode.
In this study we measure inhalable dust fraction with a personal sampler, during manual arc welding of stainless steel with and without the usage of ventilation device. The aim was to determine the difference in the amount and composition of the particles accumulated on the filter of personal sampler. The particle size and morphology characteristics was examined with scanning electron microscopy and elemental composition of samples was examined with energy dispersive spectrometry analysis. The results showed the difference in the composition of the particles that dominate in the samples and also different geometrical characteristics of inhalable dust in samples.
Key words: welding, particles, SEM, image analysis

INTRODUCTION

Manual metal arc welding is a process of joining materials, where the arc is struck between an electrode fluxes coated metal rod and the work piece. There are several types of electrode coatings, such as basic, rutile, cellulose, acidic, etc., which can be used for alloy welding [1,2]. Occupational health and safety during welding very much depends on usage of different welding procedures, basic material and electrode.
In the welding process there are numerous factors that can be hazardous to human health like: heat, noise, infrared and ultraviolet radiation, body position of workers, fires and explosions, electrical hazards, compressed gases [3]. But the main problem in the welding process, regarding to occupational safety and health, is a welding smoke which is made of fine particles and gasses [3]. That mixture can contains nickel, manganese, chromium, silica, copper, arsenic, asbestos, beryllium, ozone, cadmium, compounds of fluorine, nitrogen oxides, carbon monoxide, cobalt, zinc, selenium and lead which are very toxic and can cause serious health issues for workers [4]. Consequences on health can be reversible (irritations, dermatitis), irreversible (asbestosis) or fatal (cancer) [5].
In addition to the fact that dust particles that workers can inhale during welding process are very dangerous by chemical composition, the degree of hazard to human health and level of penetration in the human body also dependent on particles size and shape. So, for the complete evaluation of exposure to welding smoke, it is necessary to have determine physical-chemical characteristics of particles [1].
The International Standard Organization for Standardization (ISO), the American Conference of Governmental Industrial Hygienists (ACGIH), and the European Standards Organization (CEN) have defined particle size fractions according to their aerodynamic diameter: inhalable, thoracic and respirable fractions [6,7].
In this study we sampled inhalable particle fraction, including all particles smaller than 100 micrometers. A qualitative analysis of chemical composition of particles on the surface of filters collected by personal sampler is possible with the use of energy dispersive spectrometry (EDS) analysis. Investigations of particle size and shape with scanning electron microscopy (SEM) enable a complex identification and evaluation of exposures.

The aim of this work was to determine the characteristic of dust particles generated during welding processes of stainless steels, and testing the differences in samples with used and without using ventilation system during welding process.

MATERIAL AND METHODS

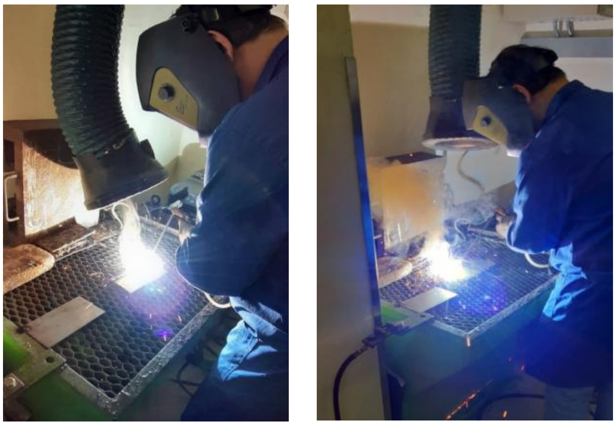
The experimental part was performed at the welding laboratory at the Faculty of Mechanical Engineering, University of Ljubljana.
With personal sampler from Department of Production Engineering, Faculty of Technical Sciences, Universitz of Novi Sad, dust particles were sampled during the welding process of stainless steel with a rutile electrode.
Analysis of the geometry and composition of dust particles was examined with scanning electron microscope at the Department of Materials and Metallurgy, Faculty of Natural Science and Engineering, University of Ljubljana.

Sampling

For the sampling of dust particles, a time-integrated method is often used in engineering practice to determine the concentration of aerosols. In this method, the sampler inhale air with a pump, simulating the level of breathing of workers. The particles, along with the air enter in to the device, and be collected in filter.
In the case of personal sampling, the sampler is located at the operator (worker) near his breathing zone (approximately 20 - 30 cm from the nose and mouth) (Figure 1), for the evaluation of workers exposure to particles [8,9]. Personal sampler operator carries with him and allow him to make any movement during the job.

Figure 1. Position of a personal sampler

Sampling was performed using the personal sampler EGO PLUS TT (Zambelli), with conical nozzle and filter with 25 mm diameter. Filters are made of mixed esters of cellulose that are suitable for use in microscopic analysis. The air flow rate was 3.5 l/min, in accordance with the manufacturer's recommendation (Zambelli). Sampling time was 1 min. The room temperature was 25 ° C, without air movement. A personal sampler was placed at the top of the chest, near the collarbone in the respiratory area of the worker/technician.
Sampling was performed in two cases, in case welding process with use air suction device (Figure 2a) and in the case of welding process without the using of a air suction device (Figure 2b).
We welded AISI 316 stainless steel (Table 1) using a manual arc welding process and rutile electrode INOX R 18/8/6 Fe (Table 2).
Time of sampling was only one minute because of the amount of particles that are generated on filter and image analysis that are more difficult with particle overlapping.



a) b)

Figure 2. Sampling in case of welding process with use a suction device (a), and without use a suction device (b)

Table 1. Composition of AISI 316 stainless steel

	C	Mn	Si	Cr	Ni	P	Mo	N
%	0.07	2.0	1.0	16.5-18.5	8-13	0.04	2-2.25	0.11

Table 2. Composition of INOX R 18/8/6 Fe electrode

	C	Si	Mo	Cr	Ni
%	0,12	< 1,2	7	19	9

Scanning electron microscopy

For the analysis of dust particles (their shape, size, composition, etc.), we used a ThermoFischer Quattro S with a field emission gun (FEG). It allows operation in three vacuum modes, namely high vacuum ($<6\ 10^{-4}$ Pa), low vacuum (up to 200 Pa) and ESEM mode (up to 4000 Pa).

For sample imaging, the FEG SEM Quattro S is equipped with detectors of secondary (SEI), backscattered (BEI) and transverse electron (STEM) detectors. It combines the principles used in transmission electron microscopes (TEM) and scanning electron microscopes (SEM). Resolution in high vacuum mode is 0.8 nm (STEM), 1.0 nm (SEI) and 2.5 nm (BEI), and 1.3 nm in ESEM mode 10 (SEI) and 2.5 nm (BEI) respectively. A new generation UltimMax detector is built in to analyze the chemical composition.

a) b)

Figure 3. Scanning electron microscopy (a); Sputter Coater Balzers SCD 050 (b)

The sample was first carbonized to determine the composition of the dust particles. Sputter Coater Balzers SCD 050 was used for the vaporization process (Figure 3b).
After evaporation, samples were analyzed using a scanning electron microscope (SEM) (Figure 3a).

Image analysis

Particle analysis is characterized by the acquisition of parameters that describe particle geometry using the image processing method. These parameters often represent interdependent variables. We use JMicroVison software. To determined particle size we use descriptors that 2D SEM image of particles convert to a circle of equivalent area. The diameter of this circle is then reported as the equivalent circle diameter (ECD) of the particle [10,11].
To determined particles shape we used descriptor which defines the textural roughness of a particle – convexity, a one to define the form of particles – elongation.

RESULTS AND DISCUSSION

EDS analysis

EDS analysis of chemical composition of inhalable particles in welding process with using air suction, are shown in Figure 4. Elemental composition of particles trapped on a filter (EDS mapping) show that the particles contain oxygen, carbon, chromium, silicon, aluminum, potassium, iron and manganese. The results indicate that the particles have been oxidized.

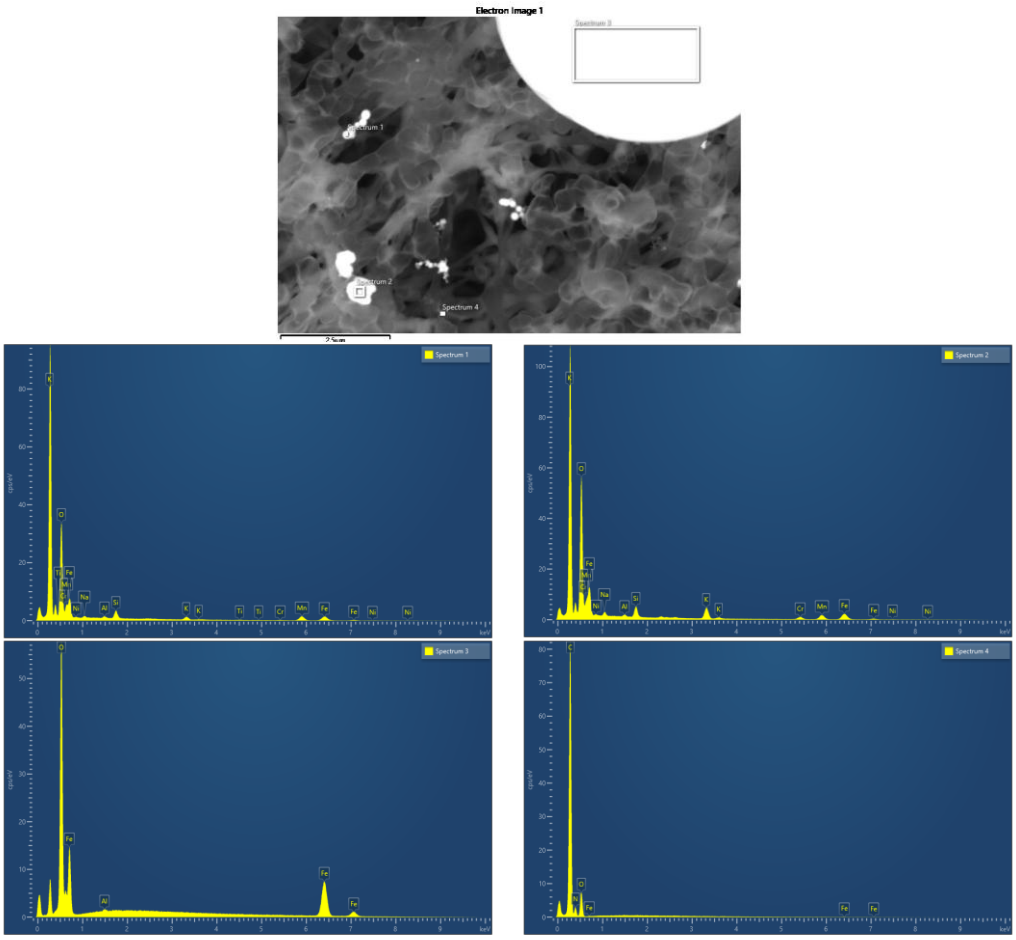


Figure 4. EDS analysis in four spectrum of chemical composition of inhalable particles in welding process with using air suction

Table 3 summarizes the results of EDS analyzes of dust particles composition generated during welding with using a suction device at four locations (1 - 4) in wt. %.

Table 3. EDS results of particles during welding with using a suction device (% by weight)

	C	N	O	Na	Al	Si	K	Ti	Cr	Mn	Fe	Ni
Spectrum 1	-	-	28.98	0.72	0.60	2.79	2.47	0.33	0.80	25.48	36.51	1.33
Spectrum 2	-	-	27.92	1.14	0.44	2.61	6.71	-	5.98	17.25	35.89	2.05
Spectrum 3	-	-	16.89	-	0.17	-	-	-	-	-	82.93	-
Spectrum 4	68.88	16.26	13.86	-	-	-	-	-	-	-	1.0	-

The results of the EDS analyzes collected in table 3 confirm that these are oxidized particles. The particle at site 1 mainly contains Fe, Mn, and O and smaller amounts of Na, Al, Si, K, Ti, Cr, Ni. The particle at site 2 has a similar composition to the particle at site 1. The larger spherical particle at site 3 represents iron oxide with a smaller amount of Al. The analysis of site 4 shows, in particular, the composition of the filter.
EDS analysis of chemical composition of inhalable particles in welding process without using air suction, are shown in Figure 5. The figures clearly show that the particles contain oxygen, carbon, chromium, silicon, aluminum, potassium, iron, nickel and manganese. The results indicate that these particles were also oxidized.

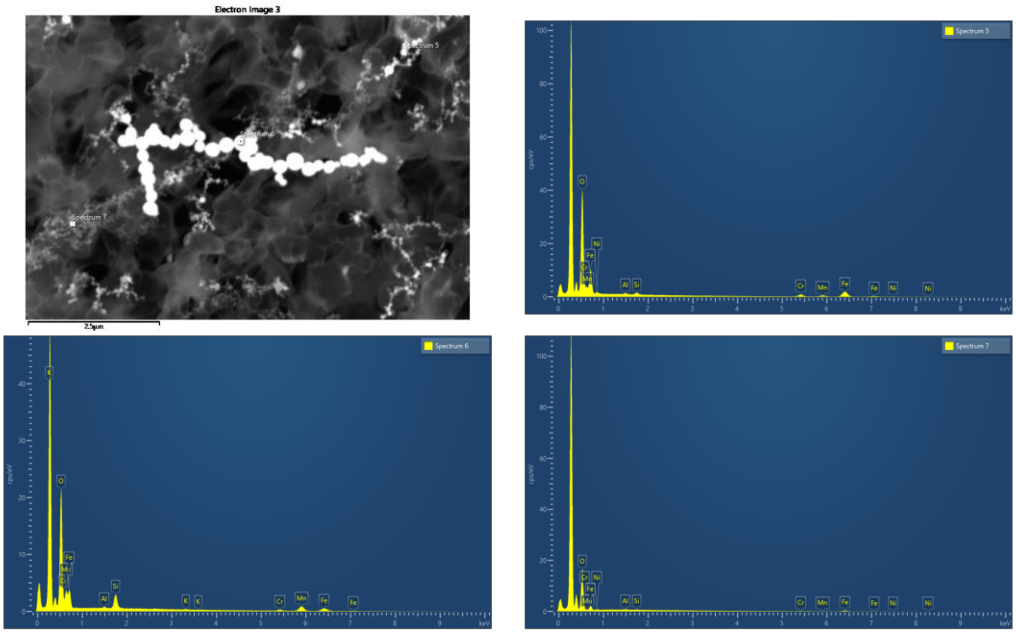


Figure 5. EDS analysis in four spectrum of chemical composition of inhalable particles in welding process without using air suction

Table 4 summarizes the results of EDS analyzes of dust particles during welding without the use of a suction device at three locations (5 - 7) in wt. %.

Table 4. EDS results of particles during welding without using a suction device (% by weight)

	O	Al	Si	K	Cr	Mn	Fe	Ni
Spectrum 5	28.32	0.44	0.76	-	8.36	6.00	52.70	3.42
Spectrum 6	32.33	0.46	5.31	0.46	4.64	29.20	27.59	-
Spectrum 7	52.90	0.73	0.47	-	1.49	1.10	36.13	7.17

The results of the EDS analyzes given in table 4 confirm that these are oxidized metal dust particles. The particle at site 5 contains mainly Fe and O, but smaller amounts of Mn, Al, Si, Cr and Ni. The particle at site 6 mainly contains Fe, Mn, and O, but smaller amounts of Al, Si, K, and Cr. And the particle at site 7 contains mainly Fe and O, but smaller amounts of Al, Si, Cr, Mn and Ni.

Size and shape descriptors

In both cases, with or without using of air suction device during the welding process, analysis of particle size over the ECD parameter showed that particles below 5 µm was dominated. The results are shown over the frequency in Figure 6.

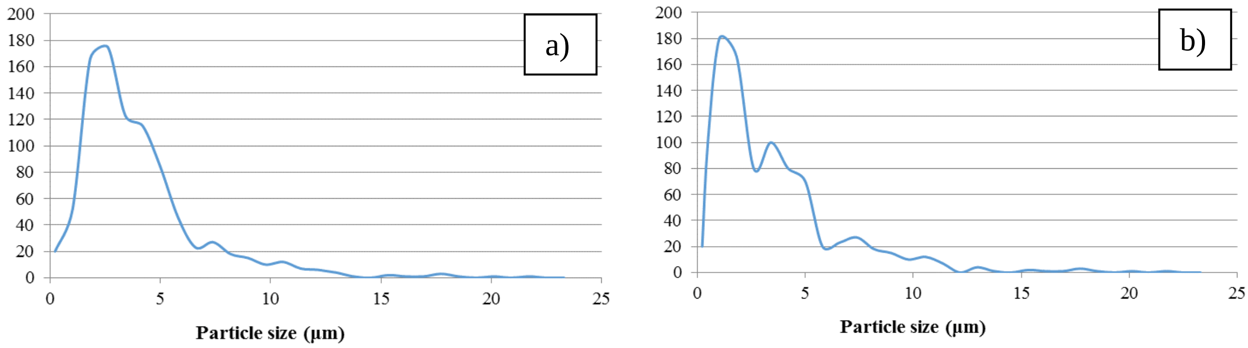
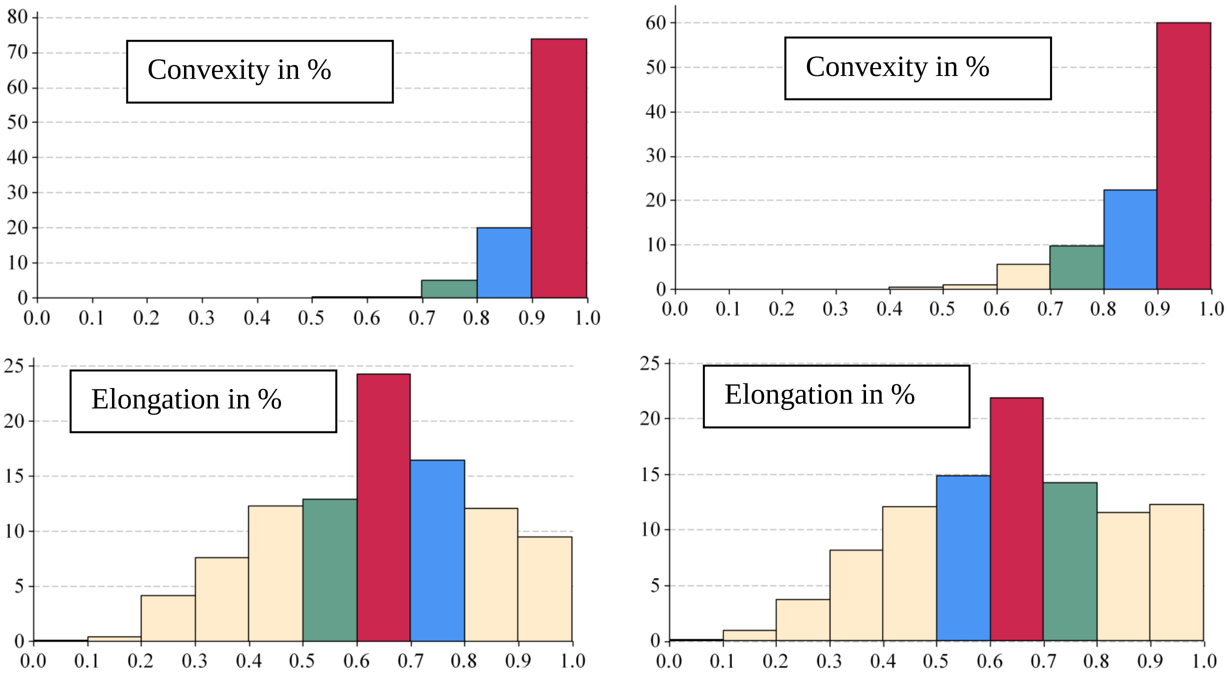


Figure 6. The frequency of occurrence of a certain particle sizes: a) sample with particles collected during the welding with usage a suction device; b) sample with particles collected during the welding without usage a suction device;

In the case of sample with particles that was collected during the welding process with using a suction device, we can see the presence of slightly larger particles, and the reason is because in the case of sample with particles collected during the welding process without using air suction, the dominant are the smaller smoke particles.
Shape factors of particles in both cases showed that in the samples the dominant particles were with very low roughness and not elongated particles.



a) **b)**

Figure 7. Convexity and elongation of particles: a) sample with particles collected during the welding with usage a suction device; b) sample with particles collected during the welding without usage a suction device;

CONCLUSION

The investigation of the chemical composition of welding inhalable particles is very important factor for evaluation the risk of process. But in the case that we need comprehensive picture of hazardous effects of welding process, we also need to determine not only by chemical but also by physical characteristic of particles in welding fumes.

The studies demonstrate that welders are exposed to cancerogenic and neurotoxic metals, but showed also that particles of smaller sizes have potentially stronger toxic effects [12]. With increasing opportunities for investigating the size and morphological characteristic of welding fumes significantly extend the knowledge about their hazardous effects [1].

The results of the study showed the presence of toxic metals in the case of both samples. In the case of the sample with particles collected during the welding with usage a suction device, slightly larger particles are present, relative to the sample with particles collected during the welding without usage a suction device. However in both cases, the most particles are in the range of the respirable fraction. (<10μm), with low roughness and more round shape.

REFERENCES

[1] Stanislawska, M., Halatek, T., Cieslak, T., Kaminsk, I., Kuras, R., Janasik, B., Wasowicz, W, Coarse, fine and ultrafine particles arising during welding - Analysis of occupational exposure, Microchemical Journal, Vol. 135, pp. 1-9, 2017.

[2] Persoons, R., Arnoux, D., Monssu, T., Culié, O., Roche, G., Duffaud, B. Chalaye, D., Maitre, A., Determinants of occupational exposure to metals by gas metal arc welding and risk management measures: A biomonitoring study, Toxicology Letters, Vol. 231, No. 2, pp. 135-141, 2014.

[3] Bailey, L., Kerper, L., Goodman, J., Derivation of an occupational exposure level for manganese in welding fumes, NeuroToxicology, Vol. 64, pp. 166-176, 2018.

[4] Michalek I.M., Martinsen, I.J., Weiderpass, E., Hansenf, ,J., Sparene, P., Tryggvadottir, L., Pukkala, E., Heavy metals, welding fumes, and other occupational exposures, and the risk of kidney cancer: A population-based nested case-control study in three Nordic countries, Environmental Research,Vol. 173, pp. 117-123, 2019,

[5] .Stanislawska, M., Cieslak, I., Kaminska, B., Janasik, R., Kuras, T., Halatek, W., Wasowicz, W., Assessment of occupational exposure to metals, fine and ultrafine particles arising during welding, Toxicology Letters, Vol. 258, pp. S222-S223, 2016.

[6] ISO 7708:1995 Air quality — Particle size fraction definitions for health-related sampling

[7] TLVs and BEIs, Threshold Limit Values for Chemical Substances and Physical Agents, Biological Exposure Indices, American Conference of Governmental Industrial Hygienists (ACGIH), 1330 Kemper Meadow Drive, Cincinnati, OH, 45240-1634, 1996

[8] MDHS: General methods for samplinh and gravimetric analysis of respirable and inhalable dust, Health and Safety Executive, UK 2014.

[9] Vincent J.H.: Aerosol Sampling: Sciencem Standards, Insrtrumentation and Applications, Wiley & Sons, Chichester, U.K 2007.

[10] Ilić Mićunović, M., Model za evaluaciju rezultata merenja karakteristika praškastih meterija zasnovan na elektronskoj mikroskopiji, doktorska disertacija, Novi Sad, 2018.

[11] Ilić Mićunović, M., Budak, I., Vučinić Vasić, M., Nagode, A., Kozmidis-Luburića, A., Hodolič, J., Puškar, T., Size and shape particle analysis by applying image analysis and laser diffraction – Inhalable dust in a dental laboratory, Measurement, Vol. 66, pp. 109-117, 2015.

[12] Xia, X.R., Monteiro-Riviere, N.A., Riviere, J.E., An index for characterization of nanomaterials in biological systems, Nat. Nanotechnol., Vol. 5, pp. 671-667, 2010.

SESSION 8. STUDENTS SESSION

COLLECTION AND DISPATCH OF OIL AND GAS FROM THE COLLECTION DISPATCH STATION

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Abstract: Since oil deposits are different in terms of their production characteristics, or in depth, so oil refinement technology has been developed to maximize the rationalization of drilling wells and reservoirs. Production system, reservoirs, wells, a collection place, as a unique hydrodynamic and thermodynamic system requires a fundamental analysis of all technological segments in it, production and dispatch. Oil is difficult to use in its original form, but after fractionation of a particular fraction there are characteristics that facilitate their use. Oil industry has since its beginnings made great progress in developing the process of processing, especially separating and converting processes. However, oil will for a long time be the main source of energy by detecting new sources, discovering new extraction from existing sources and improved processing processes.
Key words: oil, gas, drilling wells, reservoir, collection place, fraction, production, dispatch, processing, oil industry

INTRODUCTION

The expansion of the production and collection-transport system for oil and gas in the field of operations dispatching station characterize the thresholds of development, which are the result of positive findings above all by complex geological conditions.
NIS exploited 666 oil wells. The most significant oil fields are: Velebit, Kikinda, Mokrin, Rusanda, Elemir, Kikinda-varoš, Turija Sever. In the wells, world-class equipment is incorporated. A deep pump borehole is applied to a part of equipment developed and produced in our company. Contemporary methods and equipment are applied for the monitoring and control of wells in the work.

MATERIAL AND METHODS

Use and refining of oil

Oil begun to has its use in middle of the 19th century when the process for obtaining petroleum was perfected, long time to use for grease. The invention of an engine with internal combustion at the end of the century and the development of the motor industry starts a significant application of oil distillates.
Oil is difficult to use in its original form, but after fractionation of a particular fraction there are characteristics that facilitate their use.
Oil distillation up to 200°C was obtained petrol, up to 240°C petroleum, up to 340°C diesel, while the residue, after atmospheric distillation, was used as a heating oil or as a vacuum distillation raw material to obtain vacuum distillates and bitumen. Oil is non-renewable fossil fuel and therefore limited in availability.

Preparation of crude oil for processing

Processes for the preparation of processing oil include the removal of oil primes: separation of gases (separation), separation of water (drainage) and separation of salts (solubility). Removal of oleophilic primes from petroleum and above all sulfur (desulfurization) is not performed on oil but on derivatives obtained after processing.

Collector station for oil and gas

The collecting system consists of a pipeline and a series of devices between the wells and the entry point in the main pipeline. Since, as a rule, the gas pressure at the wells output is greater than the required pressure for the gas line then the compression system performs a pressure reduction. In case the pressure in the reservoir below the need for transport, the compressor work process is included. As seen in Figure 1. of the collector station, the gas pipelines with the wells are connected to the collector of collecting station.

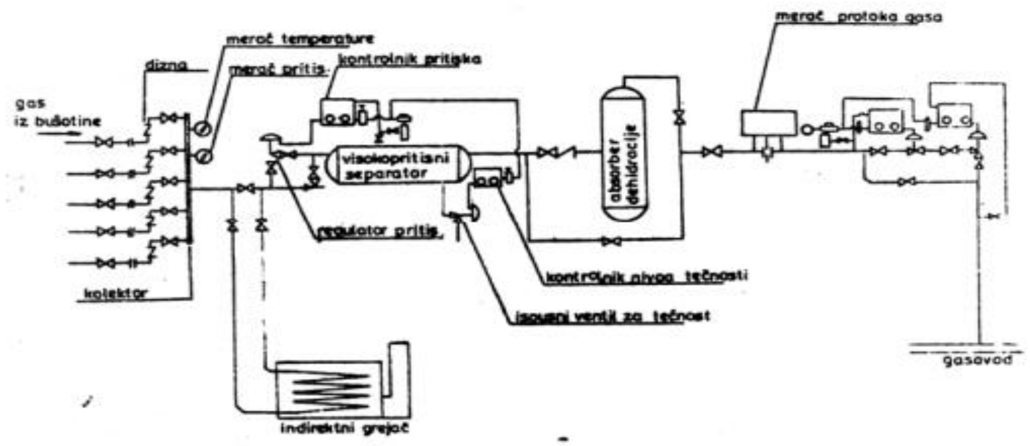

Figure 1. Gas pipelines with wells are connected to the collector of collecting station

The loading station

The role of the loading station is to receive oil into its reservoirs through the main oil pipeline from all the collector stations in one field. It also has the role of collecting oil from all collector stations and storing in it the foreseen reservoirs, which can be two or more to do in case of demolition of the oil, by mean devices of or without proper means, by heating and distillation oil with emulsifiers in the reservoirs and to allow oil to be loaded into railway tanks or tankers, or dispatch oil through pipelines to consumers.

Natural gas transport

The natural gas transport from the oilfield to the consumer is carried out through a system that includes the gas pipeline network from the site to the consumers, the purification, measuring and regulating stations, the compressor stations to increase the pressure of the gas and the storages for its storage.

Technology preparation oil for transport

Oil transportation is done from the collector station to the refinery. Oil pipes represent the cheapest and fastest transport, usually burial, a diameter that depends on flow and length of transport. The station are equipped with pumps at longer pipelines. Receiving station are used to maintain oil fluidity at low temperatures, heat in various gases, water circulation, and the like. Removal of paraffin waxes and adding additives (depresents) are different polymerization that affect crystallization.

Oil collection for transport

They are done in three phases and these are:

1. Primary phase - oil is applied to the surface under the influence of the natural energy of the reservoir.
2. Secondary phase - energy is restored or stopped by reducing and injecting water or gas.
3. Tertiary phase - heating + chemical treatment

Oil Separation

Separator efficiency is determined by the phase equilibrium that is primarily influenced by the pressure, the temperature and composition of the mixture, but also the corresponding structural elements within the separator itself, which ensure a better separation of the liquid and gas phase. Oil separation takes place in two ways, basically the following ways of separation that occur in the reservoir itself. The first way is the contact separation of the gas phase during which the liquid phase and the gas phase are in constant contact. Another way is the differential separation of the gas phase at which there is no contact between two separate phases, but the gas phase formed completely separates from the process.

Separation of liquidity and gas

Separation is a process that takes place at specific times with specific pressure and temperature. The mixture entering the process reacts to the new conditions so that the balance between the gas and liquid phase is restored.

Number of steps of separation

The number of steps of separation has a significant influence on the process. The higher the number of steps, the amount of liquid phase obtained at the end of the separation is higher. By contrast, the amount of gas is smaller, with the decrease of the density of both phases. It is because it is removed immediately when forming a gas phase, thereby reducing the partial pressure of medium heavy components, thus reducing the possibility of their evaporation. Through the steps, their partial pressure is getting smaller and more stable liquid phase is gained, but this increment slowly decreases with each new step. Therefore, a number of steps higher than the optimal is not recommended because the gain is too small for the funds invested.

Table 1. Number of steps separation relative to the initial pressure

Pressure of the first steps of separation (bar)	Number of steps
1.5-8.5	1
8.5-20	1-2
20-35	2
35-50+	2-3+

Vertical separator

Vertical separators are used mainly for the treatment of small amounts of mixture with a small fraction of the gas phase. The separation process is similar to that of a horizontal biphasic separator and begins by entering the mixture on the side of the vessel and separating it at the inlet block (1). The mixture enters the separator from the upper part, about two thirds of the height, and the entry can be made so that the smear moves tangentially or radially. If the entry is tangential, then tangential force is created that further enhances separation. After separating the bulk of the liquid at the entrance, it moves to the storage space over the bulkhead (2), whose role is to reduce the oscillation of the separator and control float.

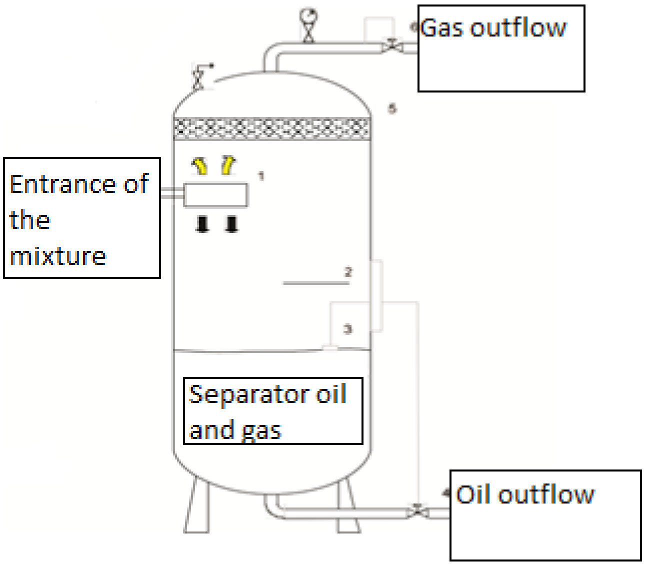

Figure 2. Vertical separator

RESULTS AND DISCUSSION

Geological exploration of oil and gas in Serbia has been carried out for more than 60 years and during this period more than 2,240 exploration and processing wells on oil and gas were drilled and 75 hydrothermal wells were drilled. Sixty three oil and gas fields were discovered, within which 271 reservoirs were defined. Geological surveys are conducted on the territory of Serbia and in the countries of the region, in accordance with the adopted strategy of geological exploration works for the period 2011-2020 years. According to this document, oil and gas production and the growth of energy reserves are planned to increase.
In order to increase efficiency in research and production and thus increase the volume of hydrocarbon production, NIS constantly monitors world trends and applies new technologies.

CONCLUSION

When collecting oil and gas, collecting stations play the most important role. Their task is to collect oil and gas from a number of wells, complete oil separation, individual and mutual measurement of these fluids, storing oil and transporting it to the loader station, as well as gas transport to the compressor station and other consumers. The number of wells connected to one collector station usually ranges from 5-40.

REFERENCES

[1] Kostic-Pulek.,A.,“Eksploatacija tečnih i gasovitih mineralnih sirovina i gasna tehnika“.,Hemija, prerada nafte i gasa., 2008.,
[2] Mićić, D, R.,“Priprema i transport nafte“.,Presentation 2,
[3] Raičević, Z.,“Preporuke za rukovanje i održavanje gaso i hidroenergetskih postrojenja“.,Praktična nastava.,Tehničar mašinske energetike., 2012,
[4] Zelić M.,Petrović D.,“Razvoj tehnologije proizvodnje, sabiranja i transporta nafte I gasa“.,Rudarsko-geološko naftni zbornik.,Zagreb.,1990,
[5] http://www.tfzr.rs/Content/files/0/Hemija%20nafte%20i%20gasa1.pdf

SIMPLE MODEL OF ELECTROSTATIC PRECIPITATOR

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Abstract: A numerous industrial plants are producing flue gases. Before discharging into the atmosphere purification is required, and it depends on the emission limit values. The most commonly used method of purification of waste gases is electrostatic purification, which is mainly used for the removal of solid particles and soot. The aim of this paper is to demonstrate the development of a simple model of electrostatic separator. The model is made according to the same operating principle as real devices and it is functional in terms of removal of solid particles from flue gas.
Key words: electrostatic precipitator, flue gas treatment, simple model

INTRODUCTION

Global power generation is based on combustion of fossil fuels [1], and the most commonly used fuel is lignite with low calorific value [2]. The major sources of harmful gases in the atmosphere are large boilers of thermal power plants and heating plants, cement plants etc. In combustion of solid fuels, along with oxides of combustible elements (carbon, sulfur and hydrogen), ash particles, nitrogen oxides, gases based on easily volatile compounds, heavy metals and other pollutants reach the atmosphere [3].
Electrostatic precipitators (ESPs) are devices used in the industry for particles removal contained in flue gas. These are industrial-strength, relatively simple and economical devices which generally have high collection efficiency, up to 99% [4,5,6]. These devices are used in various plants that produce waste gases as a by-product. The flue gases contain solid particles of different sizes, which could negatively affect the environment if they are released into the atmosphere without purification. Particulate matter (PM) is a widespread pollutant, consisting of solid particles as well as liquid components suspended in the air. According to the diameter, they are divided into particles smaller than 10 μm (PM10) and particles smaller than 2.5 μm (PM2.5) - fine particles and ultrafine particles that are smaller than 0.1 μm in diameter [7].
High concentrations of suspended particles in the air, in addition to adverse environmental impact, such as reduced visibility, could have an negative impact on human health and could cause chronic respiratory diseases [8]. Health disorder also depends on exposure time to particulate matter as well as on population age [9,10].
The working principle of electrostatic precipitator can be described in the following steps [11,12]: particle charge, particle exposure to electromagnetic field and contrary charge and particle "sticking" on grid.

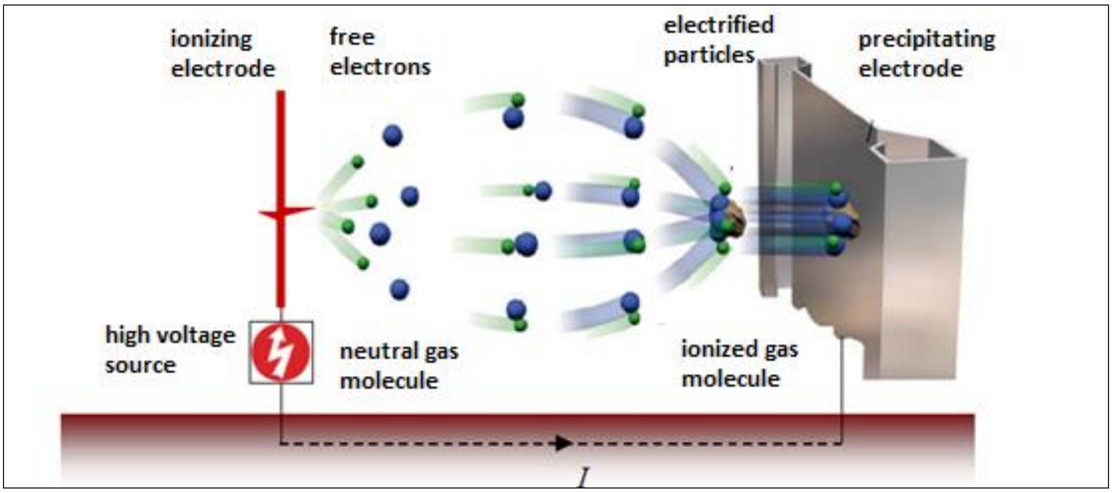

Figure 1. Working principle of electrostatic precipitator [11]

As flue gas passes trough the electrostatic field it gets negatively charged. As soon as it reach the positive electrode it participate due the neutralization process.
The aim of this paper is to demonstrate the development of a school model of electrostatic precipitator. The model represents student work, and it is used for the purpose of demonstrating air purification in teaching and extracurricular activities such as workshop at the Science Festival.

MATERIALS AND METHODS

In order to understand the working principle of electrostatic precipitators, the simple model was made. Figure 2 is a schematic representation, on its basis the model was created.

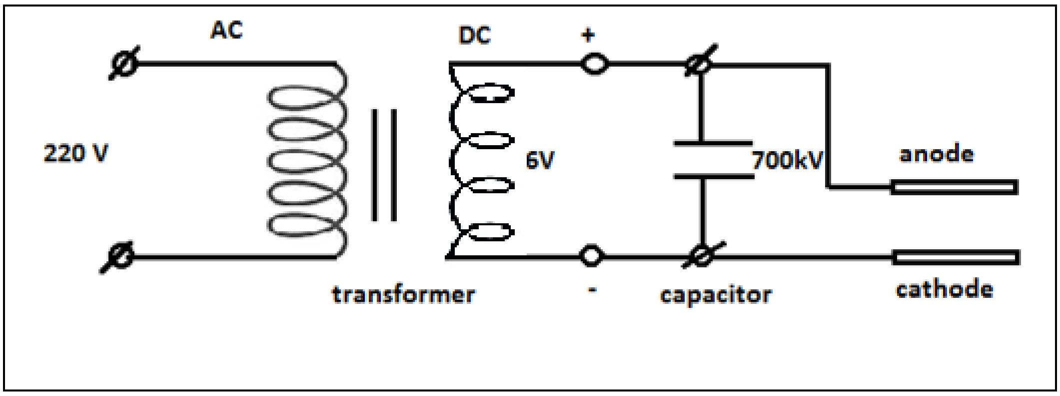

Figure 2. Schematic representation of the ESP model

The model installation consists of the following:
1. Connection to AC 220V;
2. The alternating current goes through the transformer and at the output gives 6V DC;
3. The capacitor use is to raise the voltage of the DC current;
4. This high voltage goes to grids that are in direct contact with the flue gas.

The following materials were used in the design of the model:
1. plywood thickness 10 mm,
2. plexiglass 3 mm thick,
3. transparent plastic cylinder Ø100,
4. stainless steel grate with welded screws M6,
5. butterfly nuts M6 and
6. cables.

The first phase of device's operation is connection on alternating current from the city network, the voltage of 220 V, which is directed to the transformer where the conversion to DC current is carried out and reduces the voltage to 6 V. The output from the transformer connects to a capacitor that raises the voltage to approximately 700 000 V and this voltage is supplied to the variously charged grids representing anode and cathode.
To make the model to work properly, it is necessary that airborne particles pass through a negatively charged grid (cathode) with a high voltage of 700 kV. Then the charged particles reach the anode, a positively charged grid of high voltage and remain glued on it.

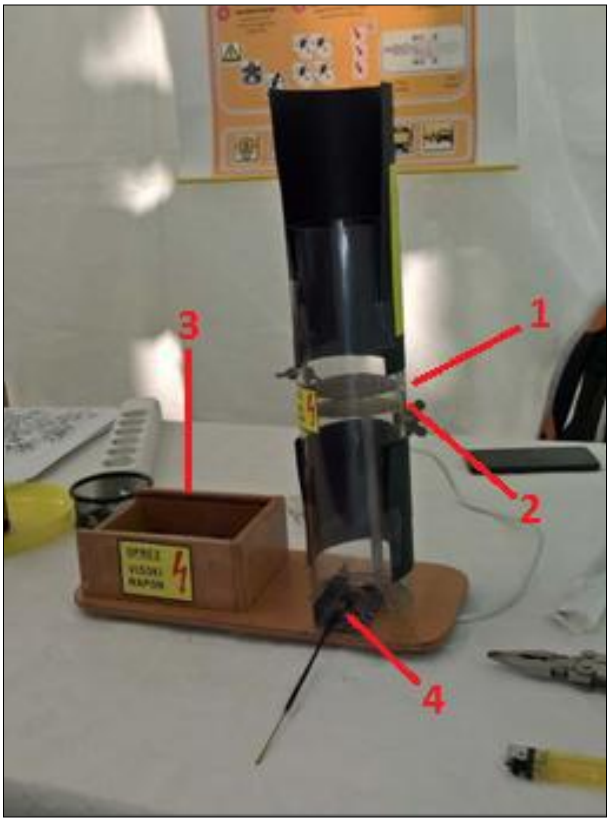

Figure 3. Constructed model with elements: 1- anode, 2 - cathode, 3 - transformer and capacitor in a protective box, 4 – burning element and firebox

Figure 3 represents constructed model of the electrostatic precipitator. At the bottom there is a simulation of the firebox, with a burning element which release a white colored smoke. In the middle, there are two grids that are attached with butterfly nuts M6 for the wall of the cylinder. The grids are made of stainless material that conducts electricity. They are positioned so that the lower grid is negatively charged and represents a cathode (smoke first passes through it), and above it is a positively charged grid with the same dimensions and it is an anode or a grid which retains polluting particles. The wooden lacquered box, dimensions 25x15x8 cm, contains a transformer that reduces voltage and converts AC power to direct current, as well as a capacitor which stores electrical charge thereby raising the voltage.

RESULTS AND DISCUSSION

A constructed model of the electrostatic air purifier is shown in Figure 5.

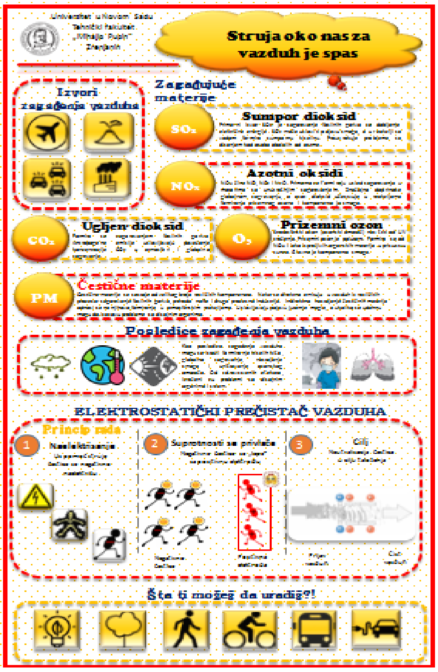

Figure 4. Poster presentation

Figure 5. Simple model of the ESP

For the caution, there are indications that the device is operating at high voltage. The demonstration of operation is represented by connection of the device to an AC source, after which electrodes (metal grids) are charged. The burning element is positioned at the intended location, below the electrodes, as shown in Figure 3.

The cylinder housing the electrodes is wrapped in black paper to make the smoke easily visible. When smoke passes through the cylinder, a clear difference can be observed when the device is connected to an electrical source and when it is not powered. The difference is visible in the smoke, when the device is switched off, the smoke is the same width below and above the electrodes, while during the operation of the device, the smoke is much more diluted above the electrodes at the outlet of the cylinder.

This representation of the thickness, or concentration of the smoke, represents the purification of the flue gas, since a large number of particles have been removed by passing through the electrodes, which is the primary goal of a such model. The solids contained in the smoke upon arrival at the first electrode are negatively charged, and as such they remain on the second electrode which is positively charged and after the pass of the smoke it was possible to notice the soot residues. Given that it is a demonstration model, it is not possible to quantify the percentage of purification.

Since the model was designed to demonstrate the operation of a real device, it was used at the Science Festival 2018 in Novi Sad city, as student work, with a poster presentation that is shown in Figure 4. The poster presentation aims to graphically and simply show device construction and work. Poster was made to represent the air pollution, major sources of pollutants and effect on air quality. The aim was to rise attention of the participants, mostly kids in school age.

CONCLUSION

A simple model of an electrostatic precipitator is student work, designed as a model for air purification simulation in industrial plants. The purification method is based on the fact that the solid particles in smoke (flue gas) pass through an electric field, receive a negative charge and then remain on the positively charged electrode and thus be separated from the smoke. This purification principle is very simple and often applicable in industry.

The electrostatic precipitator model is made of inexpensive materials and the element placement method did not require additional qualifications and expertise other than a basic knowledge of electrical engineering and device operation. In addition, the advantages of the model are reflected in its ease of application and demonstration of gas purification. Its representation on Science Festival was very successful.

REFERENCES

[1] Foster S., Elzinga D. :The Role of Fossil Fuels in a Sustainable Energy System, The Magazine of the United Nations, Vol. LII No. 3 2015
[2] Di Gianfrancesco A.: The fossil fuel power plants technology, Materials for Ultra-Supercritical and Advanced Ultra-Supercritical Power Plants, 2017.
[3] Despotović Ž., Bakić M., Vukosavić S.: Savremeni elektrostatički razdvajači, časopis Energija, 2010
[4] Wang A., Tu G., Song Q., Wang H., Yue Y., Yao Q.: Influence of flue gas cleaning system on characteristics of PM 2.5 emission from coal power plants, Key Laboratory for Thermal Science and Power Engineering of Ministry of Education, Department of Thermal Engineering, Tsinghua University, Beijing 100084, China, Int J Coal Sci Technol 1(1):4–12, DOI 10.1007/s40789-014-0001-x, 2014
[5] Souakri S., Reess T., Silvestre de Ferron A., Lemont F., Marchand M.: Flue Gas Treatment by ESP: Realization and Optimization of an Emissive Electrode, International Journal of Plasma Environmental Science and Technology, Vol.10, No.2, DECEMBER 2016
[6] Villegas P. J., Martin-Ramos J. A., Diaz J., Martinez J., Prieto M.J., Pernia M.A.: A Digitally Controlled Power Converter for Electrostatic Precipitator, Department of Electrical Engineering, University of Oviedo, 33204 Gijón, Asturias, Spain, 2017
[7] World Health Organization: Health effects of particulate matter, ISBN 97892890 00017, 2013
[8] Li X., Chen X., Yuan X., Zeng G., Leon T., Liang J., Chen G., Yuan X.: Characteristics of Particulate Pollution (PM2.5 and PM10) and Their Spacescale-Dependent Relationships with Meteorological Elements in China, Sustainability, 9, 2330; doi:10.3390/su9122330, 2017
[9] Vujić B., Pavlović A., Vujić G., Jevtić D.: Assessment of Concentration Levels of Particulate Matters (PM10, TSP and BS) in the Area of Zrenjanin, Vojvodina, Serbia, REV. CHIM. (Bucharest), 61, Nr. 10, 2010
[10] Mokhtar M.M., Hassim M.M., Rozaine M.T.: Health risk assessment of emissions from acoal-fired power plant using AERMOD modelling, Process Safety and Environmental Protection 9 2 476–485, 2014
[11] Radić M., Petković D.: Elektrostatički filteri, Fakultet zaštite na radu, Niš, 2014
[12] Shah K. P.: Construction, Working, Operation and Maintenance of Electrostatic Precipitators (ESPs)(www.practicalmaintenance.net), 2017

MEDICAL WASTE MANAGEMENT

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Abstract: Nowadays, the big challenge is disposal of all types of waste, including medical waste. It is important to keep it safe, efficient and environmentally friendly. Every institution, even a person, is a producer of some kind of waste. Health institutions produce different types of waste in their activities, which if not properly disposed, can seriously pollute the environment and be dangerous for the employees, users of health services, visitors as well as employees in the waste management. The paper includes the topic of medical waste management and treatment, as well as the legal regulations governing this area. In the first part of the paper is described what medical waste is and how it is handled. The second part is based mainly on laws and regulations in Serbia and the European Union, while in the third part is described how medical waste is handled through good practice examples.
Key words: Medical waste, laws and regulations, medical waste management plan

INTRODUCTION

Medical waste is a heterogeneous mixture of municipal waste, infectious, pathoanatomical, pharmaceutical and laboratory waste, disinfectants and packaging, as well as radioactive and hazardous chemical waste. It is a waste that consists human or animal tissues, blood and other body fluids, secretions, medicines and other pharmaceutical preparations, swabs, tupers, gauze, bandages, needles, scalpers, sharp instruments [1]. 70% to 90% of medical waste is municipal waste. Therefrom, 10% to 30% can be classified as hazardous waste which can cause health and environmental risks. Medical waste is generated in the processes of diagnosis, treatment and medical, as well as when research is conducted in health care facilities in scientific, therapeutic, diagnostic or similar medical activities. The aforementioned waste means all waste generating from the provision of health services, whether in or outside health care facilities (home care), in nursing homes or in institutions providing medical care in any form. Management of medical waste is an expensive activity, which includes the collection, sorting, packaging, marking, storage, transport, treatment or safe disposal of medical waste. Inadequate waste management is one of the important problems from the aspect of environmental protection of the Ministry of Environment and Spatial Planning of the Republic of Serbia, as well as from the aspect of the Ministry of Health and requires defining the attitude of whole society towards waste. The problem of medical waste management in the Republic of Serbia is one of the important tasks of all structures involved in its creation and disposal.

In 2007, the Ministry of Health of the Republic of Serbia launched the EU-funded Technical Assistance in Medical Waste Management project, which deals with the introduction of an infectious medical waste management system, applying unique methods of separation, labeling, packaging, transportation and treatment of infectious medical waste from health care an institution using methods of decontamination of this waste category [2]. Unfortunately, the practice in smaller healthcare organizations and underdeveloped environments is that hazardous waste is most often dumped together with other types of waste into the same, inappropriate containers, and thus treated as classic municipal waste rather than as hazardous waste. For good practice, it is crucial that healthcare professionals and associates know exactly what is expected from them in the waste sorting process, be motivated and properly trained in these activities, and also to have adequate cooperation with the management of the healthcare facility on the mentioned issues. In most health facilities, medical waste is treated as municipal waste, not as a type of hazardous waste [3]. Only in a small number of health institutions in Serbia sterilization of infectious medical waste is used, most often in autoclaves that are very old but regularly monitored and maintained [4]. This practice is present in public health institutes and institutes as well as in individual microbiology laboratories. After sterilization, sharp objects are disposed of in ordinary municipal waste containers. Used needles and syringes, cotton swabs, bandages, and other categories of infectious waste are generally not separated or sterilized in some health care facilities, but mixed with municipal waste. All medical waste is then taken to the city landfill [5].

The sorting of medical and municipal waste is rarely carried out at landfills in Serbia, which are mostly uncontrolled and unsanitary [3]. The existing practice of mixing medical with municipal waste in landfills with an inappropriate system of work can also lead to the rapid spread of infectious diseases by the transfer of microorganisms to the air (microorganisms enter the air through emissions caused by smoldering waste). The spread of infections through direct contact of landfill employees and other visitors who are unaware of the risks, and collecting waste relationships from the landfill, as well as through birds wandering around the landfill in search of food, is also one of the recognized pathways for the spread of infections. Most landfills in Serbia are not sanitary landfills and still do not bury the waste on a daily basis or treat it further. Hospitals in Serbia have about 50,998 beds with an estimated 15 million hospital days. The average occupancy of the bed is 72% annually [6]. According to World Health Organization estimates hospitals in Serbia generate an average of 1.8 kg of medical waste per hospital bed per day. It is estimated that all health institutions in Serbia generate about 48 tons of waste annually. About 9,600 tonnes of this waste can be considered as hazardous waste [7]. The aim of this paper is to establish a safe medical waste management system using the method of sterilization of infectious medical waste that occurs in the provision of health care in health institutions in the entire territory of the Republic of Serbia. It also provides basic information that will contribute to reducing the amount of medical waste in health care facilities, segregating waste into basic categories at the point of origin, as well as contributing to environmental protection and improving citizens' health.

MATERIAL AND METHODS

Law enforcement and the Legal Framework contribute to the establishment of a medical waste management system. In the EU, the field of medical waste management is regulated by directives. The basics of waste management in the European Union are contained in the Council of Europe Resolution on a Waste Management Strategy (97/C76 /01) based on the Waste Framework Directive (75/442/EEC) and other EU waste management regulations. Some of the key EU directives in this field are:

- Council Directive 75/442/EEC on waste (Framework Directive),
- Council Directive 99/31/EC on landfills;
- Directive 84/631/EEC on the supervision and control of transboundary movements of hazardous waste in the EU;
- Directive 96/61/EEC on integrated pollution prevention and control;
- Directive 97/11/EC amending Directive 87/337/EEC on the assessment of the effects of certain public and private projects on the environment.
- Directive 2008/98/EC of the European Parliament and of the Council on waste, which replaces and supplements Framework Directive 75/442/ EEC, 2006/12 / EC, establishes a system for coordinated waste management in the EU with the aim of limiting waste production [8].

In the Waste Framework Directive, Member States commit to developing a waste management plan.
The Basel Convention on the Transboundary Movements of Hazardous Waste and its Disposal (1989) is one of the most important internationally accepted legal acts in the field of hazardous waste, which has been in force in our country since 1999 and which regulates, inter alia, the transboundary movement and disposal of medical waste (as hazardous waste).The agreement was signed by 100 countries, which have accepted the principle that the only legitimate transport of hazardous waste is export from countries without plants or skilled personnel for the reliable disposal of waste to countries that have both plant and expert personnel.
The Republic of Serbia, as a future member of the EU, is obliged to align its laws with EU law. Waste management in Serbia is governed by a large number of regulations that directly or indirectly regulate this area:

- Law on Environmental Protection (Official Gazette of the Republic of Serbia, No. 135/04)
- Law on Waste Management (Official Gazette of RS No. 36/2009),
- Law on Ratification of the Basel Convention on the Transboundary Movement of Hazardous Wastes and their Disposal (Official Gazette of the FRY, International Treaties, No. 2/99)
- Law on Health Care (Official Gazette of the Republic of Serbia, No. 107/05)

- Law on the Protection of the Population from Infectious Diseases (Official Gazette of the Republic of Serbia, No. 125/04).
- The Law on Production and Traffic of Toxic Substances (Official Gazette of the Republic of Serbia 101/05, other law).
- Law on Medicines and Medical Devices (Official Gazette of the Republic of Serbia, No.84/04).
- Law on the Transport of Dangerous Goods (Official Gazette FRY 24/94, Official Gazette SCG 1/03Constitutional Charter)
- Waste Management Act (Official Gazette of the Republic of Serbia, No. 25/96,)
- Ordinance on the Management of Wastes Having Hazardous Substances (Official Gazette of the Republic of Serbia, No. 12/95)
- Rulebook on conditions and manner of sorting, packaging and storage of secondary raw materials (Official Gazette of the Republic of Serbia, No. 55/01)
- Rulebook on the manner of destruction of medicines, auxiliary medicinal products and medical devices (Official Gazette of the FRY, Nos. 16/94, 22/94, Official Gazette of SCG 1/03 Constitutional Charter).

These laws provide conditions for the establishment and development of an integrated waste management system. The Law on Waste Management is based on the basic principles of waste management and provides conditions for full compliance with EU legislation. The regulation of this area as a whole requires the adoption of all by-laws, executive regulations governing the organization of waste management, i.e. further harmonization of national regulations with EU legislation is required.

RESULTS AND DISCUSSION

Based on the existing legislation and the situation in the field of medical waste management in Serbia, the authors identified examples of good practice, that is, proper treatment of this type of waste.
The Department of Laboratory Diagnostics Bio Medicine [9] from Belgrade has a medical waste management plan and a medical waste management team. All wastes are sorted at the site of origin in the laboratory with sharp objects, needles, broken glass, waste from sampling, from microbiological laboratories, the grounds on which bacteria grow, all of which are potentially infectious. All this waste is sorted and disposed of in packaging and taken to decontamination areas. They have three autoclaves, and once a year autoclave controllers come in, and they also have internal and biological and chemical controls with each cycle. The neutral waste is carried to a central landfill. Waste producers who do not have their own autoclaves enter into contracts with companies that transport and dispose of medical waste. Waste is collected and transported by special vehicles under very rigorous control and with as little manipulation as possible. Vehicles are specially marked, in case of adverse situations, and are all covered by appropriate insurance. Generators waste is transported directly to the plant without temporary storage, which is in accordance with the Ordinance on medical waste management. The entire process is accompanied by a hazardous waste movement document that is eventually returned to the generator (certified so that the generator can see where the waste ended up). The treatment of medical waste is completely harmless to the environment, these are steam sterilizers that operate on the principle of water vapor at 121 ° C and under 2 bar of pressure. After treatment, the waste is crushed and packaged in municipal bags and then transported and disposed of in municipal landfills in special cassettes. Each healthcare facility that produces more than 500 kg of medical waste annually must draw up a medical waste management plan every three years and have a person in charge of waste management. It is very important for people to be educated, in terms of safe handling of sharp objects during and after the intervention, to prevent and spread infections. It is also required that the waste be packed in the prescribed packaging prior to picking up the waste. The waste is taken over by a vehicle specialized in the transport of infectious waste, after which it undergoes a sterilization and crushing process. Having thus lost the properties of a hazardous waste, it can be disposed of in a municipal waste container. Pathoanatomical waste is buried, there is a place for burial in each cemetery that waste is packed in brown bags. The treatment cycle lasts about an hour, and should be between 25 and 28 pounds per cycle.

Water vapor passes between the hard components and sterilizes them, so there is little space left between the wastes. A certain amount of waste is prescribed which should not be exceeded.
In Zrenjanin there is also a company REMONDIS Medison, which deals with the responsible management of hazardous medical waste through a complete service of collection, transportation and treatment of medical waste, as well as the safe disposal of treated non-hazardous waste. They also manufacture consumables for the collection of medical waste (boxes for sharp objects and bags for infectious waste). This company annually processes 350 of the 6000 tonnes of infectious waste generated in the Serbian market, and waste that is extremely hazardous to people working in hospitals and to the environment is properly and adequately disposed of. Waste after treatment in plants becomes completely harmless, dehydrated, altered in shape, 80% smaller volume than inlet, is disposed of in landfills under special conditions and in any case is completely harmless. The company was founded in 2009 and, since 2015, is the majority owner of the German company Remondis - Germany's largest environmental company.
When it comes to private practice in this area, inspections are quite rigorous, since private companies are more often controlled than public institutions. However, it can be said that efforts to improve the management of this type of waste are and that it is very important to educate people to understand that by respecting waste management regulations, they protect not only the environment but also their own health.

CONCLUSION

The pollution coming from health care facilities is specific and can be very dangerous, not only for the health of people working in health care facilities, but also for the environment, population, and the ecosystem in which waste is stored. In addition to the existing legislation, medical waste is still not separated, but mixed with municipal waste and referred to a municipal landfill, where we later encounter the problem of spreading infections. Historically, larger quantities of unused medical waste already exist, which is also a problem. What needs to be done on a daily basis is to raise awareness, which is a prerequisite for the proper management and disposal of medical waste, and that, in addition to the implementation of the law and ongoing education programs are of highest importance. With regard to pharmaceutical and chemical waste, currently the only solution is to export them to countries that have suitable destruction devices in accordance with EU regulations, because such devices do not exist in our country. There is no need to change the existing method of treating pathoanatomical waste as it complies with the relevant regulations. The problem of infectious medical waste can be solved in many ways, depending on the method of managing the medical waste that has been adopted and the financial resources available. As there is no prospect of a controlled incineration of hazardous waste being constructed in Serbia any time soon, which would be technically, environmentally and economically most acceptable, it has been suggested that the problem of infectious waste be solved at the site of origin, "in situ". This is a transitional solution, which fits in well with the final solution, as it will be used as a pre-treatment after which sterilized infectious medical waste can also be incinerated in a municipal waste incinerator. Priority would be given to the procurement of devices for institutions that are the largest and most significant producers of medical waste (clinical hospital centers and institutes), and then the devices would be procured for other institutions in accordance with the financial capacity of the city. In RS there are regulations, but they are not effectively implemented due to lack of trained staff, lack of public awareness, thousands of illegal dumps and the absence of hazardous waste treatment facilities.

REFERENCES

[1] Ordinance on the Management of Medical Waste (Official Gazette of the Republic of Serbia, No. 78/2010)
[2] Tanaskovic, M., Medical Waste, City Institute for Health Protection, Belgrade, 2007.
[3] Todic, D., Iskovski, Z., Katic, M., Hazardous Waste Management in the Republic of Serbia, Belgrade, 2013.
[4] Ministry of Health of the Republic of Serbia, National Guide to the Without. cf. med. waste, Belgrade, 2008.

[5] Borovina, B., Reverse Logistics in Healthcare - Medical Waste Management, 6th Scientific Conference with International Participation Synergy, 2010.
[6] Jovanovic, V.S. Analysis of Medical Waste Management Factors in the Health Care System, Kragujevac, 2017.
[7] Ministry of Health of the Republic of Serbia, National Guide to Safe Medical Waste Management, Belgrade, 2008.
[8] https://europa.eu/european-union/eu-law/legal-acts_en
[9] Directorate for Biomedicine - Ministry of Health of the Republic of Serbia.

MEASURING OF INDOOR $PM_{2.5}$ CONCENTRATION IN BUDAPEST, HUNGARY

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Abstract: This work represents the results of indoor air pollution measurements in Budapest, Hungary. $PM_{2.5}$ measurements were carried out by an IQAir - AirVisual Pro Air Quality Monitor in a family house in the suburban region of Budapest during a one-month period (May of 2019). $PM_{2.5}$ is one of the most important air pollutant in worldwide, and long-term exposure to $PM_{2.5}$ impacts the respiratory, cardiovascular, immune, and central nervous system. For Hungary, and especially for Budapest, an extensive measuring and modeling activity are available for the determination the outdoor air quality. However we generally spent most of our times in indoor environment, therefore the indoor air quality measurements are also very important. We have started our indoor $PM_{2.5}$ measurements in the spring of 2019. Our preliminary results show the diurnal variation of indoor air quality and its relationship with outdoor air quality.
Keywords: indoor air pollution, $PM_{2.5}$

INTRODUCTION

Indoor air quality is an important health determinant factor inside our homes, kindergartens, schools, health care facilities and workplaces. Primary school students, for example spend approximately 6–8 hours a day in school buildings. According to WHO factsheet 2018 [1], household exposure whether from the combustion of solid fuels for heating or dirty cook stoves responsible for premature death of more than 3 million people in every year all over the world. Medical researchers are particularly concerned about pollution particles smaller than 2.5 microns because they are so tiny, they aren't easily screened and more readily enter the human body [2]. Indoor air quality is partially influenced by outdoor air quality, but also several indoor sources such as smoke, cooking stoves, building materials and conditions, etc. has a contribution in high indoor air pollution [3]. Exposure to $PM_{2.5}$ can harmfully effect the human health. It can cause damage to the human respiratory system. It increasing the probability of lung cancers, chronic lung diseases, and cardiovascular system diseases [2], [4]. The most dominant $PM_{2.5}$ emission sources in Eastern Europe is the heating system from other stationary combustion categories especially in Serbia and Croatia, but also in Hungary [5].

MATERIAL AND METHODS

The indoor air quality inside a house in a residential area in the suburb region of Budapest (Hungary) Fig. 1.was investigated in the spring of 2019. Measurements were carried out by using an IQ Air – Air Visual Pro Air Quality Monitor. The monitor offers real-time $PM_{2.5}$ concentration (it is also able to measure carbon dioxide concentration, air temperature, and relative humidity that updates in real-time for continuous monitoring) [6]. The measurements were made in a living room, at 1.2 m high level. Concentration values were registered at every 5 minutes, and hourly average values were calculated for the whole month of May, 2019. Our results were compared with the measuring data of the closest (about 3 km) station of the Hungarian Air Quality Network (Kőrakás park) [7].

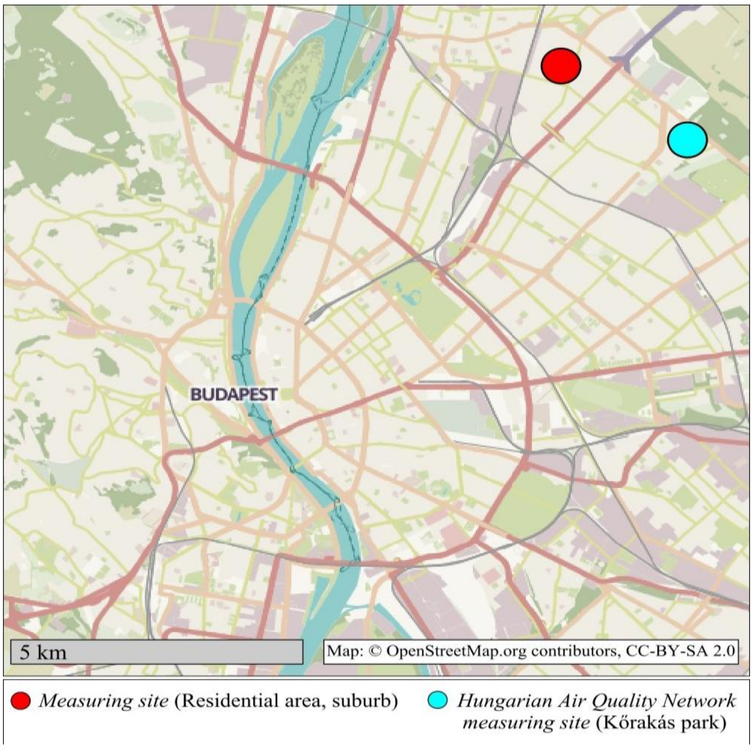

Figure 1. Location of the measuring sites in Budapest, Hungary.

RESULTS AND DISCUSSION

We started the continuous measurements in spring (May, 2019). Here we present the daily average concentrations of $PM_{2.5}$ for a one-month long period (Figure 2.).

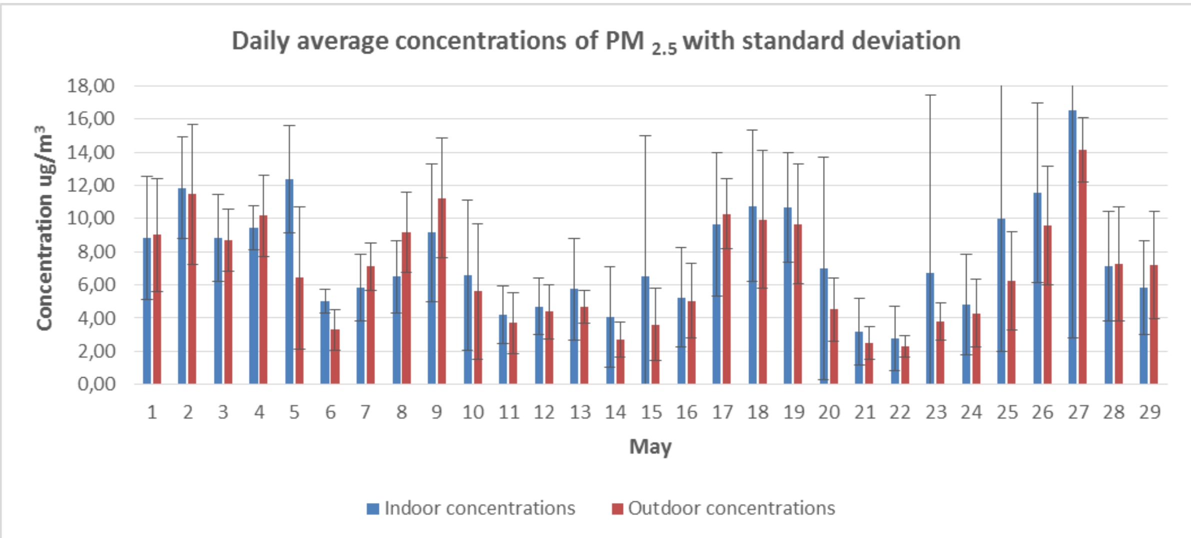

Figure 2. Average daily values of indoor and outdoor $PM_{2.5}$ concentrations with standard deviation during May, 2019. Indoor concentrations were measured in a living room, while outdoor concentration were measured by the closest station of Hungarian Air Quality Network.

The primary results show that indoor concentrations are close to outdoor concentrations (measured at a nearby station), which means that outdoor air pollution affects indoor air quality. On Fig. 3., the average daily courses of $PM_{2.5}$ concentration for all weekdays (Monday to Friday) in May both for indoor and outdoor concentrations are presented. The indoor concentrations were higher than averaged outdoor concentrations in some periods of the days (morning, early afternoon and evening hours), which are related to human activities in the house, such as cooking, cleaning, etc. Fig.4. shows the average daily courses of $PM_{2.5}$ concentration for weekends (Saturdays, Sundays of May). Indoor air quality were affected by human activities especially in daytime, when the indoor concentration values were generally higher, than outdoor averages.

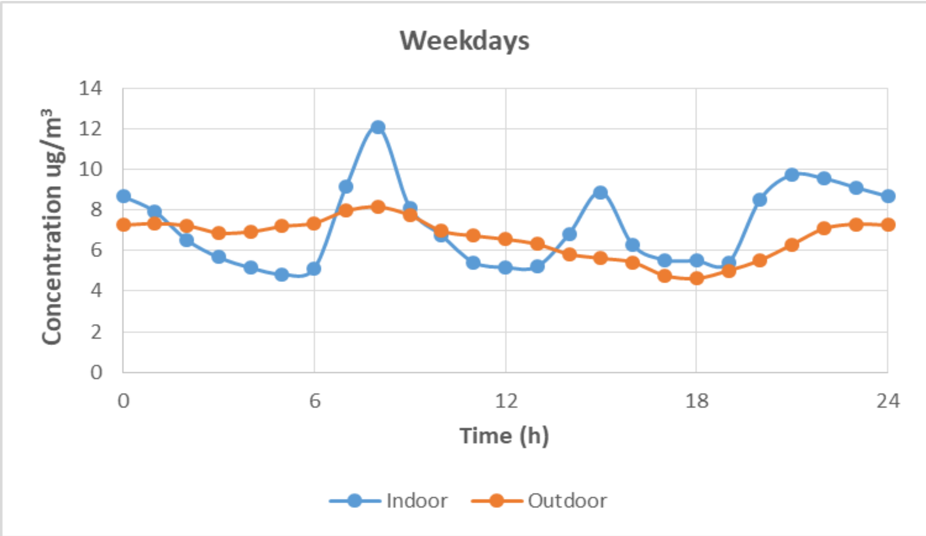

Figure 3. Average daily courses of indoor and outdoor $PM_{2.5}$ concentrations for weekdays. Indoor concentrations were measured in a living room, while outdoor concentration were measured by the closest station of Hungarian Air Quality Network.

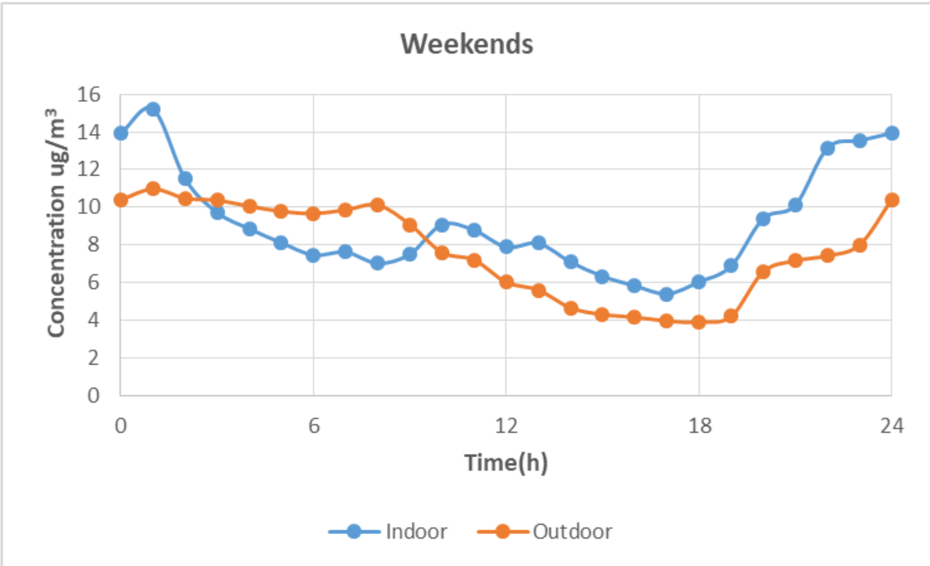

Figure 4. Average daily courses of indoor and outdoor $PM_{2.5}$ concentrations for weekends. Indoor concentrations were measured in a living room, while outdoor concentration were measured by the closest station of Hungarian Air Quality Network.

CONCLUSION

Our first results shows that a simple, portable monitor can gives information about indoor air quality. The diurnal variation and the magnitude of the measured indoor $PM_{2.5}$ concentrations were approximately the same as the outdoor concentrations, measured by the nearest station of the Hungarian Air Quality Network. However a larger variability was observable in case of indoor values due to the indoor emission sources of $PM_{2.5}$ related to human activities. Well separable pattern of daily variability of concentration were found for weekdays and weekends. Based on these results, more extensive measuring activity in different indoor environment are planned in the future.

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REFERENCES

[1] World Health Organization website, WHO factsheet, [online] Available from: https://www.who.int/en/news-room/fact-sheets/detail/household-air-pollution-and-health. [Accessed 5 May 2018].

[2] Xing YF, Xu YH, Shi MH, Lian YX. The impact of PM2.5 on the human respiratory system. Journal of thoracic disease. 2016 Jan; 8(1):E69.

[3] Majd E, McCormack M, Davis M, Curriero F, Berman J, Connolly F, Leaf P, Rule A, Green T, Clemons-Erby D, Gummerson C. Indoor air quality in inner-city schools and its associations with building characteristics and environmental factors. Environmental research. 2019 Mar 1;170:83 -91.

[4] Young BN, Clark ML, Rajkumar S, Benka- Coker ML, Bachand A, Brook RD, Nelson TL, Volckens J, Reynolds SJ, L'orange C, Good N. Exposure to household air pollution from biomass cookstoves and blood pressure among women in rural Honduras: A cross- sectional study. Indoor air. 2019 Jan; 29(1):130-42.

[5] Co- operative programme for monitoring and evaluation of the long- range transmissions of air pollutants in Europe, CEIP. [online] Available from: https://www.ceip.at/ms/ceip_home1/ceip_home/data_viewers/official_tableau/

[6] IQ air quality monitor. [online] Available form: https://www.iqair.com/air-quality-monitors/airvisual-pro

[7] Hungarian air pollution measurement network. [online] Available in Hungarian from: http://www.levegominoseg.hu/automata-merohalozat

EVALUATION OF THE POSSIBLE HARMFUL EFFECTS OF WASTEWATER DISCHARGE WITH ACUTE TOXICITY TESTS

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¶**Abstract:** Water pollution by industrial and municipal effluents is one of the main concerns regarding the environmental safety. The lack of or improper wastewater treatment facilities, and the effluents of wastewater are often discharged into water bodies, surface water sources resulting to pollution. In this study, the effect and consequences of wastewater to the environment is purposed with ecotoxicological tests with sensitive testing organisms. The aim of the tests was to determine whether the organisms could tolerate the toxicity of wastewater and to emphasize the significance of toxicity tests. Wildly used species, daphnia magna, lebistes reticulata, few species of green and blue algae were selected and tested reciprocally to measure the bio-toxicity of wastewater samples. In each testing organisms, the toxicological approaches used for the tests were unique depending on their lifestyle and living environment. Chemical and physical indicators of wastewater was tested prior and afterwards to each experiments. Along with this, the relative sensitivity of daphnia magna and algal toxicity tests were examined. Depending on the concentration and toxicity, wastewater itself has certain adverse effects on the organisms. On the other hand, the results of tests with the dilution of wastewater and purified water have not showed the fatal effects for the organisms. Preceding results of the experiment could be considered as early warning system to monitor the different operational units of wastewater treatment plants for reducing influent toxicity.
Key words: Wastewater, Pollution, Ecotoxicology, Toxicity testing approaches, Testing organisms

INTRODUCTION

Water reservoirs can be impacted by several hazardous substances through inputs from agricultural activity, sewage discharges, and groundwater leaching and runoff. The water quality assessment is very important for implementation of the monitoring and remediation programs to minimize the risk promoted by hazardous substances in aquatic ecosystems. Additionally, disposal by dilution is the simple method of discharging wastewater into surface water such as a river, lake, ocean, estuaries or wetlands. This results in the pollution of the receiving water [1]. The degree of pollution depends on the dilution, volume and composition of the wastewater as compared to the volume and quality of the water with which it is mixed. Evaluation of the degree of contamination of aquatic environments must not take in account only its chemical characterization but it must be complemented with biological assays which were developed as a tool to evaluate possible harmful effects of effluents discharged into water bodies [2]. Bioassay is using a living organism to test for the presence of a compound in a sample and comparing the result with some agreed standard [1]. In these tests, carefully chosen organisms are sensitive to the compound for which the test is conducted are exposed to whole effluent and/or effluent dilutions for a pre-determined time period in order to observe the effluent’s effect on the organisms, and thereby, the effect of compound is detected from the impact of compound on health of organism. In this study, acute tests and chronic tests are implemented. Furthermore, acute tests measure how well organisms survive, while chronic tests measure survival and sub-lethal effects, such as a sample's effect on organism growth & reproduction. Along with this, the NIEH laboratory disposes quality control systems, called GLP (Good Laboratory Practice) and NAT accreditation. The investigations are carried out with quality control system.
The test methods are based on OECD guidelines, ISO, EN, MSZ (Hungarian Standard). During the tests, examination of the dilution or concentration of the sample where the 50% of organisms could survive is called LC_{50} value (lethal concentration for 50%). For environmental water or wastewater samples, this dilution is sufficient, and it will not have effect on the ecological status of the water where it will be poured.

MATERIAL AND METHODS

Many scientific studies they refer to, abiotic (temperature, light, pH, chemical composition of the water) as well as biotic conditions (feeding, strain of test organism) have a significant influence on the test results and their variability.

Acute Daphnia test

Four sewage samples were coded as 3766, 3395, 3396, 4356 were tested with *daphnia magna* for 48 hours in 20-23˚C as it is indicated in MSZ 21978-13:1985. The main point of the experiment was to determine whether if 10:10 daphnia in 2 parallel 50/50 ml solutions could survive in the sewage water original sample and several times diluted sewage water with good quality water in total of 48 hours. The number of daphnia should be counted 2 times as specifically in 24 hours and 48 hours later. The dissolved oxygen, pH, temperature was measured in the beginning and in the end of each experiment.

Preparation of acute daphnia test

Firstly, naming the samples as preferably with numbers in each 50ml beakers such as K1, K2, 1x1, 1x2, 2x1, 2x2, 5x1, 5x2, 10x1, 10x2, 20x1, 20x2. For example, K indicates control sample which consists of only oxidized good quality-water, which is named K1, K2. As for the original sewage water sample, it is named as 1x1 and 1x2 which means only 1 time diluted first and second original samples. 20x1 and 20x2 indicate 20 times sewage water diluted with oxidized water. Overall, the whole solution should be 100 ml which means 50:50 ml in each parallel beaker. In the following table the proportion of sewage water and oxidized water in each beaker is shown. Noted: It is important to start dissolving the solutions from Control and highest to lowest times diluted samples. In this case, the chemical composition would be accurate. Only the control and original samples were used to measure dissolved oxygen, pH, and temperature in the beginning and in the end of the experiment. As for the last step of the test, 10:10 daphnia are exposed to each beaker sample for 48 hours.

Daphnia sensitivity test

With a reference toxicant $K_2Cr_2O_7$ is performed to assess the sensitivity of the organisms at the time the test material is evaluated, and the precision of results obtained by the laboratory. Stock solution is a concentrated aqueous solution of the material to be tested. The end result of the sensitivity test is analysing the EC_{50} 24h. Preparation of stock solution started with measuring the amount of 1.0g/L of $K_2Cr_2O_7$ in solid form which was later dissolved with normal oxidized water up to 1000ml. Otherwise, it can be expressed as in 1L of water 1g of $K_2Cr_2O_7$ was dissolved. Secondly, 5ml from previous 1L stock solution was measured and dissolved with 495ml normal oxidized water which means overall 500ml from solution was obtained at the end. As for naming the beakers for sensitivity test, similar method as acute daphnia test was used. The whole solution should be 100ml. At the end of test, 10:10 daphnia are exposed to each beaker sample for 24 hours. The dissolved oxygen, pH, temperature was measured in the beginning and in the end of each experiment. Using the number of alive *daphnia* after 24 hours, EC_{50} 24h is analysed in comparison with the standard number 0.9-1.5 mg/l.

Acute Green Algae test

The purpose of this test is to determine the effects of a substance on the growth of freshwater microalgae. Exponentially growing test organisms are exposed to the test substance or environmental sample in batch cultures over a period of normally 72 hours [4]. The test endpoint is inhibition of growth, expressed as the logarithmic increase in biomass during the exposure period. The chosen green algae for the test are Pseudokirchneriella subcapitata. Medium for the growing of algae is Zendar 8 which helps algae to grow. All four-sewage water samples (3766, 3395, 3396, and 4356) were tested with medium and algae cells. Guideline for the experiment is MSZ EN 8692:2012. The methodology for naming the beaker is slightly different from the method used in daphnia test. In order to measure precisely, all the dilution samples are made three times which named as K indicates control, 1 indicates original sample, 2 indicates 2 times dilution and so on. The second number shows the number of a sample.

Preparation of Zendar 8 Medium for the algae growth

Stock solution called 10x Z8 Original Medium was 10 times diluted solution. It was quite high concentration for the experiment of the algae. Therefore, diluting with purified distilled water was needed. From the 10xZ8, two mediums were made. 100ml for both from 10xZ8 and 900ml from purified distilled water = 1000ml (2 each medium was made 1000ml).

Measuring Optical Density with Spectrophotometer of Green Algae test

The average for optical density (750nm) is 0.02. At 0.02, cell number should be $5.96*10^5$ which is also standard when measuring with spectrophotometer. The main issue is to find out the amount of algae solution when the optical density reaches 0.02. In order to find out that amount, measurement was conducted several times with the usage of cuvette and pipette, and the medium sample itself. If the right amount from algae solution has been put into the medium sample, the spectrophotometer will show the target average which is 0.02. Normally, the number of algae is not constant at this certain 0.02 average because it depends on algae's general condition. Further step was to put that measured amount from algae solution into every sample excluding all the blank samples. After that, all testing samples should be placed in shaking machine which extracts light and shakes constantly. The solutions were being dissolved for 72 hours under the artificial light with the rate of 100rpm and in 24˚C. All these factors help algae to grow inside with the medium. To conclude the main point of the experiment was to determine if the number of algae cells could grow in sewage water.
Noted: Only one physical indicator was measured which was pH. The pH of only the blank samples was measured in the beginning and in the end of every experiment.

Green Algae sensitivity test

With a reference toxicant $K_2Cr_2O_7$ is performed to assess the sensitivity of the organisms at the time the test material is evaluated, and to analyze the EC_{50}72h. Preparation of stock solution 500ml of $K_2Cr_2O_7$ is same as the method used in the example of daphnia sensitivity test. The main difference from daphnia sensitivity test is that instead of dissolving the toxicant with oxidized water, medium zendar 8 was dissolved which helps for the growth of the algae. The chosen algae species are Pseudokirchneriella subcapitata. The main aim of the experiment is to determine the sensitivity of algae to the toxicant $K_2Cr_2O_7$ and its growth depending on toxicant and medium. As for naming the beakers for sensitivity test, similar method as acute daphnia test was used. The whole solution should be 200ml. The methodology of measurement with spectrophotometer to find out the right number of algae cells which must be put into the samples is the same method as used in normal acute green algae test. The main point of the experiment is to determine the sensitivity of green algae to toxicant with spectrophotometer.
The suitable numbers of algal cells were not added into the blank solutions. Hence, the blank solutions consist of only toxicant and medium rather depending on its dilution. At 0.02, 750nm, the certain amount of algae solution is measured and must be put into every sample excluding all the blank samples. After that, all testing samples should be placed in shaking machine. The solutions were being dissolved for 72 hours under the artificial light with the rate of 100rpm and in 24˚C. Noted: Only one physical indicator was measured which was pH. The pH of only the blank samples was measured in the beginning and in the end of every experiment.

Acute fish test

The fish are exposed to the test substances or environmental sample for a period of 48 hours. Mortalities are recorded at 1, 4, 24 and 48 hours. The fish test was tested twice with the sewage water samples 3766 and 4356. The guideline for the fish test is MSZ 21978:3-1986. Testing animal is *Poecilia reticulate (guppy).* In each parallel 2 glasses, 5 fish were added. The overall volume of the

solution should be 500ml. After 48 hours, the number of fish in every glass should be counted which will indicate how sewage water condition affects the mortality of fish.
The dissolved oxygen, its percentage and temperature were measured in each sample in the beginning and in the end of experiment. If the dissolved oxygen is lower than 70% which means toxic or not enough oxygen for the fish, during the experiment additional oxygen for the fish was needed. Along with the dissolved oxygen, if temperature is less than 20^0C which also means toxic for the fish because the guppies are warm water tolerant species.

RESULTS AND DISCUSSION

Acute Daphnia test

Overall, Acute daphnia tests were tested with sewage water samples named 3766, 3395, 3396, and 4356. All sewage water samples were anonyme and sent from a company in Gödöllő, Hungary. Three general indicators which were pH, dissolved oxygen and T^0C were tested with each control and original sample of 4 experiments at 0h and 48h respectively. The result has shown that there was not much difference for temperature and pH for control and original samples. pH has been neutral to basic in every samples in every sewage test. However, general condition that the dissolved oxygen decreases as temperature increases was noticed in many of the experiments. This condition was only occurred in original samples with daphnias which explains the death of daphnia. If the dissolved oxygen in original sample is above 5.0mg/l, there is a chance that it will not have fatal effects on the organisms. Oxygen levels that remain below 1-2 mg/l for a few hours can result in large fish kills. In other words, the survival of daphnias directly depends on the percentage of dissolved oxygen in the water. In average daphnia tests for 48h with WW samples (3766, 3395, 3396), original sample had 100% of fatal effect on the daphnia and two times dilution had 10% of effect. Moreover, there was an exceptional condition that all the daphnias had survived due to the purity of original sewage water 4356.
Daphnia Sensitivity test (24h, EC50 in mg/l): The Acute toxicity is expressed as the median effective concentration (EC_{50}) for immobilization. This is the concentration which immobilizes 50% of the *Daphnia* in a test batch within a continuous period of exposure which was in our case 24hrs. The result calculated in the excel program showed that **EC_{50} 24h is equal to 1.4.** Within the range of 0.9-1.5mg/l, it indicates the ability of good sensitivity. Hence, the sensitivity of daphnia was good (Table 1).

Table 1. Evaluation of daphnia in acute toxicity

The name of the sample	number of daphnia in per parallel				The number of dead animals	The percentage of dead animals (%)
	a	b	c	d		
	24h	24h	24h	24h	24h	24h
Control, K	5	5	5	5	0	0
0.1	5	5	5	5	0	0
0.5	5	5	5	5	0	0
1	2	1	3	3	11	55
2	3	4	2	2	9	45
5	0	0	0	0	20	100
10	0	0	0	0	20	100

Acute green algae test

Acute green algae test was implemented with all four sewage water samples 3395, 3396, 3766, 4356. The each end results including algae sensitivity test (optical density) was measured with spectrophotometer after 48 hours. Cuvette and pipette were used during the experiment. The average of three samples from one dilution should be calculated in order to find out the inhibition percentage. Every dilution numbers have its own belonging Log(Dil) number. The probit of inhibition can be found directly from the inhibition percentage. The relationship between Log (Dil) number and probit of inhibition shows DilTLm50 curve by probit analysis which was implemented in every algae test [3]. Control sample and 5 times diluted solutions had shown that the growth of algae cells were good comparing with the original and 2 times diluted solutions.

Acute green algae test with sewage water sample 3395

% Inhibition = (1-Average of the dilution/Average of the Control)*100

Table 2. Result of the acute green algae test for WW 3395 and calculation of % inhibition

		K	1x	2x
Numbers	1.	0.58	0.008	0.102
	2.	0.572	0.001	0.087
	3.	0.666	0.008	0.075
Average		0.606	0.006	0.088
inhibition (%) compare to the control		X	99.06	85.48

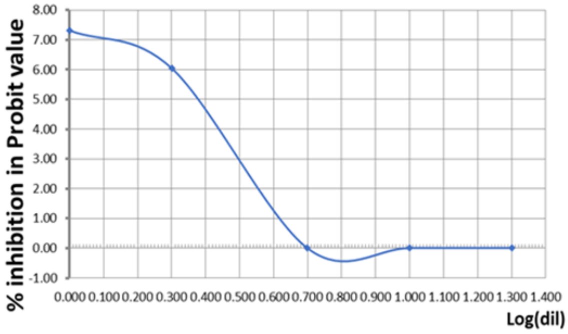

Figure 1. dilTLm50 measurement with Log(Dil) number and % probit of inhibition for the algae test with 3395 WW sample

Table 2. pH measurement at 0h and 72hours for 3395. pH is neutral to basic

The name of the sample	pH at 0 hour	pH at 72 hours
K blank	7.22	7.33
1 time diluted blank	8.23	8.98
2times diluted blank	8.17	8.76

Table 3. The standard numbers of probit of inhibition and percentage of inhibition for WW3395

Dilutions	**1**	**2**	**5**	**10**	**20**
Log (dil)	0.000	0.301	0.699	1.000	1.301
% inhibition	99	85			
Probit of inhibition	7.32	6.04			

Acute green algae test with sewage water sample 3396

Table 4. Result of the acute green algae test for WW 3396 and calculation of % inhibition

		K	1x	2x
Numbers	1.	0.58	0.012	0.28
	2.	0.572	0.007	0.336
	3.	0.666	0.005	0.32
Average		0.606	0.008	0.312
inhibition (%) compare to the control		X	98.68	48.51

Table 5. The standard numbers of probit of inhibition and percentage of inhibition for WW 3396

Dilutions	**1**	**2**	**5**	**10**	**20**
Log (dil)	0.000	0.301	0.699	1.000	1.301
% inhibition	99	49			
Probit of inhibition	7.32	4.97			

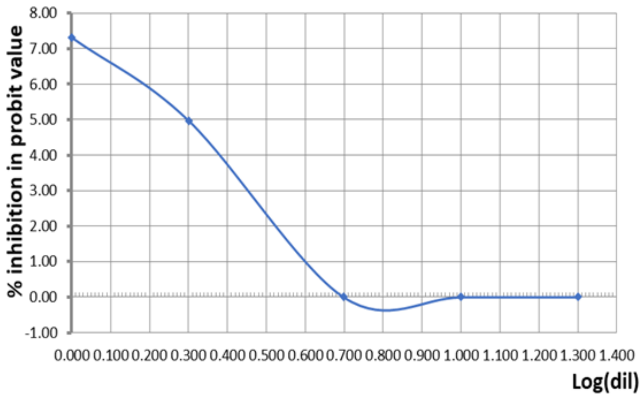

Figure 2. dilTLm50 measurement with Log(Dil) number and % probit of inhibition for the algae test with 3396 WW sample

Table 6. pH measurement at 0h and 72h for 3396. pH is neutral to basic

Sample's name	pH at 0 hour	pH at 72 hours
K blank	7.22	7.33
1 time diluted blank	8.25	9.00
2 times diluted blank	8.19	8.10

Acute green algae test with sewage water sample 3766

Table 7. Result of the acute green algae test for WW 3766 and calculation of % inhibition

		K	**1x**	**2x**	5x
Numbers	1.	0.477	0.027	0.22	0.467
	2.	0.459	0.032	0.202	0.498
	3.	0.449	0.024	0.2	0.476
Average		0.462	0.028	0.207	0.480
Inhibition (%) compare to the control		X	94.01	55.09	-4.04

% Inhibition= (1-Average of the dilution/Average of the Control)*100

Table 8. The standard numbers of probit of inhibition and percentage of inhibition for WW 3766

dilution	**1**	**2**	**5**
Log (dil)	0.000	0.301	0.699
% inhibition	94	55	-4
Probit of inhibition	6.55	5.13	

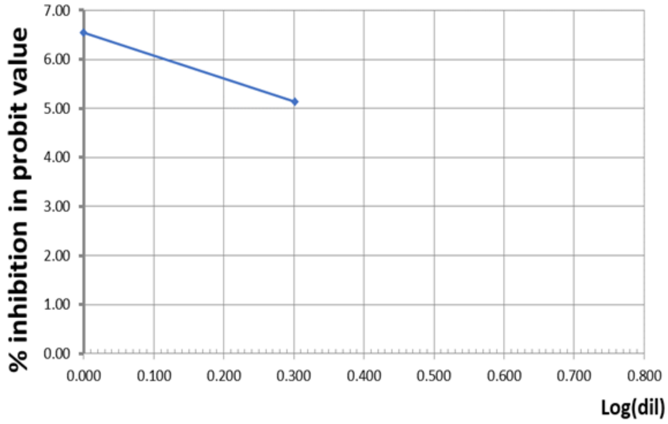

Figure 3. dilTLm50 measurement with Log(Dil) number and % probit of inhibition for the algae test with 3766 WW sample

Table 9. pH measurement at 0h and 72h for 3766. pH is neutral to basic

The name of the sample	pH at 0h	pH at 72h
K blank	7.04	7.18
1 time diluted blank	8.06	8.86
2 times diluted blank	8.03	8.65
5 times diluted blank	7.83	8.19

Acute green algae test with sewage water sample 4356

Table 10. Result of the acute green algae test for WW 4356 and calculation of % inhibition

		K	**1x**	**2x**	5x
Numbers	1.	0.53	0.41	0.528	0.583
	2.	0.538	0.456	0.576	0.547
	3.	0.474	0.416	0.531	0.537
Average		0.514	0.427	0.545	0.556
Inhibition (%) compare to the control		X	16.86	-6.03	-8.11

Table 11. The standard numbers of probit of inhibition and percentage of inhibition for WW 4356

dilution	**1**	**2**	**5**
Log (dil)	0.000	0.301	0.699
% inhibition	17	-6	-8
Probit of inhibition	4.05		

The curve of dilTLm50 measurement with Log (Dil) number and % probit of inhibition would not be shown in this case. The reason is only one point (4.05.17) will be marked in the curve graph.

Table 12. pH measurement at 0h and 72h for 4366. pH is neutral to basic

The name of the sample	pH at 0h	pH at 72h
K blank	7.30	7.49
1 time diluted blank	8.73	8.75
2 times diluted blank	8.58	8.41
5 times diluted blank	8.21	7.97

Algae sensitivity test with toxicant K2Cr2O7 and medium Z8

% Inhibition= (1-Average of the dilution/Average of the Control)*100

Table 13. The result of green algae sensitivity test and calculation of % inhibition

		K	0.1	0.5	1	2	5	10
Number	1	0.586	0.515	0.463	0.231	0.115	0.037	0.025
	2	0.471	0.507	0.452	0.235	0.121	0.035	0.027
	3	0.463	0.49	0.436	0.243	0.11	0.04	0.025
Average		0.507	0.504	0.450	0.236	0.115	0.037	0.026
inhibition (%) compare to the control		X	0.53	11.12	53.36	77.24	92.63	94.91

Table 14. The standard numbers of probit of inhibition and percentage of inhibition for sensitivity test

Concentration	0.1	0.5	1	2	5	10
Dilutions	1	2	5	10	20	
Log (dil)	0.000	0.301	0.699	1.000	1.301	
%-inhibition	0.53	11.12	53.36	77.24	92.63	
Probit of inhibition	2.67	3.77	5.08	5.74	6.48	

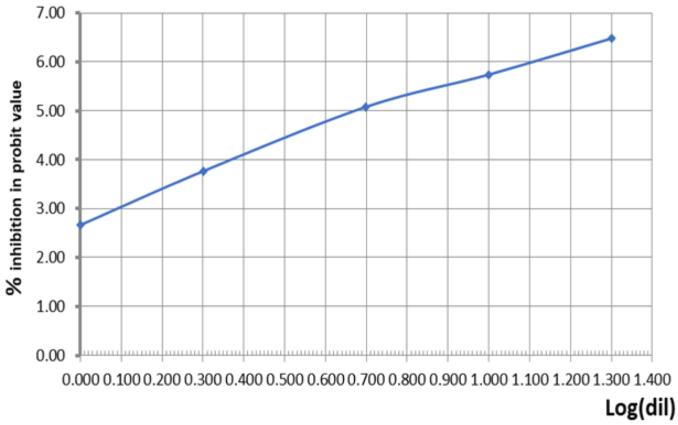

Figure 4. dilTLm50 measurement with Log(Dil) number and % probit of inhibition for the algae sensitivity test

Table 15. pH measurement at 0h and 72h for algae sensitivity test with toxicant. pH is neutral generally, but few solutions have become basic in 0.1 and 0.5

The name of the blank sample	pH at 0h	pH at 72h
K blank	7.39	7.49
0.1	7.29	8.75
0.5	7.47	8.41
1	7.50	7.97
2	7.46	7.31
5	7.36	7.25
10	7.14	7.19

Acute fish test: Fish test with sewage water sample 3766

The acute fish test was implemented with 3766 sewage water sample and organisms were exposed to the samples for 48 hours. The general condition of sewage water sample was *bad, smelly, and dirty.* The original sample had low dissolved oxygen 2,47 mg/l; 2x dilution was: 6,11 mg/l, which was toxic for the fish. The best minimum DO level is 8 mg/l. DO level of the 10x diluted sample was good. The low DO was toxic for the animals. In the meantime, extra oxygen for the fish in the original and the 2x diluted samples were implemented. The number of the fish has decreased in samples such as 2x dilution by 90% and original sample 100%. The percentage shows the toxicity. For example, 100% toxicity means all fish had died at the end of result. Meanwhile, 10x dilution and control sample had no harmful effect on the fish.

Table 11. Percentage of Toxicity effect in fish test for 48 hours

nr	dilution		
	original (1x)	2x	10x
3766	100	90	0

Table12. End result of the fish test, dilTL50

nr	dil TL50	dilTL 0
3766/2019	**3.6x dilution**	**10x dilution**

Fish test with sewage water sample 4356

The acute fish test was implemented with 4356 sewage water sample and organisms were exposed to the samples for 48 hours. The sewage water sample was quite purified and harmless for the fish. Hence, the number of the fish remained in all samples including K1, K2, 1x1, 1x2, 2x1, 2x2, 5x1, 5x2. Dissolved oxygen decreased gradually in most of the samples excluding the original sample while temperature was constant around 22^0C for every sample. The original sample had really low dissolved oxygen 3.75 mg/l which later increased to 7.48; 2x dilution was: 6.98 mg/l at 0h and then become 5.46 mg/l. The best minimum DO level is 8 mg/l.

Table13. % of Toxicity effect in fish test

number	dilution		
	original (1x)	2x	5x
4356	0	0	0

The survival of daphnias directly depends on the general condition of the sewage water and concentration of dilution with purified water. General conditions indicate pH, dissolved oxygen, temperature and most importantly the concentration of toxic chemicals in the sewage water. Specifically, the level of dissolved oxygen and survival of daphnia had direct relationship as it was shown in the result section. The concentration of toxic chemicals for WW samples 3395, 3396, 3766 can be assumed as high according to the results of acute daphnia and fish test (3766 only) has showed. As for 4356 sewage water sample which was rather good quality sewage water, both acute fish and daphnia tests were implemented successfully regarding the fact that every organism survived. Dilution of purified water is the most important aspect of all experiments. The significance of dilution must be highlighted because samples which were diluted with higher amount of purified water showed harmless effect on the testing organisms. Usually the samples with lowest dilution and original sewage water samples showed fatal effect. The methodology of acute algae test is rather different than normal acute fish and daphnia tests. The aim of the algae tests was to determine the percentage inhibition of the algae cell growth and how the sewage water condition affects the growth of algae cells. Moreover, the samples of algae tests were consisting of medium Z8 which was made especially for the Pseudokirchneriella subcapitata, sewage water sample in 50ml and lastly, the algae cells measured with spectrophotometer. As a result, the samples with higher dilution such as 5 times diluted or control samples without sewage water showed the highest growth of algae cells which can be seen from the optical density results with spectrophotometer. The domestic and industrial wastewater (sewage) begins to cause nuisance as it becomes smelly and brings out diseases caused by wastewater. Hence it brings to the methods of sewage disposal include disposal by dilution and disposal by land treatment. The main aspect of this study was to show the significance of dilution of WW with environmental water by testing the samples with biological assays. Likewise, disposal by dilution method means the raw sewage or the partially treated sewage is thrown into natural waters having large volume [13]. The review showed that using biological toxicity tests to evaluate the toxic industrial waste water is feasible, so ecotoxicity indicators should be introduced in the waste-water emission standards. Currently, researchers on various indicates biological acute toxicity experiment of research do have are compared full, can on various indicates biological do chronic toxicity experiment of research; industrial wastewater in the contains large of organic, production wastewater also contains large of organic, can will various different nutrition level of indicates biological for production wastewater of toxicity test, and evaluation analysis out which species indicates biological can more fast, and simple of monitoring production wastewater biological toxicity [14]. Aquatic toxicity of municipal wastewater was evaluated in an acute toxicity test using water flea, Daphnia magna as an freshwater aquatic experimental animal model. Toxicity test were performed on samples of both untreated (raw) and treated wastewaters were collected Manisa municipal effluents. Undiluted untread and treated effluents were very toxic to D. magna and cause to death of all exposed daphnids. Dilution of wastewaters was observed to decrease percentage of influence of biological toxicity based on dilutional rate. Acute toxic effect of untreated wastewater on D. magna was more than that of treated wastewater. In addition, the longer the period of exposure to D. magna, the more significantly toxic effect increased [15]. Kim and Farnazo [16] mentioned that acute and chronic toxicity tests were successfully employed for the evaluation of the reduction of toxicity of sewage water effluents for two sewage treatment plants. The above mentioned reviews are in agreement with our results.

CONCLUSION

The sewage in due course of time is purified by what is known as the self-purification capacity of natural waters. The limit of discharge and degree of treatment of sewage are determined by the capacity of self-purification of natural waters. There are few conditions made to be certain before disposing the dilution off into the water bodies. Firstly, Primary treatment for WW must be provided. Secondly, dissolved oxygen content of diluting waters should be high which was also proven by the preceding results of acute tests of daphnia and fish. Lastly, the sewage should be relatively fresh, and it is possible to bring it to the point of discharge within four or five hours of its production.

Evaluation of the level of contamination of aquatic environments must be accompanied by biological assays which assess the possible adverse effects of effluents discharged into water bodies. Furthermore, acute tests with biological assays are significant for appropriate use of toxicity data in environmental risk assessment. As the results of biological assay experiments with testing organisms have shown that, not properly purified original wastewater can have a serious outcome in aquatic ecosystem and its organisms. On this assumption, related health issues caused by the wastewater pollution to the user of water bodies might occur. Therefore, wastewater effluent should be treated efficiently to avert adverse health risk of the user of surface water resources and the aquatic ecosystem. There should be proper enforcement of water and environmental laws to protect the health of inhabitants of both rural and urban communities. After all, disposal by dilution of sewage water in high volume according to the standards of dilution is exceedingly recommended for the future.

REFERENCES

[1] Sandeep Garg, Deepika Kansal, Use of bioassay test as a performance indicator in effluent treatment systems including role in encouraging shift towards use of green chemicals, International Journal of Multidisciplinary Research and Development, 1(2): 142-145, 2349-4182, 2014.
[2] Persoone G., Baudo R., Cotman M., Blaise C., Thompson K.Cl., Moreira-Santos M., Vollat B., Törökne A., Han T., Review on the acute daphnia magna toxicity test – Evaluation of the sensitivity and the precision of assays performed with organisms from laboratory cultures or hatched from dormant eggs, Knowledge And Management Of Aquatic Ecosystems, 393, 01., pp. 01p1-01p29, 2009. DOI: 10.1051/kmae/2009012
[3] Probit Analysis, Chapter 575, Ncss Statistical Software, Available From https://www.ncss.com/wp-content/themes/ncss/pdf/Procedures/NCSS/Probit_Analysis.pdf
[4] "Alga, Growth Inhibition Test", Oecd Guideline For Testing Of Chemicals 201 Available From Http://Www.Oecd.Org/Chemicalsafety/Risk-Assessment/1948257.Pdf Accessed:1984-06-07 pp.14
[5] Apha-Awwa-Wef, Standards Methods For The Examination Of Water And Wastewater, 20th Edition, American Public Health Association, American Water Works Association And Water Environmental Federation, Washington, Dc 20005- 2605. 1998.
[6] Gsm (1989) Examination Of Water, Wastewater And Sludge, Bio-Assays (Group L) Determining Tolerance Of Daphnia To Toxicity Of Wastewater By Way Of A Dilution Series, Gsm (German Standard Methods) (L-30), Dih-38412, Part 30, March 1989.
[7] Organization For Economical Cooperation And Development (Oecd) Daphnia Sp, 14-Day Reproduction Test (Including An Acute Immobilisation Test). Guidelines For Testing Of Chemicals, 202 (1984).
[8] Us Environment Protection Agency. Methods For Measuring The Acute Toxicity Of Effluents And Receiving Waters To Freshwater And Marine Organisms (Fifth Edition) Epa-821-R-02-012. Washington Dc: Usepa; 2002. 275 Pp
[9] Palma P., Alvarenga P., Palma V., Matos C., Fernandes R.M., Soares A., Barbosa IR., Evaluation Of Surface Water Quality Using An Ecotoxicological Approach: A Case Study Of The Alqueva Reservoir (Portugal), Environ Sci Pollut Res Int. 2010 Mar;17(3):703-716. 2009 doi: 10.1007/s11356-009-0143-3
[10] Blinova I., Use Of Bioassays For Toxicity Assessment Of Polluted Water. Proceedings Of The Symposium Dedicated To The 40th Anniversary Of Environmental Engineering At Tallinn Technical University. 24- 26 September, Tallinn. Tallinn, 149-154, 2000.
[11] Ebert D., Introduction To Daphnia Biology; Ecology, Epidemiology, And Evolution Of Parasitism In Daphnia, Chapter 2, ISBN-10: 1-932811-06-0, National Center For Biotechnology Information (Us); 2005.
[12] Whitehouse P., Crane M., Redshaw C.J., Turner C., Aquatic toxicity tests for the control of effluent discharges In The Uk – The Influence Of Test Precision. Ecotoxicology, 5, 155–168. 1996
[13] United States Environmental Protection Agency (USEPA), Methods for measuring the acute toxicity of effluents and receiving waters to freshwater and marine organisms, Fifth Edition, EPA821-R-02-012, Washington Dc, USA, 266 P. 2001
[14] Xiao N., Qin L., Zhang X., Li Y., Zhang F., Industrial wastewater biological toxicity research status, International Conference on Energy and Environmental Protection, 521-526, ICEEP 2016.

[15] Koçbaş F., Oral R., Daphnia magna as a Test Species for Toxicity Evaluation of Municipal Wastewater Treatment Plant Effluents on Freshwater Cladoceran in Turkey. Turkish Journal of Fisheries and Aquatic Sciences 15: 619-624. 2015.

[16] Kim, Y., Farnazo, D.M., Toxicity characteristics of sewage treatment effluents and potential contribution of micropollutant residuals. J Ecology Environ., 41: 39. (2017) https://doi.org/10.1186/s41610-017-0057-9

FUZZY LOGIC AND ROUGH SETS

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Abstract: *This paper presents the basis on which the fuzzy logic is based. Its roots draw to the fundamental principles of the theory of sets, and the connection with it is explained. Considering that fuzzy algorithms have wide application in modern robotics and controllers, the basic and most common examples are presented in this paper. Information about the objects that surround us are almost indispensable, and for this reason the need for classification and general grouping of objects is growing. In these situations, the importance of rough sets is shown. To the extent that satisfies information about them and the presentation of basic operations, rough sets are described in this paper. Considering that the application of mathematical knowledge is the most useful in the information sphere, the example of the implementation of the logical phase is shown through a mini - application. The application was created in the Java programming language.*
Key words: *fuzzy logic, rough sets, Java*

INTRODUCTION

In most situations, knowledge is not represented in an absolutely precise way. Let's say: "Dusan is a tall man". In order for this information to make sense, it is necessary to abandon the logic behind which something is true or incorrect (black or white). If for height information, we set a limit of 170cm, then a 171cm high would belong to a set of high people, while a person with 169cm would not. So a person would only be two centimeters lower than a high person, classified as low. In such situations, the stage is the logic of the information in which the information is "to a certain extent". (Everything is gray).
Fuzzy logic relies on the natural language, so the inputs and outputs generally have linguistic names. The variables are given descriptive names, such as "water level", "high earnings", "quick car", etc. Linguistic variables have both linguistic values, say "very good", "medium good", "too fast" ... These representations can be assigned numerical values for easier and shorter markups. The mathematical representation of such expressions enables fuzzy logic. It implies the degree of belonging to elements of a set, unlike the theory of sets.
In the following image, a graphic representation of the function showing the affiliation of a high-level group using a binary logic (Figure 1).

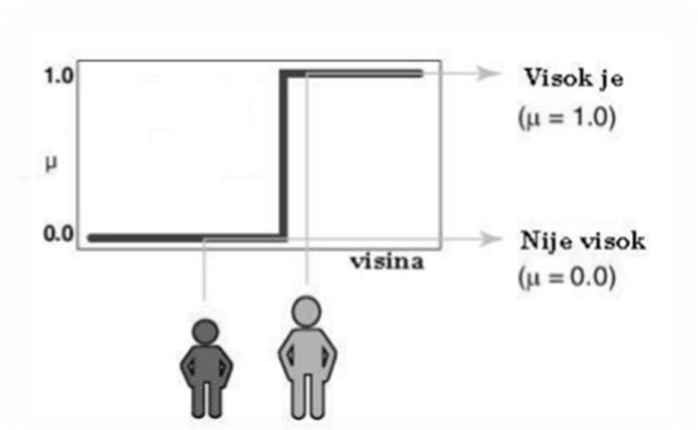

Figure 1. Belonging to a set of high people through binary logic

The same function can be displayed using fuzzy logic, which can be more often encountered in everyday life. The following image gives an example (Figure 2).

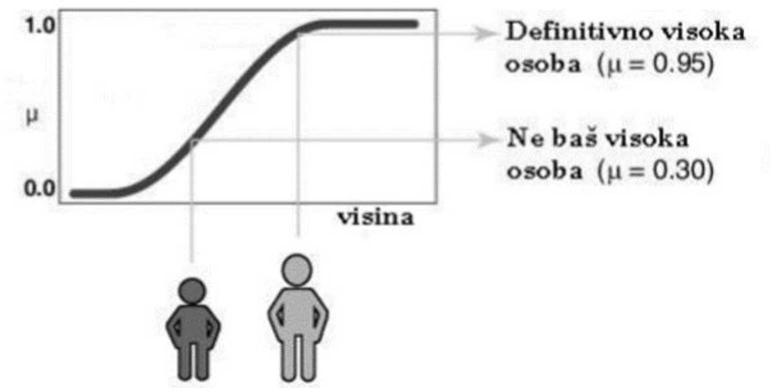

Figure 2. Affiliation to a set of high-level individuals through the fuzzy logic

AN APPLICATION THAT IMPLEMENTS FUZZY LOGIC

An application, simply called "Fuzzy", is an application made in the Java programming language, in the Eclipse IDE 2018-12 environment. No libraries were used outside of the standard Java programming language. So, the application is written "from scratch".

The purpose of the application is to help the user to decide whether it is necessary to invest more resources in the security of a police administration. First of all, there is a need for a so-called knowledge base, or experience of previously invested budgets in the same or different police administration. In order for it to exist, it is necessary to enter data on the number of reported cases to the police, the number of officials, the percentage of successfully executed tasks, and the budget that was allocated to achieve such a thing.

In the knowledge base, there is no precise data on their exact number, but only descriptions of the numbers that are characteristic of that administration. For example, the number of officials is shown as "big" or "small", the percentage of cases solved is described in nuances from "not so successful" to "successful".

These are descriptions that can be very subjective to the experience of the user or user. Therefore, there is a need for the database to have as many different data as possible for a specific administration.

After launching the application, a startup window opens, which looks like the following picture (Figure 3).

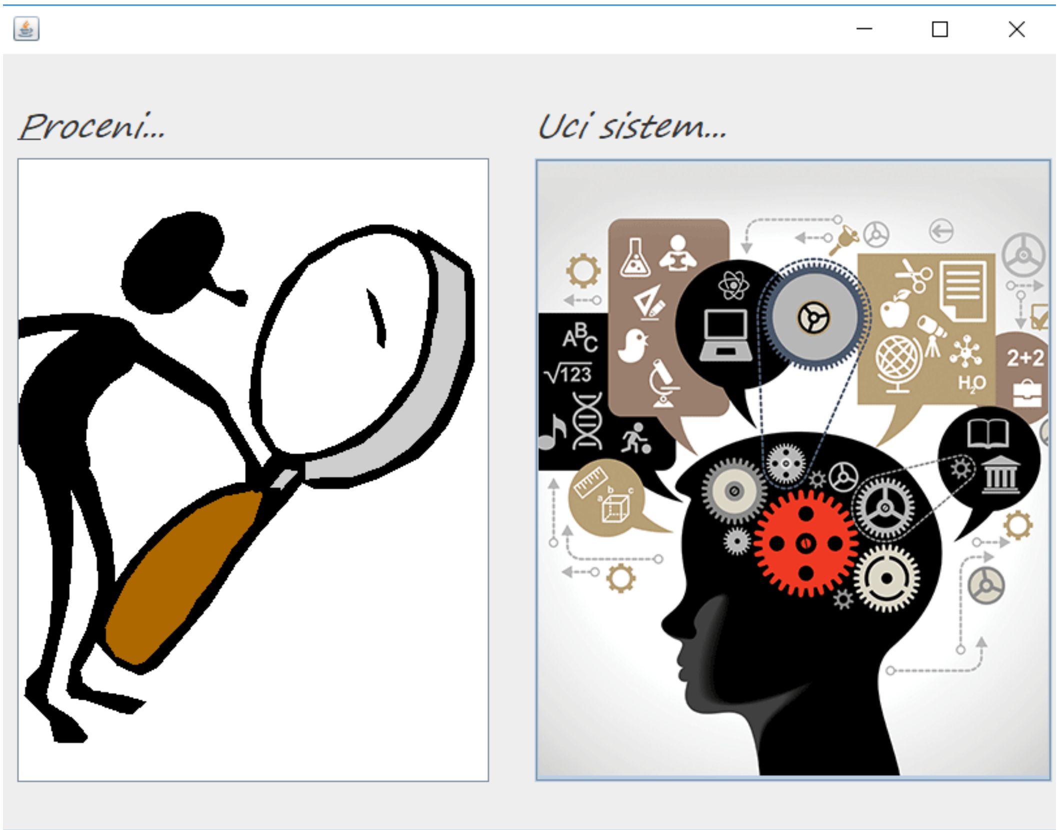

Figure 3. The initial window of the application

Therefore, the user chooses whether he only wants to evaluate his administration or wants to "learn the system" in what way to think. This practically means entering the database descriptions like "small" and "large" numbers, on the basis of which the program will evaluate the required budget.
If a user chooses to "train the system", a window opens as in the following picture (Figure 4):

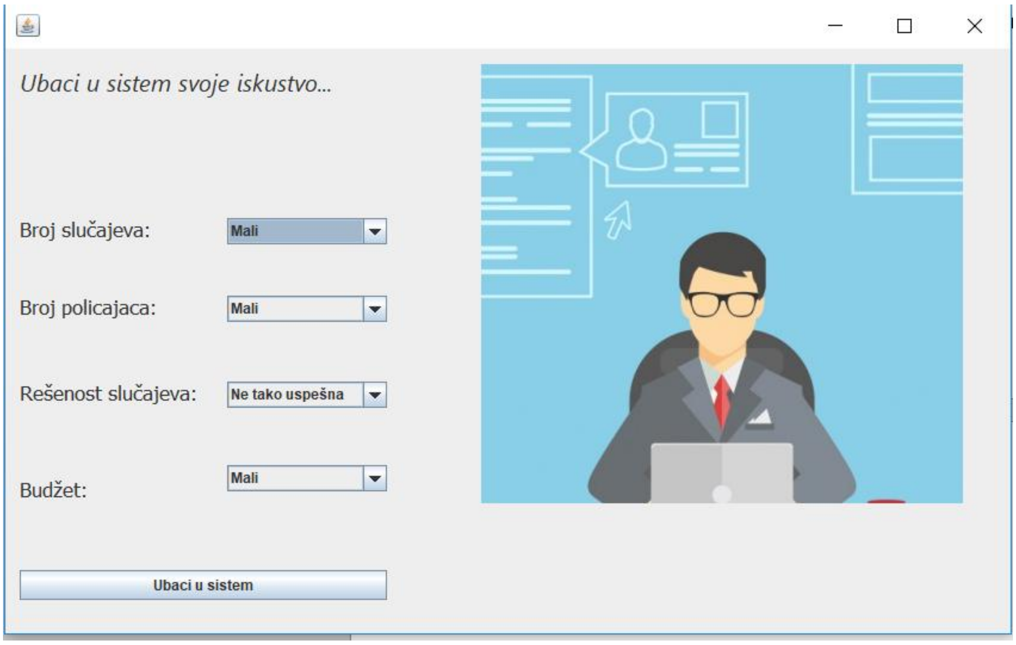

Figure 4. A window in which user inserts previous experience into system

By clicking on any of the comboboxes, a drop-down menu is obtained by describing the given case.

When the user finishes describing the administration, it confirms and brings the combination by clicking the "Insert into the system" button. Of course, the user has the ability to enter a number of combinations, taking care to be as diverse as possible.
After that, it is necessary to go back and choose "evaluation". In the start window, clicking the "Estimate" image opens the window as in the following figure (Figure 5).

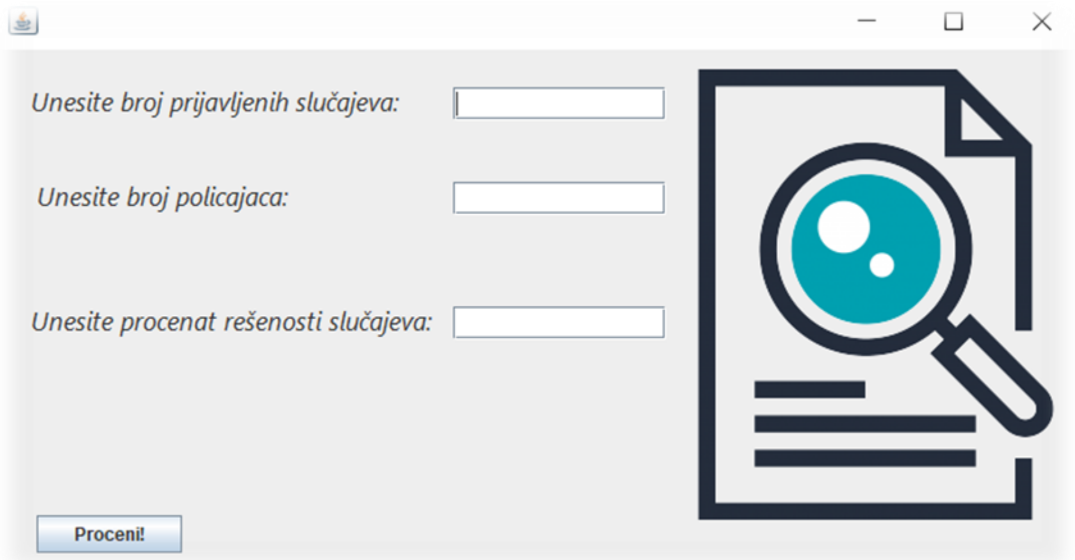

Figure 5. A window that is obtained by clicking on the "Estimate"

In these fields, the user enters the exact number of reported cases for the administration he / she wants to assess, the number of employed officials and the percentage of cases solved. Upon completion of the entry, clicking the "Estimate!" button confirms the data.
By clicking the button, the program starts searching the database. He compares the exact number with the words described by the numbers and assigns a word that describes them. It may happen that there is no case in the database that is appropriate and the program informs the user about it. This means that the database is not diverse, that is, the data that is repeated several times is entered.
In the following picture (Image 6), a window is displayed which the user receives if the program fails to assign a description of the word data.

Figure 6. The program fails to assign a description of the word data

If there is an appropriate case, the program will describe the required budget with the words "small", "medium" and "large". This is the recommendation of the system, or an estimate of how much money is needed to make the case solved, or if it is already, in order to maintain itself as "successful".
The message is printed at the bottom of the screen, above the "Estimate!" button as shown in the following picture (Figure 7).

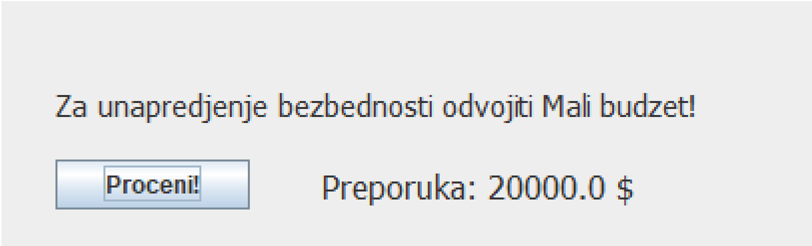

Figure 7. Recommendation for investing the budget in the administration's security

Thus, the calculation is carried out according to the formula in which the index of belonging to each of the descriptions "small, medium or large" is multiplied with the limit values.

CONCLUSION

Fuzzy logic has a great use in the daily description of objects. For this reason, its application is growing and the need for its use is increasingly felt. It is emphasized that this topic is relatively new, and that in this area there are many places for further study and improvement.

The application is one example of how this way of thinking can be used in one of the spheres of interest. Of course, with the increasing advancement of technology and information systems, science has a greater benefit if its logic is translated into a computer language, that is, an implemented algorithm that will provide the user with the necessary information as a result of work.

ACKNOWLEDGEMENTS

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REFERENCES

[1] Timothy Ross, *Fuzzy logic with with engineering applications*, A John Wiley and Sons, Ltd., Publication, 2010.
[2] George J. Klir, Ute St. Clair, Bo Yuan, Fuzzy Set Theory Foundations And Applications, 1997.
[3] H.-J. Zimmermann, *Fuzzy Set Theory-and Its Applications*, Springer Science+Business Media, LLC, 2001.
[4] George J. Klir, *Architecture of Systems Problem Solving*, Springer Science+Business Media, LLC, 1985.
[5] Demant, C., Streicher-Abel, B., and Waszkewitz, P. (2002).Industrielle Bildverarbeitung: wie optis-che Qualit¨atskontrolle wirklich funktioniert. Springer, Berlin
[6] P. H´ajek and P. Cintula. On theories and models in fuzzy predicate logics,The Journal of Symbolic Logic71: 863–880, 2006.
[7] C. Noguera.Algebraic study of axiomatic extensions of triangular norm basedfuzzy logics, Monografies de l'Institut d'Investigaci´o en Intel·lig`encia Artificialvol. 27, Barcelona, 2007
[8] S. Maruthai, J. Gunna, R.H. Ranganathan: Integrated Fuzzy Logic Based Intelligent Control of Three Tank System, Serbian Journal of Electrical Engineering, Vol. 6, No. 1, May 2009, pp. 1 – 15.
[9] Cinthia Peraza, Fevrier Valdez, Juan R. Castro, and Oscar Castillo ''Fuzzy Dynamic Parameter Adaptation in the Harmony Search Algorithm for the Optimization of the Ball and Beam Controller'', dvances in Operations Research Volume 2018, Article ID 3092872, 16 pages, https://doi.org/10.1155/2018/3092872