Република Србија
МИНИСТАРСТВО НАУКЕ,
ТЕХНОЛОШКОГ РАЗВОЈА И ИНОВАЦИЈА

20th International Conference
Man and Working Environment
Safety Engineering & Management
Science - Industry - Education

Conference Proceedings

FACULTY OF OCCUPATIONAL SAFETY
UNIVERSITY OF NIŠ, SERBIA
7-8 DECEMBER 2023

www.znrfak.ni.ac.rs/semsie

20th International Conference Man and Working Environment
Safety Engineering & Management - Science, Industry, Education
SEMSIE

UNIVERSITY OF NIŠ
FACULTY OF OCCUPATIONAL SAFETY

The 20th International Conference "Man and Working Environment"
SAFETY ENGINEERING & MANAGEMENT –
SCIENCE, INDUSTRY, EDUCATION (SEM-SIE 2023)

CONFERENCE PROCEEDINGS

Ministry of Science, Technological Development and Innovation of the Republic of Serbia

7–8 December 2023
Niš, Serbia

The 20th International Conference "Man and Working Environment"
SAFETY ENGINEERING & MANAGEMENT
SCIENCE, INDUSTRY, EDUCATION (SEM-SIE 2023)

Conference Organiser:
UNIVERSITY OF NIŠ
FACULTY OF OCCUPATIONAL SAFETY

Conference Co-organisers:
Ministry of Science, Technological Development and Innovation of the Republic of Serbia
Faculty of Engineering, South-West University "Neofit Rilski", Blagoevgrad, Bulgaria
Faculty of Natural and Technical Sciences, "Goce Delčev" University, Štip, North Macedonia

Publisher:
University of Niš, Faculty of Occupational Safety

For the publisher:
Prof. Dr. Srđan Glišović, Dean

Editors:
Prof. Dr. Vesna Nikolić
Prof. Dr. Evica Jovanović

Technical Editor:
Rodoljub Avramović, MSc

Proofreading:
Prof. Predrag Niketić, PhD
Aleksandra Petković, MA

Printout:
"Unigraf X-copy" doo Niš

Number of copies: 100

CIP - Каталогизација у публикацији
Народна библиотека Србије, Београд

331.45/.46(082)(0.034.2)
502/504(082)(0.034.2)
614.8.084(082)(0.034.2)

INTERNATIONAL Conference Man and Working Environment (20 ; 2023 ; Niš)
Safety engineering & management - science, industry, education (SEM-SIE 2023) [Elektronski izvor] : conference proceedings / The 20th International Conference "Man and Working Environment", 7-8 December 2023 Niš ; [conference organiser] University, Faculty of occupational safety ; [editors Vesna Nikolić, Evica Jovanović]. - Niš : Faculty of Occupational Safety, 2023 (Niš : Unigraf X-copy). - 1 USB fleš memorija : tekst, slika ; 1 x 6 x 9 cm

Tekst štampan dvostubačno. - Na nasl. str.: Ministry of Science, Technological Development and Innovation of the Republic of Serbia. - Tiraž 100. - Napomene i bibliografske reference uz tekst. - Bibliografija uz svaki rad.

ISBN 978-86-6093-115-5

а) Заштита на раду -- Зборници б) Животна средина -- Заштита -- Зборници в) Превентивно инжењерство -- Зборници

COBISS.SR-ID 132040457

Conference Organiser:

UNIVERSITY OF NIŠ

FACULTY OF OCCUPATIONAL SAFETY

Conference Co-organisers:

Faculty of Engineering, South-West University "Neofit Rilski", Blagoevgrad, Bulgaria

Faculty of Natural and Technical Sciences, "Goce Delčev" University, Štip, North Macedonia

UNDER THE AUSPICES OF:

Ministry of Science, Technological Development and Innovation of the Republic of Serbia

Република Србија
МИНИСТАРСТВО НАУКЕ,
ТЕХНОЛОШКОГ РАЗВОЈА И ИНОВАЦИЈА

www.nitra.gov. rs

PROGRAMME COMMITTEE

Vesna Nikolić, PhD, Chair
University of Niš, Faculty of Occupational Safety, Serbia

Srđan Glišović, PhD
University of Niš, Faculty of Occupational Safety, Serbia

Miomir Raos, PhD
University of Niš, Faculty of Occupational Safety, Serbia

Dejan Mirakovski, PhD
"Goce Delčev" University, Faculty of Natural and Technical Sciences Štip, North Macedonia

Snezhina Andonova, PhD
South-West University "Neofit Rilski", Faculty of Engineering, Bulgaria

Saša Kenjereš, PhD
Delft University of Technology, Faculty of Applied Sciences, The Netherlands

Joana Duarte, PhD
University of Porto, IJOOES, Portugal

Rogert Sorí Gómez, PhD
University of Vigo, Environmental Physics Laboratory (EPhysLab), Spain

Radoslav Hristov Kartov, PhD
Academy of the Ministry of Interior, Faculty of Fire Safety and Civil Protection, Bulgaria

Mirko Markič, PhD
University of Primorska, Faculty of Management, Koper, Slovenia

Goran Šimunović, PhD
University of Slavonski Brod, Faculty of Mechanical Engineering, Croatia

Marija Hadži-Nikolova, PhD
"Goce Delčev" University, Faculty of Natural and Technical Sciences Štip, North Macedonia

Ivan Samardžić, PhD
University of Slavonski Brod, Faculty of Mechanical Engineering, Croatia

Snježana Kirin, PhD
University of Applied Sciences, Karlovac, Croatia

Mirjana Vojinović-Miloradov, Professor Emeritus
University of Novi Sad, Faculty of Technical Sciences, Serbia

Miodrag Hadžistević, PhD
University of Novi Sad, Faculty of Technical Sciences, Serbia

Dragan Mlađan, PhD
University of Criminal Investigation and Police Studies, Serbia

Biljana Vranješ, PhD
University of Banja Luka, Faculty of Mechanical Engineering, Bosnia and Herzegovina

Želimir Kešetović, PhD
University of Belgrade, Faculty of Security Studies, Serbia

ORGANISING COMMITTEE

Evica Jovanović, PhD, Chair
University of Niš, Faculty of Occupational Safety, Serbia

Aca Božilov, MSc
University of Niš, Faculty of Occupational Safety, Serbia

Aleksandra Petković, MA
University of Niš, Faculty of Occupational Safety, Serbia

Mirjana Milutinović, MSc
University of Niš, Faculty of Occupational Safety, Serbia

Rodoljub Avramović, MSc
University of Niš, Faculty of Occupational Safety, Serbia

CONTENTS

INVITED PAPERS

SAFETY ENGINEERING & MANAGEMENT IN SCIENCE

SAFETY ENGINEERING & MANAGEMENT IN EDUCATION

SAFETY ENGINEERING & MANAGEMENT IN INDUSTRY

Invited Papers

20th International Conference Man and Working Environment

SEMSIE

Safety Engineering & Management – Science, Industry, Education

20th International Conference Man and Working Environment

SEMSIE

Safety Engineering & Management – Science, Industry, Education

20th International Conference Man and Working Environment

SEMSIE

Safety Engineering & Management – Science, Industry, Education

20th International Conference Man and Working Environment
SEMSIE
Safety Engineering & Management – Science, Industry, Education

www.znrfak.ni.ac.rs/semsie

ROGERT SORÍ[1]
ORLANDO MORENO[2]
MILICA STOJANOVIC[1]
JORGE DAVID ALONSO[3]
ZULIMA GARCÍA[2]
ROBERTO GARRIAGA[2]
ARGUIL PÉREZ[2]
ALIANA LÓPEZ MAYEA[3]

[1]Centro de Investigación Mariña, Environmental Physics Laboratory (EPhysLab), Campus As Lagoas s/n, Universidade de Vigo, Ourense, Spain
[2]Provincial Delegation of the Ministry of Science, Technology and Environment, Ciego de Ávila, Cuba
[3]Centro Meteorológico Provincial de Ciego de Ávila, Instituto de Meteorología, Avenida de los Deportes S/N, Ciego de Ávila, Cuba

[1]*rogert.sori@uvigo.es*

DANGER, VULNERABILITY AND RISK OF FOREST FIRES IN CIEGO DE AVILA, CUBA: THE ROLE OF ANTHROPOGENIC AND ENVIRONMENTAL FACTORS

Abstract: *In this study, we determined the threat, vulnerability, and risk of forest fires in the province of Ciego de Ávila, Cuba. This province stands out for its agricultural production, one of the largest in the country, as well as for having regions of high ecological importance such as the Great Northern Wetland. Recorded data from forest fires were used and parameters such as the susceptibility and danger of different types of vegetation to ignition were determined. To determine total vulnerability, exposure factors and the relative importance of each different type of vulnerability were taken into account. Other environmental factors such as wind, temperature, gradient of the terrain, etc. were also taken into account. Finally, the risk estimation was carried out taking into account the danger and vulnerability. The results show clear differences between the dry and rainy periods, with the former affected to a greater extent by forest fires. In addition to the crucial role of precipitation climatology in the occurrence of a greater impact on forest fires, anthropogenic action was identified as the most dangerous due to negligence, falling electrical cables, fire passes, automotive sparks, and accidents. In this way, the risk of being affected by forest fires is medium and high in a greater number of municipalities in the province during the dry period.*

Keywords: forest fires, danger, vulnerability, risk

INTRODUCTION

Throughout the evolution of life on planet Earth, fire has been predominant as an active element of environmental dynamics and as a regulator of the growth and renewal of multiple plant associations and natural ecosystems (He et al., 2019). Various causes, such as global warming caused by anthropogenic action, changes in the patterns of the hydrological cycle and the behaviour of droughts, are influencing the increase in rural fires in many parts of the world (Turco et al., 2017; Sutanto et al., 2020). Its direct effects lie in the damage and more frequently in the death of organisms, flora and fauna, which make up forestry and agro-productive ecosystems. These incidents cause soil erosion with the loss of vegetation cover and its immediate impact on agriculture. In addition, the loss of mineral elements when the ashes are carried by the wind impacts the cycle of nutrients that organic matter provides to the soil. In Cuba, although to a lesser extent compared to the effects that can be critical in other nations, reported forest fires are a common occurrence (Ramos-Rodríguez et al., 2013).

Ciego de Ávila is a province located in the central region of Cuba (Figure 1), and its orography is predominantly flat. The fundamental economic activities for many years have been the agriculture of sugarcane and other crops such as pineapple (a fruit with which the province is identified), bananas, citrus fruits, etc. and to a lesser extent oil production and fishing. Taking into account the development of sugarcane agricultural activity and other crops in the province, and its commitment to the national balance, the need to conserve our small forest heritage and the natural values and biodiversity associated with it, justify this study. Thus, the objective of this study is to assess the forest fire danger, the vulnerability of the municipalities, and finally to estimate forest fire risks in the province. This study is part of a national initiative named: *Studies of Danger, Vulnerability and Risks of Forest Fires in Cuba*, coordinated by the Ministry of Science, Technology and Environmental Sciences (CITMA). The results will also provide a tool for decision-making, mitigation, and allocation of resources in the management operations of forest fires.

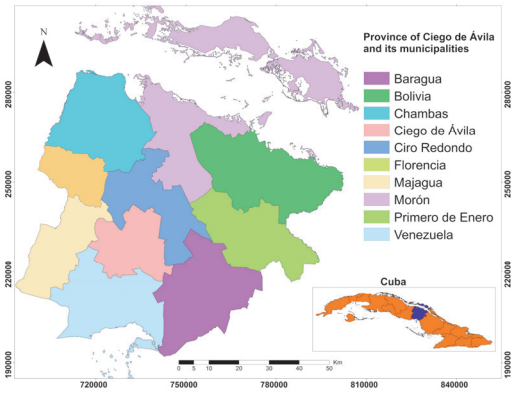


Figure 1. *Geographical location of Ciego de Ávila and its municipalities*

MATERIAL AND METHODS

The methodology proposed by the Risk Assessment Group of the Environmental Agency (AMA) of the CITMA for carrying out studies on Danger, Vulnerability and Disaster Risk due to forest fires was used in this study. It corresponds to the Directive No. 1 /2010 of the President of the National Defence Council "For Disaster Reduction" (D1, 2010), for which the glossary of terms prepared by the National General Staff of the Civil Defence of Cuba (2002) was taken into account. This methodology is based on the compilation and analysis of historical records of fire occurrence, the calculation of danger and vulnerability and, finally, the calculation of risk. The historical data on rural fires in the province of Ciego de Ávila is scarce and sometimes incomplete. However, in this study, we use a period of continuous and confident records of forest fires, which are available from January 2008 to May 2018.

To determine the susceptibility of different types of vegetation to ignition, the opinion of a group of experts on the subject was taken into account, following the current classification used by the Forest Ranger Corps (CGB), which considers 16 forest formations, including non-forest formations, among which are agricultural plantations such as sugarcane, pastures, and herbaceous communities. Table 1 shows five biophysical and human factors that impact the behaviour of vegetation in fires according to their classes. Each factor has a weighted weight that appears in the table, where they appear ordered from highest to lowest.

Table 1. *Hierarchy criteria of biophysical and human factors that impact the behaviour of vegetation*

No	Criteria	Hierarchical Position	Weighted Weight
1	Vegetation type	1	0.33
2	Water stress index	2	0.27
3	Terrain gradient	3	0.20
4	Human factors	4	0.13
5	Atmospheric electrical discharges	5	0.07
	Total		1

The determination of total vulnerability (*V*) is a function of the exposure factors and the relative importance of each type of vulnerability. The following vulnerability classifications were considered in this study: structural, non-structural, functional, social, economic, and ecological. At this stage, it is necessary to collect information on the exposed material assets, and the social, economic, and ecological values of the territory, such as the forest heritage, elements of the agricultural sector, tourism, protected areas, and especially the population exposed to danger.

Total vulnerability determination is a function of the exposure factors and the relative importance of each type of vulnerability (not shown). The danger (*Pi*) will be calculated based on the susceptibility (*S*) and the fire frequency of forest fires per grid (*Fr*) with a resolution of 250 meters, which is expressed as follows:

$$Pi = F(S, Fr). \quad (1)$$

Finally, the risk (*R*) estimation is calculated based on the P*i* and *Vi*, according to the following equation:

$$R = \sum_{i=1}^{n} Vi * Pi. \quad (2)$$

To obtain the risk map, each previously obtained danger and vulnerability factor is combined, as shown in Table 2, to finally establish classification criteria for the categories of low, medium, and high risk.

Table 2. *Hierarchy criteria to estimate the risk*

Danger	***Vulnerability***	***Risk***
High	High	High
High	Medium	High
High	Low	Medium
Medium	High	High
Medium	Medium	Medium
Medium	Low	Low
Low	High	High
Low	Medium	Medium
Low	Low	Low

RESULTS AND DISCUSSION

The historical data used from 2008 to May 2014 counts a total of 418 forest fires. The year 2011, with 119 records, was extreme, representing 28.1% of the total forest fires of the entire studied period. A spatial representation of the location of the fires in the province of Ciego de Ávila reveals that they generally occur during the dry period and are usually close to roads and rural settlements (Figure 2). The close location of fires to roads and rural and urban settlements is an important factor due to the risk it represents for vulnerable elements normally located outside towns or near roads. Of the total fires reported, 279 cases were located less than 1 kilometre from the roads, which represents 66%, a fact that suggests taking into account the appearance of fires due to incidents of anthropic origin. Figure 3 shows the causes of forest fires, which varied from anthropic origin (cigarette butts, vehicle sparks, bonfires and charcoal ovens, etc.), intentional due to negligence (32%), thunder, electric cables (23%), or fire pass (fire pass is the phenomenon of extension of a fire due to the non-existence or ineffectiveness of firebreak trails) (27%). These three causes add up to 82%, so the rest are less frequent. Sparks start at 14%, so they also need to be considered. Crown fire were represented with 1.8%, because when there is significant torching, many of the tree crowns catch fire.

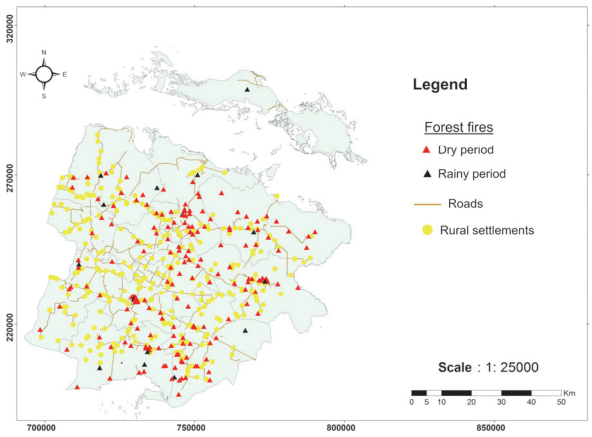


Figure 2. *Location of forest fires in the rainy (May – October) and dry periods (November – April)*

The distribution of vegetation danger from fire is shown in Figure 4; the largest area is occupied by the very dangerous category at 32.7%, followed by non-hazardous areas at 31.5%, and the dangerous category at 21%. High-danger zones coincide in the municipalities of Baraguá and Chambas in sugarcane growing areas, while the absence of danger predominates to the south of the Majagua and Venezuela municipalities (southwest of the province), coinciding with extensive fields of temporary crops as well as isolated areas in the centre north of the province in the area occupied by the Great Wetland of the North of Ciego de Ávila.

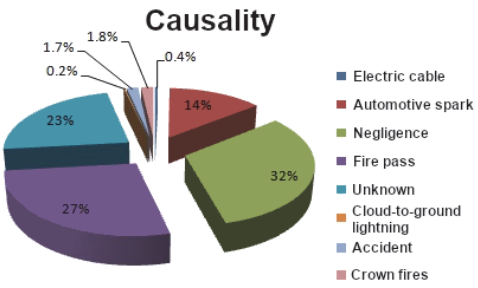


Figure 3. *Percentage of causes responsible for the occurrence of forest fires*

In the northern keys, no danger and low danger predominate, in correspondence with the island climate, which is characterised by high humidity, strong winds, and warm conditions modulated by the thermal inertia of the surrounding waters. In addition, a multi-criteria evaluation technique was applied to finally obtain the susceptibility to the occurrence of fires for each period, rainy and dry. In the rainy season, there are no areas of high susceptibility, although there are areas with medium susceptibility in the northeast and central west of the province, corresponding to extensions of sugarcane cultivation (figures not shown). In the dry season, areas with medium susceptibility increase throughout the province.

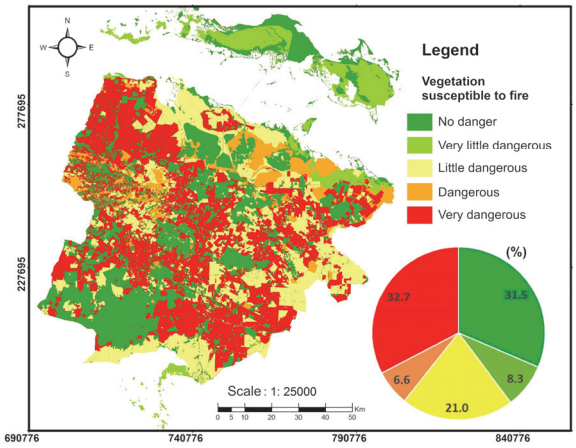


Figure 4. *Fire danger classes according to the type of vegetation*

The determination of forest fire danger reveals that areas characterised by low danger prevail during the rainy period, as seen in Figure 5a, particularly in the municipalities of Primero de Enero, Bolivia, Chambas, and Florencia. Areas in the medium danger category are justified by the presence of sugarcane and the elevations in northwest of Florencia or Loma de Cunagua and Santa María in Bolivia. There are no high-danger zones on this map. No danger predominates in areas of various crops in the municipality of Venezuela and Majagua, throughout the northern Cays of the province, and in the urban settlements.

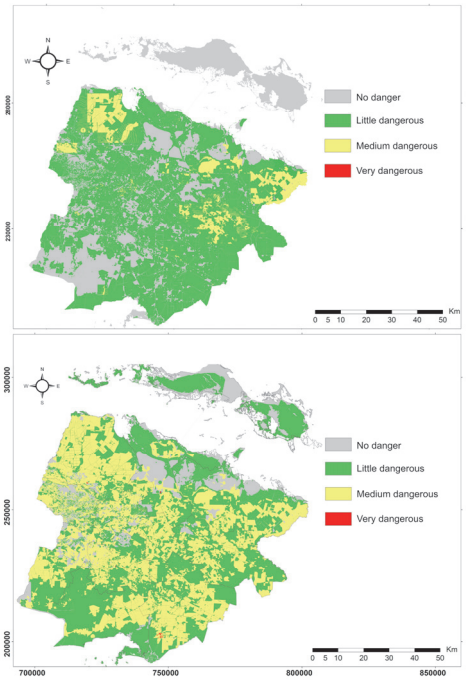


Figure 5. *Forest fire danger for the (a) rainy (May – October) and (b) dry (November – April) period*

In the dry period (Figure 5b), in correspondence with the major number of fires, small areas of high danger appear in the south of Baraguá municipality as well as surrounding the northern ring road of the city of Ciego

de Ávila. Other high-danger points are distinguished at the northern exit of the city of Morón towards Cayo Coco, an area frequently burned every year. This was also observed in the southern area of Chambas. The medium danger classification covers almost the entire municipality of Chambas and Baraguá, both with representative extensions of sugarcane cultivation and, as in the previous period, the western half of Venezuela and Majagua is characterised by low danger. In this period, there are fewer areas without danger, which are now mainly located to the north of Morón, in the Great Wetland of the north, and to the west of the province in the municipalities of Majagua and Florencia, where semi-deciduous forests are present.

Finally, the forest fire risks in the rainy season (Figure 6a) reveal that only the municipalities of Chambas, Morón, Bolivia, and Primero de Enero are in the medium risk category, while the rest are at low risk.

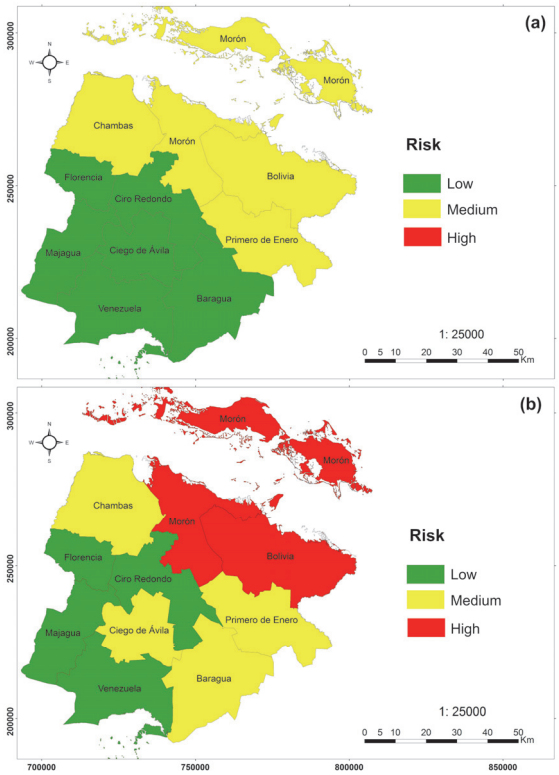


Figure 6. *Forest fire risk for the (a) rainy (May – October) and (b) dry (November – April) period*

This is in agreement with the time of the year in which the lowest number of fires are registered in the province. The rainfall regime during this period of the year favours the vegetation growth, the crops and the agricultural practices, which are factors that modulate the risk of forest fires. In the dry period (Figure 6b), the municipalities of Ciego de Avila and Baragua, which were previously at low risk, changed to medium risk, with four of the municipalities in this period being in this category, as Morón and Bolivia are at high risk. Even the cays of Jardines del Rey are at medium risk and then at high risk from November to April; however, in these months, these territories are more directly affected by frontal systems, so this category should not behave in this way during the six months of the dry period in the northern keys.

CONCLUSION

In this study, it was confirmed that 66% of the forest fires occurred within 1 kilometre from the roads. The results revealed that anthropogenic causes largely determine this result. Indeed, 32% of the fires were caused by negligence, followed by 27% due to the fire pass, and 23% due to electric cables. These three causes represent 82%, so the rest are less frequent. Other factors, such as danger to vegetation according to its type, and wind direction and velocity were analysed (figures not shown), revealing that a major part of the vegetation is susceptible to catching fires, while winds can propagate fires from the south to the centre of the province and from the northeast to southwest in the centre and to the north of it.

The rainy period stands out because of the prevalence of low susceptibility, which changes for the dry period, when the soil increases the susceptibility to the occurrence of fires (particularly in elevated areas). Consequently, this period is characterised by the prevalence of no danger and low danger, particularly in the centre and south of the province. In the dry season, areas of medium danger increase significantly and a small area of high danger is detected to the south of Baraguá municipality. Following this analysis, the assessment of vulnerabilities revealed an average total vulnerability in all municipalities. This information, in addition to the danger of forest fire estimations, made it possible to calculate the risk. It revealed that the municipalities in the north of the province are at medium risk of occurrence during the rainy period, whereas during the dry period, the risk is raised to high in the municipalities in the northeast of the province and the northern cays. These municipalities (Morón and Bolivia) are home to a large part of the Gran Humedal del Norte, a region with high ecosystemic value due to its biodiversity. In this period the east and northeast of the province are at medium risk, while the southeast is at low risk.

ACKNOWLEDGEMENTS

Rogert Sorí acknowledges the support from the postdoctoral contract "Ramón y Cajal" No. RYC2021-034044-I, financed by the Ministerio de Ciencia e Innovación of Spain. Milica Stojanovic acknowledges the support of grant no. ED481B-2021/134 from the Xunta of Galicia (regional government).

REFERENCES

D1 (Directiva No. 1 /2010) del Presidente del Consejo de Defensa Nacional para la organización, planificación y preparación del país ante situaciones de desastres. (2010). La Habana, Cuba. Retrieved 20 June 2023, from https://minfar.gob.cu/sites/default/files/2018-12/Directiva%201-2010.pdf

He, T., Lamont, B. B., & Pausas, J. G. (2019). Fire as a key driver of Earth's biodiversity. *Biol Rev*, *94*, 1983-2010. https://doi.org/10.1111/brv.12544

Sutanto, S. J., Vitolo, C., Di-Napoli, C., D'Andrea, M., & Van-Lanen, H. A. J. (2020). Heatwaves, droughts, and fires: Exploring compound and cascading dry hazards at the pan-European scale. *Environment International*, *134*, 105276. https://doi.org/10.1016/j.envint.2019.105276

Turco, M., von Hardenberg, J., AghaKouchak, A., Llasat, M. C., Provenzale, A., & Trigo, R. M. (2017). On the key role of droughts in the dynamics of summer fires in Mediterranean Europe. *Sci Rep*, *7*, 81. https://doi.org/10.1038/s41598-017-00116-9

20th International Conference Man and Working Environment
SEMSIE
Safety Engineering & Management – Science, Industry, Education

www.znrfak.ni.ac.rs/semsie

DEJAN MIRAKOVSKI[1]

[1]Goce Delčev University, Faculty of Natural and Technical Sciences

[1]*dejan.mirakovski@ugd.edu.mk*

PERSONAL EXPOSURE TO RESPIRABLE DUST IN EXTRACTIVE INDUSTRIES IN WESTERN BALKAN COUNTRIES

Abstract: *Despite the various advancements made in recent years, workers in the extractive industries continue to face the potential hazard of exposure to detrimental particulate matter. Also, despite the significant economic contribution of the extractive industries to the Western Balkan region, there is a lack of data pertaining to the level of personal dust exposure experienced by people employed in these industries. This study shows the findings of a personal exposure sampling program that was carried out in five distinct enterprises located in Macedonia, Serbia, and Albania. The respirable personal dust levels observed at metal mining sites displayed a wide range of values, ranging from 0.12 to 1.78 mg/m^3. The dust exposure experienced by workers in the industrial mineral processing sector has a similar range, from 0.04 to 4.71 mg/m^3. The measured values at the locations where metal processing occurs were determined to be the most minimal on record, falling within the range of 0.03 to 1.36 mg/m^3. This study provides empirical evidence that showcases the ongoing prevalence of elevated levels of respirable dust exposure among workers employed in the extractive industry in Western Balkan countries. The results emphasize the ongoing necessity for the adoption of efficient monitoring and control measures in order to mitigate dust exposure among employees in extractive sectors.*

Keywords: respirable dust, personal exposure, sampling, monitoring, extractive industry

INTRODUCTION

According to the United Nations Conference on Trade and Development (UNCTAD), the extractive industry encompasses a range of activities aimed at extracting raw materials from earth's crust, including metals, minerals, and aggregates. These commodities are subsequently processed and utilized by consumers. Those industrial activities usually include a wide range of different processes that involve primary processing of metallic ores, fuels, building materials, ceramics, detergents, electronics, filtration, glass, medications and medical devices, paints, paper and plastics, and many more industrial and domestic products.

Despite the advancements in safety legislation, technology, and awareness, workers in extractive industries continue to face the potential hazard of being exposed to dangerous dust particles. Contemporary extractive industries encompass a diverse array of processes, which encompass activities such as mining or quarrying, drilling and blasting, crushing, and the subsequent processing of raw materials. Each of these actions has the potential to generate dust, particularly in the absence of adequate dust management methods.

Wide range of materials, including silica-containing minerals, coal, metals, and even organic materials pose its unique health risks when airborne, and workers can be exposed to a mix of dust types, increasing the complexity of managing health risks. Utilization of robust machinery and equipment adds to the problem, due to high potential to emit significant quantities of respirable dust particles into the atmosphere. High-volume operations frequently result in elevated levels of dust formation, particularly in enclosed environments.

The term *dust* is commonly described as particles that are suspended in the air, typically within a size range of 1 to 100 μm (World Health Organization, 1999). Portion of a dust cloud that is capable of being inhaled through the nose or mouth and frequently gets caught in the upper respiratory tract is referred to as inhalable particulates (World Health Organization, 1999), and it is usually correlated with respiratory ailments, including asthma, tracheitis, pneumonia, and allergic rhinitis (Rumchev et al., 2023).

Finer particles that possess dimensions small enough to be effectively absorbed into the pulmonary system, or 50% cut-point of 4 μm, are defined as respirable dust (International Organization for Standardization, 1995). Respirable dust particles possess dimensions that allow them to evade the inherent protective systems of the respiratory system, such as those present in the nasal and throat regions, hence facilitating their penetration into the lower regions of the lungs. The inhalation of those particles can have varying effects on respiratory health, including chronic bronchitis, silicosis, tuberculosis, emphysema, renal failure, and cancer (Cecala et al., 2021).

Given the abundance of information available, regulatory bodies, industrial associations, and the scientific community in developed nations have acknowledged the crucial importance of monitoring occupational exposure to respirable dust. A substantial body of scientific data (Duarte et al., 2022), along with specialized databases such as IMA-DMP (Zillaot et al., 2017) and CONTAM (Rumchev et al., 2023), which collect representative occupational exposure data from various workplaces in extractive industries, is utilized to assess current levels of exposure and track exposure patterns over time.

However, although the extractive industries are vital part of all Western Balkan economies, a search of relevant research databases, including Web of Knowledge (Current Contents and Web of Science), Scopus, SAGE journals, American Chemical Society, Directory of Open Access Journals (DOAJ), Elsevier (Science Direct), Emerald, IEEE Xplore, and PubMed did not return any entries reporting personal exposure to respirable dust in Western Balkan countries. Even one of the largest occupational exposure databases, the IMA – DMP, which contains almost 30,000 personal exposure records from 160 different worksites owned by 35 industrial mineral companies in 23 countries across Europe, does not contain any record from a Western Balkan country with the exception of 18 records reported from a site in Bosnia and Herzegovina.

Therefore, this research attempts to clarify the methods of personal exposure sampling while examining the personal exposure data collected from several sampling campaigns carried out in extractive industry sites throughout several Western Balkan countries.

MATERIALS AND METHODS

Personal exposure monitoring, alternatively referred to as personal sampling or personal air monitoring, is a technique employed to evaluate an individual's exposure to potentially harmful substances, including but not limited to dust, gases, or biological agents, within occupational or other settings. This approach involves determining the levels of contaminants present in the ambient air that an individual is exposed to throughout their designated work shift or a predetermined duration.

Exposure monitoring generally encompasses a series of sequential procedures, commencing with the positioning of sampling devices, followed by the collection of samples, subsequent analysis of the collected samples, and ultimately the interpretation of the obtained data.

A sampling device, such as a wearable monitor or a pump equipped with an air sampling device, is positioned within the breathing zone, which refers to the region surrounding the nose and mouth of the worker. The device is responsible for monitoring and/or collecting air samples for the duration of the work shift, thereby offering a precise depiction of the contaminants to which the worker is exposed during their occupational tasks. The findings are analysed in order to evaluate the level of exposure experienced by the worker. Subsequently, a comparison is made between these findings and the established occupational exposure limits (OELs) or regulatory requirements in order to ascertain whether the degree of exposure experienced by the worker is above the acceptable thresholds.

In recent times, advancements in personal sampling pumps, sensor technology, and battery technology have facilitated the exploration of individual exposure to diverse environmental toxins beyond the scope of cumulative particle or gas sampling (Koehler & Peters, 2015).

Typically, personal size-selective samplers are the most commonly employed approach for assessing individual exposure to different dust fractions. Size-selective samplers typically employ a cyclone or impactor mechanism to exclude particles that exceed a specific size threshold, subsequently capturing smaller particles onto a filter medium.

There are many size-selective samplers available to gather particles in accordance with respirable or inhalable conventions. Inhalable samplers commonly consist of devices equipped with a mouth-like entrance, such as the IOM sampler, or perforated curved surface inlets, such as the Button Aerosol Sampler from SKC Inc. Respirable samplers commonly utilize a cyclone intake, such as the Dorr Oliver and Higgins Dewell cyclones, to eliminate larger particles (with a 50 % cut-point of 4 μm). Subsequently, a filter is employed to capture the smaller particles that are capable of entering deep in the lungs (Koehler & Peters, 2015). For determining the size distribution of a particulate exposure, personal cascade impactors are also available. Cascade impactors are composed of a series of successive impactors that are arranged in a decreasing order of cutoff sizes, such as Sioutas (SKC Inc.) or 290 Series (Tisch Environmental) personal cascade impactors. Particles that exceed the predetermined size level are deposited onto impaction substrates, while particles smaller than the minimum cutoff size are captured by a filter. The size distribution of the aerosol can be determined by analysing specific substrates (Misra et al., 2002).

The most widely used direct-reading instruments are light-scattering monitors. The operation of these monitors is based on the idea of light scattering, wherein a light source is used to illuminate airborne particles, and sensors are employed to detect the resulting scattered light. Through the examination of the dispersed light patterns, these monitors have the capability to offer instantaneous information regarding the concentration and size distribution of particles present in the air. The utilization of personal, belt-mounted light scattering devices enables valuable real time data, allowing professionals to take more informed decisions. Examples of such devices include the SidePak and DustTrak monitors (TSI Inc.), Personal DataRam (Thermo Scientific), and Aeroqual Series 200 (Aeroqual).

Occupational exposure limits (OELs) refer to the quantities of specific chemicals or substances present in the immediate breathing vicinity of workers, which are considered safe and should not result in negative health consequences or excessive discomfort for the majority of individuals.

Regulatory authorities at both the European Union (EU) and national levels establish these limitations, considering the existing information and up-to-date data regarding the potential dangers associated with a particular substance. These limitations primarily focus on evaluating the substance's carcinogenicity, mutagenicity, toxicity to reproduction, repeated dose toxicity, and short-term exposure effects.

The majority of Western Balkan countries follow the European Council Directive 98/24/EC of 7 April 1998 on the protection of the health and safety of workers from the risks related to chemical agents at work (and subsequent amendments establishing lists of indicative occupational exposure limit values adopted to date), that determine the permissible levels of exposure to respirable dust, with a limit of 4 mg/m^3 over an 8-hour time-weighted average (Directive 98/24/EC). The standards set forth by the American Conference of Governmental Industrial Hygienists propose that airborne concentrations of respirable dust should be maintained at levels below 3 mg/m^3. Australia has also implemented exposure limits that align with these recommendations.

Personal exposure measurements

This study describes the findings of a personal exposure sampling program that was undertaken in five distinct enterprises located in Macedonia, Serbia, and Albania. These companies were characterized as metal mining, metal processing, and industrial minerals production sites. A total of 155 personal samples of respirable dust, each collected over an 8-hour shift, were obtained over the course of the past 2 years.

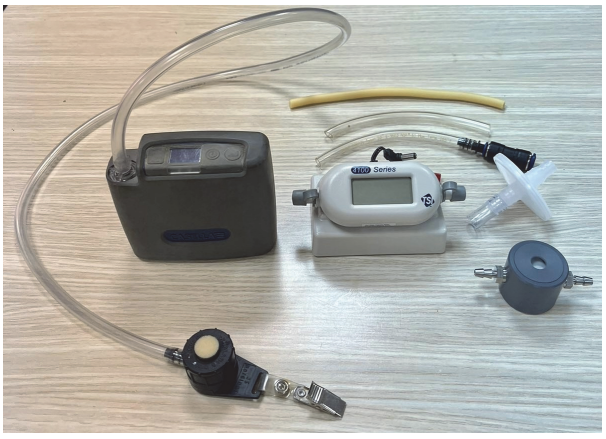


Figure 1. *Personal dust sampling set*

Sampling of respirable dust was performed according to a modified version of MDHS 14/4, which is a standard method for sampling and gravimetric analysis of respirable, thoracic, and inhalable aerosols (Health and Safety Executive, 2014) using an IOM 'multidust' dual-fraction respirable sampler (inhalable and respirable fraction) with 25-mm PVC membrane filters (GLA 5000 -PVC with 5 µm pore size, SKC Inc.) connected to a constant flow (2.0 l min−1) sampling pump (APEX 2, Casella). The quantification of the amount of dust deposited on the filters was performed using a gravimetric method.

Before sampling, all filters were individually identified and conditioned at a temperature of 20°C and a relative humidity of 50% in a climate chamber (ICH 110, Memmert, Germany) for a minimum of 24 hours. The filters were weighed twice, with a reconditioning interval of at least 12 hours between each weighing, in order to verify the stabilization of their mass. Two blank filters were designated for each batch to be used as weighing room blanks. Sampled filters after exposure were returned to the weighing room and conditioned in a controlled temperature and humidity chamber for more than 24 hours. Subsequently, the filters were weighed. The same conditions were applied to the field blanks. The weighing procedure was conducted using the Radwag MYA5.3Y.F micro balance, which is equipped with electronic control and has a resolution of 1 µg. The balance was situated in a controlled environment with regulated temperature and humidity, and an antistatic ionizer was employed to enhance accuracy. Mass concentration of respirable dust was calculated as the difference in mass between the exposed and the unexposed filter, divided by the sampled volume of air, determined as the flow rate multiplied by the sampling time. Measurement results are expressed as mg/m^3, where the volume of air is that under ambient conditions near the inlet during the sampling.

RESULTS AND DISCUSSION

The respirable personal dust levels observed at metal mining sites varied between 0.12 and 1.78 mg/m^3, with a geometric mean of 0.52 mg/m^3. It is worth noting that all recorded levels were found to be within the European Occupational Exposure Limits (OELs) of 4 mg/m^3.

The personal exposures of workers at industrial mineral processing sites demonstrate a lower respirable dust exposure, with values ranging from 0.04 to 4.71 mg/m^3 (geometric mean of 0.43 mg/m^3). However, it is worth noting that two of the samples exceeded the European Occupational Exposure Limits (OELs) of 4 mg/m^3.

The metal processing sites exhibited the lowest recorded values, which ranged from 0.03 to 1.36 mg/m^3 (with a geometric mean of 0.18 mg/m^3). It is noteworthy that all recorded values were found to be below the European Occupational Exposure Limits (OEL) of 4 mg/m^3.

Table 1. *Personal exposure to respirable dust fraction (time weighted average, 8-h working shift) in mg/m³*

Site classification	n	GM	MIN	MAX	STD
Mining metals	39	0.52	0.18	1.78	0.38
Metals processing	69	0.18	0.03	1.36	0.31
Industrial Minerals	47	0.43	0.04	4.72	1.17

The dust exposure levels observed in metal mining locations were consistent with the values reported in existing literature. The geometric mean values derived from a dataset of 8561 entries in the Australian CONTAM database were reported as 0.26 mg/m^3 (Rumchev et al., 2023).

The values obtained from metal processing and industrial minerals were also found to be consistent with those reported in the academic literature. For instance, Klasson et al. (2016) reported values of 0.048 ± 1.6 mg/m^3 for the Swedish hard metal industry.

The exposure data collected from industrial mineral sites exhibited similarities, with the geometric mean exposure to respirable dust reported in the IMA-DMP database for the year 2016 being 0.12 mg/m^3.

CONCLUSIONS

This study provided evidence that workers employed in the extractive industry in Western Balkan countries continue to encounter elevated levels of respirable dust exposure. The results emphasized the ongoing necessity of implementing efficient monitoring and control measures to mitigate dust exposure among workers in extractive sectors.

In order to address the potential hazards linked to individual dust exposure, it is imperative for workers to utilize suitable personal protective equipment, such as dust masks or respirators.

Additionally, employers should establish and enforce efficient dust management systems.

It is also imperative that workers receive proper education regarding the potential risks associated with dust exposure, as well as regarding the necessity of adhering to safety protocols in order to safeguard their well-being.

REFERENCES

Cecala, A. B., O'Brien, A. D., Schall, J., Colinet, J. F., Franta, R. J., Schultz, M. J., Haas, E. J., Robinson, J. E., Patts, J., Holen, B. M., Stein, R., Weber, J., Strebel, M., Wilson, L., & Ellis, M. (2019). *Dust Control Handbook for Industrial Minerals Mining and Processing* (2nd ed.). Centers for Disease Control and Prevention; National Institute for Occupational Safety and Health. https://www.cdc.gov/niosh/mining/userfiles/works/pdfs/2019-124.pdf

Directive 98/24/EC. *On the protection of the health and safety of workers from the risks related to chemical agents at work.* European Parliament and Council. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:01998L0024-20190726

Duarte, J., Castelo Branco, J., Rodrigues, F., Vaz, M., & Santos Baptista, J. (2022). Occupational Exposure to Mineral Dust in Mining and Earthmoving Works: A Scoping Review. *Safety, 8*(1), 9. MDPI AG. http://dx.doi.org/10.3390/safety8010009

International Organization for Standardization. (1995). *Air Quality – Particle size fraction definitions for health-related sampling* (ISO Standard No. 7708).

Koehler, K. A., & Peters, T. M. (2015). New Methods for Personal Exposure Monitoring for Airborne Particles. *Curr Environ Health Rep, 2*(4), 399-411. https://doi.org/10.1007/s40572-015-0070-z

Klasson, M., Bryngelsson, I. L., Pettersson, C., Husby, B., Arvidsson, H., & Westberg, H. (2016). Occupational Exposure to Cobalt and Tungsten in the Swedish Hard Metal Industry: Air Concentrations of Particle Mass, Number, and Surface Area. *The annals of occupational hygiene, 60*(6), 684–699. https://doi.org/10.1093/annhyg/mew023

Misra, C., Singh, M., Si, S., & Hall, P. (2002). Development and evaluation of a personal cascade impactor sampler (PCIS). *Journal of Aerosol Science, 33*, 1027-1047. https://doi.org/10.1016/S0021-8502(02)00055-1

Health and Safety Executive. (2014). MDHS 14/4 – General methods for sampling and gravimetric analysis of respirable, thoracic and inhalable aerosols.

Rumchev, K., Van Hoang, D., Lee, A. H. (2023). Exposure to dust and respiratory health among Australian miners. *International Archives of Occupational and Environmental Health, 96*(3), 355-363. https://doi.org/10.1007/s00420-022-01922-z

World Health Organization. (1999). *Hazard prevention and control in the work environment: airborne dust*. Occupational and Environmental Health Team. https://iris.who.int/handle/10665/66147

Zilaout, H., Vlaanderen, J., Houba, R., & Kromhout, H. (2017). 15 years of monitoring occupational exposure to respirable dust and quartz within the European industrial minerals sector. *International Journal of Hygiene and Environmental Health, 220*. https://doi.org/10.1016/j.ijheh.2017.03.010

Zilaout, H., Houba, R., & Kromhout, H. (2020). Temporal trends in respirable dust and respirable quartz concentrations within the European industrial minerals sector over a 15-year period (2002-2016). *Occupational and environmental medicine, 77*(4), 268–275. https://doi.org/10.1136/oemed-2019-106074

20th International Conference Man and Working Environment
SEMSIE
Safety Engineering & Management – Science, Industry, Education

www.znrfak.ni.ac.rs/semsie

DRAGAN ADAMOVIĆ[1]

[1]University of Novi Sad,
Faculty of Technical Sciences

[1]*draganadamovic@uns.ac.rs*

BTEX EMISSIONS FROM PASSENGER CARS IN URBAN DRIVING CONDITIONS

Abstract: *The constant increase in car fleets, especially in the urban environment, produces significant amounts of exhaust gases loaded with large amounts of polluting substances. Components of exhaust gas mixtures very often belong to hazardous air pollutants, such as aromatics from the group of BTEX compounds. The results of the research in the BTEX concentration field in spark ignition engines' exhaust gases under different operating conditions are presented in this paper. The paper aims to provide a more specific insight into the impact of various engine working parameters on the concentrations of benzene, toluene, ethylbenzene, and xylene isomers during the movement of the passenger car Fiat Punto Classic (FPC) in urban driving conditions. The experimental research was performed on the SCHENCK 230W test stand with the controlled IC engine. Based on the simulation results, the engine working points were chosen and considered to be the usual driving conditions in line with the New European Driving Cycle (NEDC). Concentrations of BTEX compounds in exhaust gas mixtures have been detected by gas chromatography technique using the Supelcowax 10-Polyethylene glycol column and the photoionization detector (PID). The amounts of BTEX compounds emitted per cycle were estimated using the results of the simulation.*

Keywords: BTEX compounds, NEDC, exhaust gases, engine testing

INTRODUCTION

Constant emissions of pollutants into ambient air affect global processes by increasing concentration levels of pollutants, distribution and allocation between basic environmental compartments, and biotic and abiotic matrix. The consequences of uncontrolled emissions of pollutants are related to the presence of large amounts of various gases in the atmosphere, such as CO_2, SO_2, CH_4, N_xO_y, and VOCs (Alyuz & Alp, 2014). In addition to these compounds, there are a large number of specific hazardous and carcinogenic substances in the atmosphere.

A significant part of environmental air pollution and a wide range of health hazards originate from motor vehicle emissions (Caprino & Togna, 1998; Poorfakhraei et al., 2017). This has induced strong legislative efforts to reduce the harmful vehicle emissions. The notably reduced traffic emissions have been achieved by new engine technologies, exhaust aftertreatment, and newly developed, reformulated fuels. However, only a part of the exhaust compounds are legally regulated, such as nitrogen oxides (NO_X), carbon monoxide (CO), total hydrocarbons (HC), and particulate matter (PM). On the other hand, more specific, carcinogenic compounds, such as BTEX, remain largely unregulated (Westphal et al., 2010).

The most recent European Union ecological standards related to the exhaust gases of motor vehicles from Euro 1 to Euro 6, which has been applied since September 2014, are focused on lowering greenhouse gas emissions: CO_2, CO, N_xO_y, suspended particles, and total HCs (Diesel Net, n.d.). The results of many experimental studies, including the results of this study, point to high concentration levels of BTEX aromatic compounds in motor vehicle exhaust gases **(**Lan & Minh, 2013; Macedo et al., 2017; Truc and Kim Oanh, 2007). These high concentrations appear as a result of the substitution of lead, an anti-detonator, by aromatic compounds in unleaded fuels with the purpose of increasing the octane number (Truc & Kim Oanh, 2007).

The chemical structure of hydrocarbons in petrol has a great influence on detonation. BTEX are very resistant to self-detonation, which is why they are used as octane number increasers in unleaded fuels (Mendes et al., 2012). Consequently, the problem of the presence of lead in the environment has been replaced by a new, and possibly greater, problem of BTEX compounds.

BTEX have become the common components in the atmosphere of most urban areas (Murena, 2007; Zalel et al., 2008), and their negative impacts on environmental and public health have already caused general concern (Moolla et al., 2015; Rezazadeh et al., 2012; Tohon et al., 2014).

They are highly reactive in the troposphere, and therefore play an important role in the atmospheric chemistry (Atkinson, 2007). These compounds have been recognized as important photochemical precursors for tropospheric ozone and organic aerosols (Zhang et al., 2012). Aromatic BTEX can be seriously toxic at both short- and long- term exposures.

Benzene is the most harmful compound from the BTEX group, and it has been categorized as a known

human carcinogen (Group 1) by the International Agency for Research on Cancer (IARC) (Mehlman, 2008).

The other BTEX compounds have also been identified as neurotoxic (Chen et al., 2011; Fustinoni et al., 2010), carcinogenic, and mutagenic at concentration levels found in urban environments (Bono et al., 2003). Exposure to BTEX compounds causes symptoms such as fatigue, confusion, weakness, drunken-type actions, memory loss, nausea, and loss of appetite (Edokpolo et al., 2014)

The New European Driving Cycle – NEDC

A driving cycle is a fixed schedule of vehicle operation that allows emission tests to be conducted under reproducible conditions (Barlow et al., 2009). Driving cycles are usually defined in relations of vehicle speed as a function of time.

The NEDC is a stylized cycle, with periods of acceleration, deceleration, and constant speed, and it is supposed to represent the typical usage of a passenger car in Europe. The cycle is divided into two main parts. The first part simulates the driving of a motor vehicle in urban areas, while the second part is reserved for the simulation of driving on the open road, as shown in Figure 1.

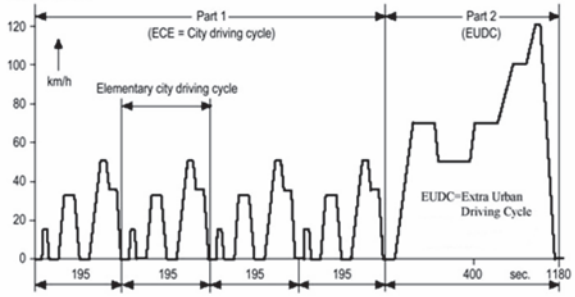


Figure 1. *The New European Driving Cycle (NEDC)*

The purpose of this cycle is to simulate vehicle and engine operation that usually occurs during the regular exploitation of passenger cars.

Engine testing

Engine testing is an expensive and complex process that requires a lot of research time and effort, complicated measuring equipment, and skilled manpower. For the purposes of this study, it was necessary to examine the toxicity of combustion products generated during engine operation.

The selection of characteristic set points of measurements is a very complex process, because it is necessary to know the features of the motor-vehicle-environment system.

The set points can be obtained in two different ways. The first is an empirical determination through experiments with real motor vehicles, while the other way would be reserved for retrieving the set points via numerical simulations.

There are many operating points where the engine works for very short periods of time. On the other hand, there are many points at which the engine is kept running longer and it passes through them more frequently. These points are the focus of our experimental research.

The main intention of this paper is to quantify the pollution formation of BTEX compounds from a vehicle engine, and the focus of the research is placed on engine regimes that are expected to be the most frequent in the urban exploitation of vehicles. To ensure the reproducibility of the experimental tests, the NEDC was selected as the pattern of driving of passenger cars in urban driving conditions. Based on the results of emission measurements at characteristic operating points of the cycle, the quantities of emitted BTEX compounds have been assessed during the movement of a Fiat Punto Classic (FPC) passenger car in accordance with the NEDC pattern.

MATERIALS AND METHODS

During the experimental research, the emission characteristics of a naturally aspirated Oto engine with the specifications given in Table 1 were investigated, with the purpose of predicting the quantities of BTEX compounds emitted during the movement of the FPC passenger car in accordance with the NEDC.

Table 1. *Main engine data*

Engine	Data
Engine model	1.1 EFI
Engine type	In-line, 4-stroke
Bore and stroke	
Total engine displacement	1.1 L
Firing order	1-3-4-2
Compression ratio	10:1
Valves per cylinder intake/exhaust	1/1
Aspiration	atmospheric
Injection system	multipoint
Peak power @ 6000 RPM	40 kW
Peak torque @ 3500 RPM	60 Nm
Engine speed	1000-6000 rpm
Testing load range	10-50%
Fuel	Euro Premium unleaded petrol
Emission standard	Euro 4
Exhaust gas control	TWC

This process is carried out with a SCHENCK 230W dynamometer, giving the tuner a controlled environment to work in. Tuners often utilize a chassis dynamometer for street and other high-performance applications.

Measurements of BTEX concentrations

The target compounds in exhaust gas samples were analysed by the Perkin Elmer Photovac Voyager-mobile GC. The Voyager uses the principles of gas chromatography (GC) to separate and identify volatile organic compounds. The target VOCs were identified

by GC retention times in comparison with the authentic Messer Technogas standards.

Before conducting the experimental procedures of measuring the BTEX concentrations in exhaust gases of the IC engine, proper values of the operating points during driving in urban areas were defined. A simulation was performed in order to achieve the values of vehicle speed from the NEDC, which are described in Figure 1. After choosing the powertrain and defining the motor vehicle type and the velocity profile, it was possible to calculate the engine speed. These values are clearly defined areas in which the engine operates during exploitation in the city and outside the city run. The velocity profile that is used when driving a motor vehicle under the conditions of NEDC was taken as an input parameter of the simulation.

Commercial Euro Premium unleaded petrol was used as the motor fuel. After defining the characteristic operating points, measurements of concentration levels of BTEX compounds were carried out in controlled conditions. The sampling of exhaust gases was conducted on an experimental engine exhaust pipe in order to determine the concentration levels of BTEX compounds in the mixture of exhaust gases. The sampling process lasted for 20 seconds, and the analysis of each portion of the exhaust gas lasted 20 minutes.

RESULTS AND DISCUSSION

Based on the results of BTEX emission measurements in controlled experimental conditions, the concentration profiles of BTEX compounds that are emitted during movement of the FPC passenger car in accordance with the NEDC driving pattern were defined. The measurements were carried out five times under the same conditions, and all results were averaged over the five measurements. The results are shown in Figure 2.

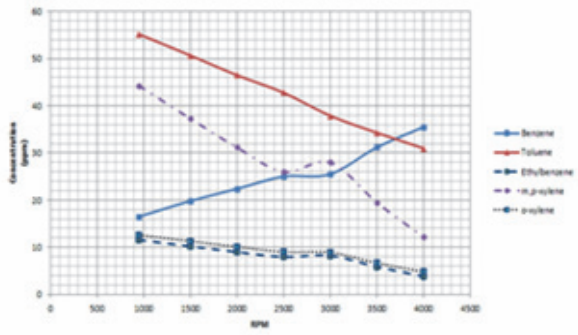


Figure 2. *The results of BTEX compound concentration level measurements at different RPMs*

The literature data point to the fact that BTEX accounts for roughly 95% of the total VOCs emitted by the engine. In addition, toluene dominates (40–50%) all VOC emissions (Agarwal et al., 2015). The results of the quantification of BTEX compounds in the exhaust gas stream suggest the prevalence of toluene emissions at almost all operating points (Fig. 2).

The results obtained from the experimental measurements indicate a trend of decrease in concentration levels of almost all compounds of the BTEX group, except benzene. Namely, increasing the engine speed and therefore the piston speed increases the turbulence intensity of the flame during combustion (Brequigny et al., 2016). With higher RPM values, higher temperatures are reached in the combustion chamber of internal combustion (IC) engines (Heywood, 1988; Kilicarslan & Qatu, 2017), which enables a more complete combustion of fuel if there are sufficient amounts of oxygen, which is supplied by the wide lambda probe. The increase in concentration levels of benzene in the exhaust gas stream, together with higher RPM, can be explained by simultaneous reaching of optimal conditions for the hydro-dealkylation of toluene and xylene to benzene at higher temperatures (Rabinovich & Maslyanskii, 1973; Alibeyli et al., 2003; Agency for Toxic Substances and Disease Registry, 2007). In this way, at the expense of disappearance of a part of higher aromatics, benzene is formed in the exhaust gas stream. In their research for the Ford Motor Company, Kaiser and associates demonstrated that pure toluene fuel generates a substantial amount of benzene emissions. This conversion contributes to the benzene enrichment in the exhaust gas stream, since petrol normally contains appreciable toluene and other higher aromatics (Kaiser, 1992). This confirms that dealkylation of substituted benzenes is a significant source of benzene emission.

CONCLUSION

The simulation in the field of IC engines and motor vehicles today represents a sophisticated world-recognized tool for solving complex problems in the area of defining emission characteristics. The modelling of the motor vehicle emissions via simulations significantly reduces the time that is normally needed for extensive experiments and prototypes, because these simulations can perform predictions of a large number of experiments. One such model can be used later for numerous studies where in many cases the high costs of engine testing can be avoided. It would be unrealistic to say that numerical calculation can completely replace test bench, but with validation, for example, of several working points and definition of the motor model in accordance with the proven results, accurate results in other operating points can be expected. Experimental investigation, conducted within this paper, was used to define the most important engine operating points, where the engine works most of the time. In this way, the unnecessary experiments were avoided, i.e. set points that do not occur during engine exploitation of motor vehicles in urban driving conditions. In this way, the investigation that leads to the loss of valuable time on the analysis of toxicity of unnecessary operating points can be avoided.

ACKNOWLEDGEMENTS

This research is supported by the Ministry of Science, Technological Development and Innovation through project no. 451-03-47/2023-01/200156 “Innovative scientific and artistic research from the FTS (activity) domain”.

REFERENCES

Agarwal, A. K., Shukla, P. C., Gupta, J. G., Patel, C., Prasad, R. K., & Sharma, N. (2015). Unregulated emissions from a gasohol (E5, E15, M5, and M15) fuelled spark ignition engine. *Appl. Energy 154*, 732–741. doi:10.1016/j.apenergy.2015.05.052

Agency for Toxic Substances and Disease Registry. (2007). *Toxicological Profile for Benzene*. Author.

Alibeyli, R., Yeniova, H., Koçak, M. Ç., & Karaduman, A. (2003). Kinetic Pecularities of Benzene Production from the Benzene–Toluene–Xylene Fraction of Pyrolysis Gasoline by Catalytic Hydrodealkylation at High Temperature. *Pet. Sci. Technol. 21*, 789–803. doi:10.1081/LFT-120017450

Alyuz, U., & Alp, K. (2014). Emission inventory of primary air pollutants in 2010 from industrial processes in Turkey. *Sci. Total Environ. 488–489*, 369–381 doi:10.1016/j.scitotenv.2014.01.123

Atkinson, R. (2007). Gas-phase tropospheric chemistry of organic compounds: a review. *Atmos. Environ. 41*, 200–240. doi:10.1016/j.atmosenv.2007.10.068

Barlow, T., Latham, S., Mccrae, I. S., & Boulter, P. G. (2009). *A reference book of driving cycles for use in the measurement of road vehicle emissions*. TRL. doi:10.1108/WJSTSD-06-2014-0009

Bono, R., Scursatone, E., Schilirò, T., & Gilli, G. (2003). Ambient air levels and occupational exposure to benzene, toluene, and xylenes in northwestern Italy. *J. Toxicol. Environ. Heal. – Part A 66*, 519–531 doi:10.1080/15287390306357

Brequigny, P., Halter, F., Mounaïm-Rousselle, C., & Dubois, T. (2016). Fuel performances in Spark-Ignition (SI) engines: Impact of flame stretch. *Combust. Flame 166*, 98–112. doi:10.1016/j.combustflame.2016.01.005

Caprino, L., & Togna, G. I. (1998). Potential health effects of gasoline and its constituents: A review of current literature (1990-1997) on toxicological data. *Environ. Health Perspect. 106*, 115–125. doi:10.1289/ehp.98106115

Chen, J., Randall, R. B., & Peeters, B. (2016). Advanced diagnostic system for piston slap faults in IC engines, based on the non-stationary characteristics of the vibration signals. *Mech. Syst. Signal Process. 75*, 434–454. doi:10.1016/j.ymssp.2015.12.023

Diesel Net. (n.d.). *EU: Cars and Light Trucks – Emission Standards*. Retrieved 5 September 2023, from https://dieselnet.com/standards/eu/ld.php#stds

Edokpolo, B., Yu, Q. J., & Connell, D. (2014). Health risk assessment of ambient air concentrations of benzene, toluene and xylene (BTX) in service station environments. *Int. J. Environ. Res. Public Health 11*, 6354–6374. doi:10.3390/ijerph110606354

Fustinoni, S., Rossella, F., Campo, L., Mercadante, R., & Bertazzi, P. A. (2010). Urinary BTEX, MTBE and naphthalene as biomarkers to gain environmental exposure profiles of the general population. *Sci. Total Environ. 408*, 2840–2849. doi:10.1016/j.scitotenv.2010.03.017

Heywood, J. B. (1988). *Internal Combustion Engine Fundamentals*. McGraw-Hill, Inc.

Kaiser, E. W. (1997). Impact of operating conditions and fuel composition on vehicle emissions. *ACS Div. Fuel Chem. Prepr. 42*, 885–889.

Kilicarslan, A., & Qatu, M. (2017). Exhaust Gas Analysis of an Eight Cylinder Gasoline Engine Based on Engine Speed. *Energy Procedia 110*, 459–464. doi:10.1016/j.egypro.2017.03.169

Lan, T. T. N., & Minh, P. A. (2013). BTEX pollution caused by motorcycles in the megacity of Ho Chi Minh. *J. Environ. Sci. (China) 25*, 348–356. doi:10.1016/S1001-0742(12)60045-X

Macedo, V. C., Daemme, L. C., Penteado, R., da Motta, H. N., & Corrêa, S. M. (2017). BTEX emissions from flex fuel motorcycles. *Atmos. Pollut. Res. 8*, 1160–1169. doi:10.1016/j.apr.2017.05.006

Mehlman, M. A. (2008). Benzene, a multi-organ carcinogen. *Eur. J. Oncol. 13*(1), 7–19.

Mendes, G., Aleme, H. G., & Barbeira, P. J. S. (2012). Determination of octane numbers in gasoline by distillation curves and partial least squares regression. *Fuel 97*, 131–136. doi:10.1016/j.fuel.2012.01.058

Moolla, R., Curtis, C. J., & Knight, J. (2015). Occupational exposure of diesel station workers to BTEX compounds at a bus depot. *Int. J. Environ. Res. Public Health 12*, 4101–4115. doi:10.3390/ijerph120404101

Murena, F. (2007). Air quality nearby road traffic tunnel portals: BTEX monitoring. *J. Environ. Sci. 19*, 578–583. doi:10.1016/S1001-0742(07)60096-5

Rabinovich, G. L., & Maslyanskii, G. N. (1973). A new process for toluene dealkylation. *Chem. Technol. Fuels Oils 9*(2), 85–87.

Rezazadeh Azari, M., Naghavi Konjin, Z., Zayeri, F., Salehpour, S., & Seyedi, M. D. (2012). Occupational exposure of petroleum depot workers to BTEX compounds. *Int. J. Occup. Environ. Med. 3*, 39–44.

Tohon, H. G., Fayomi, B., Valcke, M., Coppieters, Y., & Bouland, C. (2015). BTEX air concentrations and self-reported common health problems in gasoline sellers from Cotonou, Benin. *Int. J. Environ. Health Res. 25*, 149–161. doi:10.1080/09603123.2014.915017

Truc, V. T. Q., Kim Oanh, N. T. (2007). Roadside BTEX and other gaseous air pollutants in relation to emission sources. *Atmos. Environ. 41*, 7685–7697. doi:10.1016/j.atmosenv.2007.06.003

Westphal, G. A., Krahl, J., Brüning, T., Hallier, E., & Bünger, J. (2010). Ether oxygenate additives in gasoline reduce toxicity of exhausts. *Toxicology 268*, 198–203. doi:10.1016/j.tox.2009.12.016

Zalel, A., & Broday, D. M. (2008). Revealing source signatures in ambient BTEX concentrations. *Environ. Pollut. 156*, 553–562. doi:10.1016/j.envpol.2008.01.016

Zhang, Y., Mu, Y., Liu, J., & Mellouki, A. (2012). Levels, sources and health risks of carbonyls and BTEX in the ambient air of Beijing, China. *J. Environ. Sci. 24*, 124–130. doi:10.1016/S1001-0742(11)60735-3

Safety Engineering & Management in Science

20th International Conference Man and Working Environment
SEMSIE
Safety Engineering & Management – Science, Industry, Education

20th International Conference Man and Working Environment
SEMSIE
Safety Engineering & Management – Science, Industry, Education

www.znrfak.ni.ac.rs/semsie

DARKO PALAČIĆ[1]

[1]University of Applied Sciences in Security and Safety, Zagreb

[1]*darko@vss.hr*

CONCEPTS AND PHILOSOPHY OF OHS RISK MANAGEMENT

Abstract: *The concept of risk, due to its ambiguity and complexity, has always attracted the attention of scientists from various fields and branches of study. Risk has been approached from different aspects, so that even today there is no single definition of risk. The concept of risk management consists of the principles of management, the management framework, and the risk management process. Risk management is the method used to control, eliminate, or reduce the hazard within parameters of acceptability. Risk management is unique to each individual since there are no two people exactly alike in skills, knowledge, training, and abilities. The first part of the paper presents the theoretical principles and philosophy of occupational health and safety risk management. Also, analysed problems from case studies are presented. The second part of the paper describes the concepts of occupational health and safety risk management, as well as the basic philosophy of these concepts. The discussion and conclusion provide guidelines and recommendations for a deeper understanding of the philosophy of occupational health and safety risk management and open up the possibility of creating new empirical research.*

Keywords: concepts, philosophy of risk management, occupational health and safety, risk management

INTRODUCTION

Risk is a complex concept that occurs in both personal and professional spheres of life. Risk constantly accompanies all human activities, and exists in every business, and the probability that a certain risky event will occur depends on its nature. Risk refers to the future and future events. Risk management organises what cannot be organised, because individuals, corporations and governments have little choice but to do so. The risk management of everything holds out the promise of manageability in new areas. But it also implies a new way of allocating responsibility for decisions that must be made in potentially undecidable situations. OHS risk management is based on the principles, framework, and process. The purpose of risk management is the creation and protection of value. It improves performance, encourages innovation, and supports the achievement of objectives. Establishing a process that ensures hazard recognition is the primary goal of a progressive organization with a strong safety management program. The organization removes or reduces the risks associated with these hazards to the lowest possible and reasonable level.

OHS risks, in their different forms and inter-relationships, may be the subject of observation and management based on different perspectives. Although the concept of treating OHS risk has changed over time, it is clearly recognized in the scientific literature.

The philosophy of OHS risk management is very complex. The philosophy of OHS risk management is very complex. It consists of a number of philosophical perspectives and aspects. Perhaps in no other field of management does the ethical and moral approach have as much importance as in OHS risk management.

METHODOLOGY

Aim and tasks of the research

The problem recognized in this area is the lack of knowledge about the concepts and philosophy of OHS risk management. The aforementioned problem is manifested in the lack of published current research in this area. With regard to the recognized problem, the goal of the research is to identify the concepts and philosophy of OHS risk management.

According to the set goal, the research tasks are:

- analyse and present OHS risk management concepts
- analyse and present the philosophy of OHS risk management
- encourage further empirical research into the concepts and philosophy of OHS risk management.

Research methodology

In the analysis, a number of scientific methods are applied, which, by their combination and order, form an established research methodology. A combination of deductive and inductive analysis is applied in order to classify and summarize the basics of the research subject. Concepts and philosophy of OHS risk management are analysed using the method of studying the content of scientific and professional literature. A combination of deductive and inductive analysis is used in order to classify and summarize the theoretical foundations of the research subject. The method of content analysis is used to analyze theoretical assumptions. The method of description describes the essential Concepts and philosophy of OHS risk management. The key characteristics are compiled and conclusions are made following analysis and comparison.

RESULT AND DISCUSSION

OHS management system

Occupational health and safety (OHS) is mainly defined as the science of the anticipation, recognition, evaluation, and control of hazards arising in or from the workplace that could impair the health and well-being of workers, considering the possible impact on the surrounding communities and the general environment. This domain is necessarily vast, encompassing many disciplines and numerous workplace and environmental hazards. A wide range of structures, skills, knowledge, and analytical capacities are needed to coordinate and implement all "building blocks" that make up national OHS systems so that protection is extended to both workers and the environment (Alli, 2008).

Occupational safety and health has grown in importance from an ethical, legal, and economic standpoint. Companies are attempting to remain profitable in an ever more competitive global economy. For these companies, addressing safety, health, and environmental issues may mean more than good business practices. For many companies, strong safety, health, and environmental programs may actually mean survival (Friend, Kohn, 2007).

Therefore, OHS can be defined as a system of technical, health, legal, psychological, pedagogical, and other activities, that detect and eliminate dangers and harms that can endanger the life and health of people at work. On this basis, it is concluded that the purpose of OHS is to create safe conditions to prevent injuries at work, occupational diseases, and accidents at work (Palačić, 2023).

Occupational safety is part of the organization of work and performance of the work process, and is achieved by performing occupational safety and applying the prescribed, agreed, as well as recognized rules of occupational safety and ordered measures and instructions of the employer (World Health Organization, 2021).

The employer is responsible for the organization and implementation of occupational safety on the basis of objective responsibility, regardless of whether it has hired an occupational safety expert, or organized an occupational safety service or has contracted cooperation with an authorized person for occupational safety, institution or company for occupational safety (Palačić, 2011).

The scope of occupational safety and health has evolved gradually and continuously in response to social, political, technological and economic changes. In recent years, globalization of the world's economies and its repercussions have been perceived as the greatest force for change in the world of work, and consequently in the scope of occupational safety and health, in both positive and negative ways. Liberalization of world trade, rapid technological progress, significant developments in transport and communication, shifting patterns of employment, changes in work organization practices, the different employment patterns of men and women, and the size, structure and life cycles of enterprises and of new technologies can all generate new types and patterns of hazards, exposures and risks. Demographic changes and population movements, and the consequent pressures on the global environment, can also affect safety and health in the world of work (Alli, 2008).

OHS risk management

Establishing a process that ensures hazard recognition is the primary goal of a progressive organization with a strong safety management program. The organization removes or reduces the risks associated with these hazards to the lowest possible and reasonable level.

The state of OHS, or in other words, the efficiency and effectiveness of the prevention of injuries at work and occupational diseases, depends on the success of the implementation of occupational safety in relation to the existing risks at work. Therefore, the key precondition for the planning and implementation of occupational safety is the assessment of occupational risks, and further and continual management of occupational risks. Risk management is a preventive process by which risks at work are identified and further procedures are carried out to avoid and/or reduce them (Palačić, 2023).

The evaluation of risks in the workplace starts with the identification of the types of hazards existing at the facility. Establishing a process to ensure hazards has been identified as the primary goal of a progressive organization with a strong safety management program. The organization eliminates or reduces the risks associated with those hazards to the lowest achievable and reasonable level (Friend, Kohn, 2007).

Concepts of OHS risk management

Risk is a complex concept that occurs in all areas of life, in private and business terms. Risk constantly accompanies all human activities.

Even in prehistoric times, there was a risk of the impossibility of achieving basic living conditions when it was not known what to find in the day to eat, whether to catch an animal, etc. Nowadays, risks in everyday life there are various risks such as participation in traffic in which there is a real danger of a traffic accident, and so on. Therefore, we can say that risk develops over time and that our daily activities have become increasingly insecure (Grubišić, Palačić, 2023).

Risks, in their different forms and inter-relationships, may be the subject of observation and management based on different perspectives. The main risk observation perspectives stem in particular, from studies in the economic-corporate and production areas, and may be summarized as, strategic perspective, corporate governance perspective, financial perspective, and operational perspective. Therefore, it emerges that, with a view to detecting the many facets and forms under which they appear, risks should be simultaneously observed from many and different perspectives (Borghesi, Gaudenzi, 2013).

The concept of risk due to its ambiguity and complexity has always attracted the attention of scientists from various fields and branches of science. Risk has been approached from different aspects, so that even today there is no single definition of risk. Therefore, risk is defined in many ways, of which the most significant are listed below:

- risk is the uncertainty of outcomes within the exposure range, which arises from a combination of the impact and probability of potential events (HM Treasury)
- risk is the uncertainty of an event that could affect the achievement of objectives, the risk is measured in terms of consequences and probability (The Institute of Internal Auditors)
- risk is a condition in which there is a possibility of a negative deviation from the desirable outcome that we expect or hope for. (Andrijanić, Klasić, 2002).
- risk is the possibility of something bad happening at some time in the future; a situation that could be dangerous or have a bad result (Oxford English Dictionary)
- risk is a combination of the probability of an event and its consequences, and the consequences can be positive or negative (The Institute of Risk Management)
- risk is the degree of uncertainty (U.S. Department of Transportation, 2013)
- risk is the effect of uncertainty on objectives (an effect is a deviation from the expected - positive and/or negative) (ISO 31073:2022 Risk management – Vocabulary)
- risk is the effect of uncertainty (ISO 9000:2015 Quality Management Systems - Fundamentals and vocabulary)

An integral and fundamental part of any risk management concept is risk assessment.

A breakthrough in risk assessment occurred in 1654 when Pierre de Fermat and Blaise Pascal laid the foundations of risk theory (Pograc, Majić, 2015). Risk management is the method used to control, eliminate, or reduce the hazard within parameters of acceptability. It is unique to each individual, since there are no two people exactly alike in skills, knowledge, training, and abilities (U.S. Department of Transportation, 2013).

Also, risk management involves the coordinated activities to direct and control an organization regarding risk. (ISO 31073:2022 Risk management – Vocabulary)

Risk management and risk 'talk' are all around us. The risk-based description of organisational life is conspicuous. Not only private sector companies, but hospitals, schools, universities, and many other public organisations, including the very highest levels of the central government, have all been invaded to varying degrees by ideas about risk and its management (Power, 2004).

Uncertainty is a term that encompasses many fundamental concepts. There have been many attempts to define the term, and continue to be developed, to categorize types of uncertainty, including:

- uncertainty that recognizes the internal variability of some phenomena, and this cannot be reduced by further data; for example, rolling dice (sometimes called aleatory uncertainty);
- uncertainty that generally results from a lack of knowledge and can therefore be reduced by collecting more data, refining models, improving sampling techniques, etc. (sometimes called epistemic uncertainty).

Risk includes the effects of any form of uncertainty. Uncertainty can lead to positive or negative consequences or both. Risk is often described in terms of sources of risk, potential events, their consequences and certainty. An event can have multiple causes and lead to multiple consequences. Consequences can have different discrete values, be continuous variables, or be unknown (Borghesi, Gaudenzi, 2013).

OHS risk management is essential for ensuring the safety and well-being of workers in various industries. Here are some key concepts:

Hazard Identification: Identifying potential hazards in the workplace is the first step in OHS risk management. Hazards can be physical, chemical, biological, ergonomic, or psychosocial in nature.

Risk Assessment: After identifying hazards, a risk assessment is conducted to evaluate the likelihood and severity of harm that may result from each hazard. This helps prioritize risks for further action.

Risk Evaluation: In this step, risks are evaluated based on criteria such as severity, likelihood, and potential exposure. This helps determine which risks are most urgent and require mitigation.

Risk Control: Once risks are identified and assessed, control measures are put in place to mitigate or eliminate the risks. Control measures can include engineering controls, administrative controls, and personal protective equipment (PPE).

Monitoring and Review: OHS risk management is an ongoing process. It involves monitoring the effectiveness of control measures, conducting regular safety audits, and reviewing risk assessments to ensure they remain accurate and up to date.

Communication: Effective communication is crucial in OHS risk management. This includes informing employees about risks, control measures, and emergency procedures. It also involves reporting incidents and near-misses.

Legal and Regulatory Compliance: Compliance with OHS laws and regulations is essential to ensure a safe workplace. Employers are typically required to follow local, national, and international standards related to workplace safety.

Training and Education: Providing training and education to employees on safety practices, hazard

recognition, and proper use of PPE is a key component of OHS risk management.

Safety Culture: Fostering a culture of safety within the organization is critical. This involves creating an environment where all employees take responsibility for safety and are encouraged to report hazards and incidents.

Emergency Response and Planning: Developing and implementing emergency response plans and procedures is vital to mitigate the consequences of accidents or disasters in the workplace.

Continuous Improvement: OHS risk management should be a dynamic process that continuously evolves to adapt to changing conditions and emerging risks.

Based on everything shown, we can conclude that the risk is transversal.

Risk cannot be eliminated because it always exists. Organizations must therefore manage all the factors that increase and decrease these risks in order to achieve improved safety and reduced costs. This includes effective risk classification which in turn supports better risk management.

Philosophy of OHS Risk Management

Risk management generally has its own philosophy. Given that OHS risk management can be considered a subtype of general risk management, it has its own philosophy.

Risk management is based on the principles, framework, and process. The purpose of risk management is the creation and protection of value. It improves performance, encourages innovation, and supports the achievement of objectives (Palačić, 2021).

The principles of risk management provide guidance on the characteristics of effective and efficient risk management, communicating its value and explaining its intention and purpose. The purpose of the risk management framework is to assist the organization in integrating risk management into significant activities and functions. The risk management process involves the systematic application of policies, procedures, and practices to the activities of communicating and consulting, establishing the context and assessing, treating, monitoring, reviewing, recording, and reporting risk.

Enterprise risk management is an area in which the discipline of risk management has recently developed into an approach called enterprise or enterprise-wide risk management (ERM). The main feature that distinguishes ERM from what might be considered more traditional risk management is the more integrated or holistic approach used in ERM. In many ways, it can be considered a unifying philosophy that unifies the management of all types of risk, rather than a new or different approach. ERM is an overall philosophy that consolidates the management of individual risks into a single and consistent approach to risk across the enterprise (Hopkin, 2017).

Hansson provides an overview of philosophical issues in risk research. These include the definition of risk, the relationship between risk and uncertainty, the effects of cognitive limitations on the limits of rationality, the implications of unknown possibilities, and the difficulties facing current decision theory and moral theory as they apply to problems of risk. It is concluded that some of the models and assumptions commonly used in risk studies are deeply problematic (Hansson, 1999).

Risk management philosophy is an integral element of risk management strategy. The role of philosophy in the development of risk science was rather limited.

There are many problems in risk analysis and management that philosophers could contribute to solving. Several central terms, including "risk" itself, still need terminological clarification. Much of the argumentation in risk issues is unclear and analysis of the argumentation is required. There is still a need to uncover implicit or "hidden" values in risk assessments that purportedly have no value.

Eight philosophical perspectives in risk theory are outlined:

1. From the point of view of epistemology, issues of risk have led to problems of trust in expertise and the division of epistemological work.

2. In decision theory, the degree of control of decision-makers over risks is often problematic and difficult to model.

3. In the philosophy of probability, posterior revisions of risk estimates (in the so-called hindsight bias) represent a challenge to the standard model of probabilistic reasoning.

4. In the philosophy of science, questions of risk give us reason to investigate what impact the practical use of knowledge can legitimately have on the scientific process.

5. In the philosophy of technology, it is necessary to investigate the nature of safety engineering principles and their relationship with risk assessment.

6. In ethics, the most pressing problem is how standard ethical theories can be extended or adapted to deal with the ethics of risk-taking.

7. In the philosophy of economics, the comparison and summation of risks falling on different persons create new fundamental problems for welfare theory.

8. In political philosophy, issues such as trust and consent discussed in relation to risk give us reason to revisit central issues in democratic theory.

Risk has its objective and subjective aspects. Objective aspects imply a fact-based risk assessment. Subjective concepts form a set of values adopted by the person who assesses the risk, depending on the knowledge of the risks and hazards that the assessor knows, and depending on the exposure of the assessor to a hazard (Peschard, Benétreau-Dupin, Wessels, 2023).

The philosophy of OHS risk management encompasses the underlying principles, beliefs, and approaches that

guide how organizations and individuals handle risks. Here are some key aspects of the philosophy of risk management:

Proactive Approach: Risk management philosophy emphasizes the importance of taking a proactive stance towards identifying, assessing, and mitigating risks before they materialize into problems. This proactive approach helps prevent or reduce the impact of adverse events.

Risk Aversion vs Risk Tolerance: It involves the consideration of an organization's or individual's risk aversion or risk tolerance. Some may adopt a risk-averse philosophy, seeking to minimize risks at all costs, while others may be more risk-tolerant, willing to take calculated risks to achieve specific objectives.

Balancing Risk and Rewards: It involves the recognition that risks are inherent in many endeavors, and there is often a need to balance potential risks with potential rewards. This philosophy acknowledges that avoiding all risks is not always feasible or desirable.

Data-Driven Decision Making: A data-driven philosophy of risk management places a strong emphasis on collecting and analyzing data to inform decisions. This includes risk assessment, modeling, and the use of historical data to make informed choices.

Sustainability and Resilience: This philosophy encourages a long-term perspective, considering the sustainability and resilience of an organization or system in the face of risks. It recognizes that managing risks is not only about avoiding losses but also about ensuring the ability to recover and adapt.

Ethical Considerations: Ethical principles play a role in the philosophy of risk management. It involves making choices that align with ethical values, including fairness, transparency, and accountability in how risks are managed.

Continual Improvement: A philosophy of continuous improvement is central to risk management. It recognizes that risks change over time, and the risk management process should adapt and improve in response to evolving threats and opportunities.

Crisis Response: While proactive risk management is essential, it also recognizes the importance of having effective crisis response and management plans in place. This is the philosophy that even with the best risk management practices, some crises will still occur, and readiness is crucial.

Cost-Benefit Analysis: The philosophy of risk management often incorporates a cost-benefit analysis, considering the costs of risk mitigation measures against the potential benefits in terms of risk reduction.

Integration with Decision-Making: Risk management is integrated into decision-making processes. Decisions are made with a clear understanding of the associated risks, and risk management strategies are embedded into organizational strategies.

The philosophy of OHS risk management can vary between organizations and individuals and is influenced by factors such as industry, culture, and personal values. It is a dynamic field that continues to evolve in response to changing risk landscapes, emerging technologies, and new insights into risk assessment and mitigation.

Decisions about risk are often frustrated by conflicts and uncertainties at the interface of science and policy. Hannson has proven that there is considerable room for improvement in the decision-making process, and in particular its use of science. Philosophical tools and distinctions can play a key role in removing or dealing with the uncertainties associated with risk. Many of the so-called scientific controversies are not really conflicts within science, but between science and science denial or other forms of pseudoscience. In these cases, alleged uncertainties can be resolved by throwing out pseudoscientific claims and fabricated controversies. A significant portion of the remaining uncertainty is irrelevant to the decision even though it appears to be. Decision theory and ethics provide the means to address the remaining scientific uncertainties relevant to decision making (Hansson, 2018).

CONCLUSION

Risk management is especially important in the field of occupational health and safety.

Based on everything shown, we can conclude that the risk is transversal. Risk cannot be eliminated because it always exists. Organisations must therefore manage all the factors that increase and decrease these risks in order to achieve improved safety and reduced costs.

The concept of OHS risk management has changed over time. In the beginning, it implied only hazard identification and risk assessment. Over time, the concept was expanded to include other important parts, such as risk evaluation, risk control, monitoring and review, risk communication, legal and regulatory requirements, safety culture, emergency planning and preparedness, and continuous improvement.

The philosophy of OHS risk management is very complex. The philosophy of OHS risk management is very complex. It consists of a number of philosophical perspectives and aspects. Perhaps in no other field of management does the ethical and moral approach have as much importance as in OHS risk management.

It is very important to understand that risk has its objective and subjective aspects. Objective aspects imply a fact-based risk assessment. Subjective concepts form a set of values adopted by the person who assesses the risk, depending on the knowledge of the risks and dangers that the person knows, and depending on the person's exposure to a certain danger.

It can be stated that the goals and objectives of this research have been achieved. The analysis was carried out and the concepts of occupational safety risk management were presented. The philosophy of occupational safety risk management was analysed and presented. It is undeniable that further empirical research into the concepts and philosophy of occupational health and safety risk management is needed.

REFERENCES

Alli, B.O. (2008). *Fundamental principles of occupational health and safety.* International Labour Organization. Geneva.

Andrijanić I., Klasić K. (2002). *Tehnika osiguranja i reosiguranja.* Mikrorad. Zagreb.

Borghesi, A., Gaudenzi, B. (2013). *Risk Management - How to Assess, Transfer and Communicate Critical Risks*. Springer-Verlag Italia. Verona.

Björnberg, K.E., Hansson, S.O., Belin, M-A., Tingvall, C. (eds) (2022). *The Vision Zero Handbook: Theory, Technology and Management for a Zero Casualty Policy*. Springer.

Friend, M.A., P. Kohn, J.P. (2007). *Fundamentals of occupational safety and health.* Government Institutes. Linham.

Grubišić, A., Palačić, D. (2023) *Model procjene kemijskih i bioloških rizika u djelatnosti patologije,* 18th International Conference Management and Safety 2023. ESSE. Maribor and online. 18, 206-218.

Hansson, S.O. (1999). *A Philosophical Perspective on Risk*. AMBIO. 28(6). 539-542.

Hansson, S.O. (2018). *Risk, Science and Policy.* Ethical Perspectives. 25(3), 391-418. DOI: 10.2143/EP.25.3.3285423

HM Treasury. The Orange Book: Management of Risk - Principles and Concepts. Retrieved 5 October 2023. from https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/866117/6.6266_HMT_Orange_Book_Update_v6_WEB.PDF

Hopkin, P. (2017). *Fundamentals of Risk Management – Understanding, evaluating and implementing effective risk management*. 4th edition. Kogan Page. IRM.

ISO 31073:2022 Risk management – Vocabulary

ISO 9000:2015 Quality management systems - Fundamentals and vocabulary

Oxford University Press. (2023, March 15). Oxford English Dictionary, Retrieved 15 March 2023. from https://www.oed.com/

Palačić, D. (2011). *Sustavi upravljanja sigurnošću*. IPROZ. Zagreb.

Palačić, D. (2021). *Occupational health and safety risk management model.* 16th International Conference Management and Safety 2021. ESSE. Online Conference. 16. 52-63.

Palačić, D. (2023). *Chemical Health and Safety Risk Management Model***.** 18th International Conference Management and Safety 2023. ESSE. Maribor and online. 18. 26-36.

Peschard, I., Benétreau-Dupin, Y., Wessels, C. (2023). *Philosophy and Science of Risk: An Introduction*. Routledge. DOI: 10.4324/9780429023521

Pongrac, B., Majić, T. (2015). *Upravljanje poslovnim rizicima.* Tehnički glasnik. 9(1). 94-98.

Power, M. (2004). *The Risk Management of Everything - Rethinking the politics of uncertainty*. Demos. London.

Roeser, S., Hillerbrand, R., Sandin, P., Peterson, M. (eds) (2012).: *Handbook of Risk Theory: Epistemology, Decision Theory, Ethics, and Social Implications of Risk*. Springer. https://doi.org/10.1007/978-94-007-1433-5

The Institute of Internal Auditors, Inc. (2023, October 5). OnRisk: The Giude to Understanding, Aligning, and Optimizing Risk 2020, Retrieved 5 October 2023. from http://contentz.mkt5790.com/lp/2842/275148/OnRisk-2020-Report_0.pdf

The Institute of Risk Management, (2023, March 15). Retrieved 15 March 2023. from https://www.theirm.org

U.S. Department of Transportation (2013). Risk Management Handbook. Washington.

World Health Organization (2021). *Compendium of WHO and other UN guidance on health and environment.* Department of Environment, Climate Change and Health.

20th International Conference Man and Working Environment
SEMSIE
Safety Engineering & Management – Science, Industry, Education

www.znrfak.ni.ac.rs/semsie

MARIJA HADŽI-NIKOLOVA[1]
DEJAN MIRAKOVSKI[1]
NIKOLINKA DONEVA[1]
AFRODITA ZENDELSKA[1]
TEODORA TOPČEVA[2]

[1]Goce Delčev University, Faculty of Natural and Technical Sciences, Štip, North Macedonia
[2]Goce Delčev University, Faculty of Mechanical Engineering, Štip, North Macedonia

[1]*marija.hadzi-nikolova@ugd.edu.mk*
[1]*dejan mirakovski@ugd.edu.mk*
[1]*nikolinka.doneva@ugd.edu.mk*
[1]*afrodita.zendelska@ugd.edu.mk*
[2]*teodora3263@student.ugd.edu.mk*

COMPARISON OF NOISE POLLUTION IN AGGLOMERATIONS VS SMALL URBAN AREAS

Abstract: *In the last few decades, noise pollution has had a growing impact on quality of life, as a result of inadequate, unplanned urbanization, traffic intensification, usage of obsolete motor vehicles, etc. A number of surveys and monitoring studies in recent decades have shown that noise pollution, as a part of air pollution, presents a real threat to people's health and quality of life. Therefore, a two-year monitoring of noise level in three urban areas, the cities of Skopje, Tetovo (as an agglomeration), and Štip (as a smaller urban area), was performed. The Municipality of Štip was chosen as a representative of a small urban area with dynamic development, whose noise dispersion model (NDM) can be applied to all other similar urban areas. Based on performed measurements, a noise dispersion model for the three urban areas using SoundPLAN Software was developed.*
The aim of this paper is to point out the fact that small urban areas, such as Štip, also have a problem with high noise levels. On the other hand, they have no legal obligation to develop strategic noise maps and action plans for solving noise pollution problems, or to assess health effects related to high noise levels and apply noise reduction measures. The paper attempts to answer if small urban areas are safe from noise pollution and if they should also develop noise reduction action plans.

Keywords: strategic noise maps, action plans, noise dispersion model, human health

INTRODUCTION

A number of surveys and monitoring studies in recent decades have shown that environmental noise pollution is a real threat to human health and quality of life (Ising et al., 2009). Noise level generally increases each subsequent year, so some authorities claim that the average noise level in cities has increased by 1 dB per year for the last 30 years (Lambert et al., 1994). In developing countries, the problem of increased noise levels is mainly due to inadequate urban planning and overcrowding of cities. These countries are striving to engage in modern technological and industrial development trends and their governments are ready to sacrifice the environment for intensifying development and industrialization that will allow these countries to be competitive on the world market, neglecting the health of the population exposed to high noise levels (Hadzi-Nikolova, 2013).

Noise pollution is considered today as one of the main environmental problems in cities, as cited by the World Health Organization (2011), as the second among a series of environmental stressors for its public health impact in a selection of European Countries.

In this regard, strategic noise maps present the main tool for assessing exposure of the population to environmental noise as outlined in the European Directive 2002/49/EC (Directive 2002/49/EC). Different strategies can be considered for noise mapping. One is the elaboration of noise maps through computerized methods, usually performed by different commercial software, whereas a second option is *in situ* measurements (Bunn et al., 2016; Fiedler et al., 2015; Sarantopoulos et al., 2014; Romeu et al., 2011; Hadzi-Nikolova et al., 2013; Hadzi-Nikolova et al., 2012).

In the Republic of North Macedonia, according to available literature data, no extensive research about environmental noise levels and its harmful health effects has been carried out. There is no established state network for continuous noise level monitoring and, consequently, strategic noise maps have not been prepared yet.

Accordingly, the main objective of this paper is to define and analyse noise levels in urban areas and to consider proposed measures for improving the situation with noise pollution. As representative urban areas, the cities of Skopje and Tetovo were taken as agglomerations that, according to the Regulation on agglomerations, main roads, main railways, main airports for which strategic noise maps should be prepared (2011), have an obligation to develop a strategic noise map, while the City of Štip, as a smaller urban area, does not belong to the agglomeration group and has no obligation to develop a strategic noise map.

METHODS AND MATERIALS

Noise level measurements at 30 measurement points in the City of Skopje and the Municipality of Tetovo, as well as at 20 measurement points in the Municipality of Štip during 2 years of monitoring were performed in the one-third frequency octave band according to ISO 1996 2:2017 Acoustics – Description, measurement and assessment of environmental noise – Part 2: Determination of environmental noise levels (International Organisation for Standardisation, 2017), using a Sound Level Meter type CR:171C, an instrument Class 1 according to IEC 61762. Locations of all measurement points were selected near a busy intersections and commercial buildings as the main noise sources in urban areas.

Measurements were performed at 1.5 m height nearby main noise sources (frequency crossroad, commercial buildings) and on the most exposed facades of buildings at a 3.5 m distance from the buildings' walls and other reflective surfaces in accordance with the Regulation on locations of measuring stations and measuring points (2008). Frequency analysis provided additional information about the noise source as well as about the prevalence of certain frequencies and whether they are within the human hearing range. With measurements in the 1/3 frequency octave band, the following indicators were directly measured:

- L_d (Indicator for noise disturbance during the day) or daily noise level, which is A-equivalent long-term average sound level defined in ISO 1996-2:2017 (International Organisation for Standardisation, 2017);
- L_e (Indicator for noise disturbance during the evening) or evening noise level, which is A-equivalent long-term average sound level defined in ISO 1996-2:2017 (International Organisation for Standardisation, 2017);
- L_n (Indicator for noise disturbance during the night) or night noise level, which is A-equivalent long-term average sound level defined in ISO 1996-2:2017 (International Organisation for Standardisation, 2017);
- L_{eq} (Equivalent noise level) is an indicator of the noise calculated from the measured noise levels in an interval.

L_{den} (day-evening-night-weighted sound pressure level as defined in section 3.6.4 of ISO 1996-1:2017 (International Organisation for Standardisation, 2017) was estimated based on 24-hour noise levels data for each measurement location using the formula below:

$$L_{den} = 10 log \left[\frac{12}{24} 10^{0.1 L_d} + \frac{4}{24} 10^{0.1(L_e+5)} + \frac{8}{24} 10^{0.1(L_n+10)} \right] \text{D}$$

ay-evening-night level is a descriptor of noise level based on energy equivalent noise level (Leq) over a whole day with a penalty of 10 dB for night-time noise (23.00-7.00) and an additional penalty of 5 dB for evening noise (19.00-23.00).

Noise level data (source specific profiles) were embedded within the digital ground model (DGM) for each intersection, using one of the most advanced noise and air pollution modelling software packages, SoundPLAN 7.2, produced by Braunstein + Berndt GmbH / SoundPLAN International LLC19. The software features easy to use tools for DGM development, noise sources approximation, and contour maps calculation.

Fig. 1 shows a general overview of model development and contents of noise maps using the SoundPLAN 7.2 noise and air pollution modelling software.

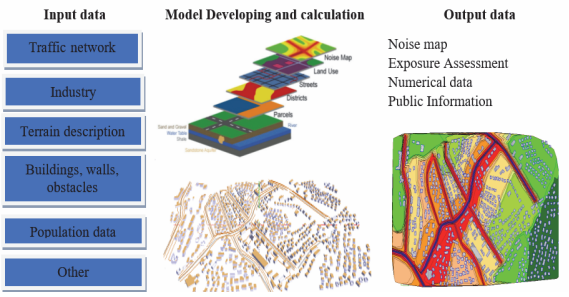


Figure 1. *General overview of model development and contents of noise maps (Hadzi-Nikolova, 2013)*

Noise maps present the existing and predicted noise emission level within the monitored area, determine the total noise exposure of the population caused by all human activities, giving directions on how to solve noise management issues and ensure efficient physical planning, planning of protection of existing spaces from noise sources, and 'acoustic space zoning' according to legally permissible noise levels.

RESULTS AND DISCUSSION

The results obtained during the 2-year monitoring for noise level indicators (L_d, L_e, L_n, $L_{eq,24h}$) in three urban areas, the City of Skopje, the Municipality of Tetovo, and the Municipality of Štip are presented in Table 1.

Table 1. *Measured noise levels in three urban areas*

Urban area	L_d (07.00-19.00)			
	Min dB(A)	Max dB(A)	$L_{eq,24h}$ dB(A)	Stan. dev.
Skopje	50.1	69.4	65.4	6.1
Tetovo	53.2	65.4	58.6	2.9
Štip	57.1	66.7	60.2	2.7
	L_e (19.00-23.00)			
	Min dB(A)	Max dB(A)	$L_{eq,24h}$ dB(A)	Stan. dev.
Skopje	56.5	69.8	62.8	6.1
Tetovo	51.2	62.4	56.1	3.3
Štip	56.3	65.1	58.6	1.9
	L_n (23.00-07.00)			
	Min dB(A)	Max dB(A)	$L_{eq,24h}$ dB(A)	Stan. dev.
Skopje	54.3	69.1	62.2	5.6
Tetovo	50.3	63.8	54.0	4.1
Štip	52.3	65.8	59.0	3.5

Table 2 compares the estimated day-evening-night level (L_{den}) and measured night noise level (L_n) values to the WHO (2018) recommended values.

Table 2. *Estimated day-evening-night level (L_{den})*

	L_{den} dB(A)	Max* dB(A)	L_n dB(A)	Max* dB(A)
Skopje	69.2	53	62.2	45
Tetovo	61.5	53	54.0	45
Štip	65.5	53	59.0	45

*WHO Guidelines strongly recommend reducing noise levels produced by road traffic below 53 dB during day-evening-night time (L_{den}) and below 45 dB during night-time (L_n).

Based on noise level measurement data and the number of vehicles on specific streets in the City of Skopje, Noise Dispersion Models (NDMs) were developed for individual parts of these three urban areas. The NDM for Aerodrom district was developed using data about the daily flow of vehicles for the following streets: Kuzman Josifovski Boulevard, Jane Sandanski Boulevard, Nikola Karev, Belasica, Bojmija, Vladimir Komarov, Vasko Karangeleski, Franjo Kluz, and Gjuro Djonović.

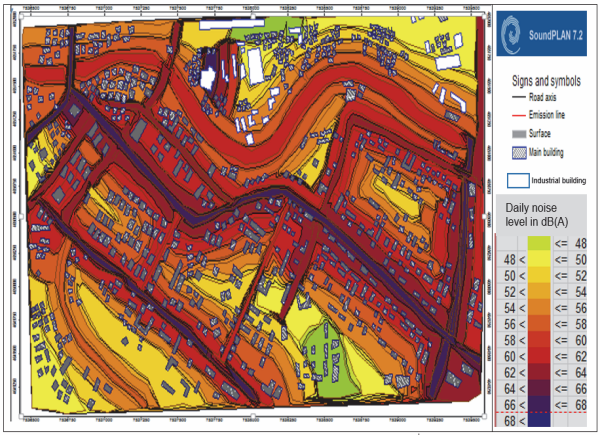


Figure 2. *Daily noise map for Aerodrom district – City of Skopje*

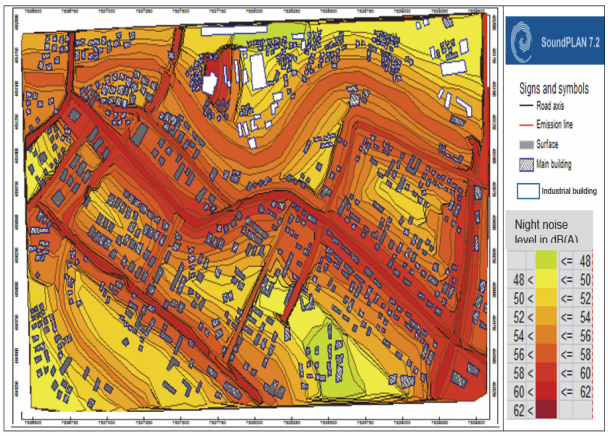


Figure 3. *Night noise map for Aerodrom district – City of Skopje*

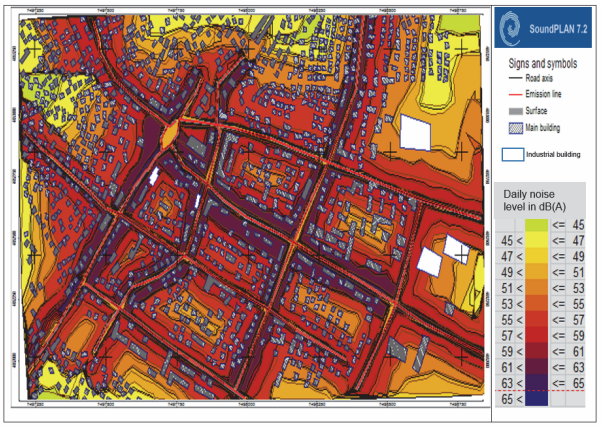


Figure 4. *Daily noise map for the central part of Tetovo*

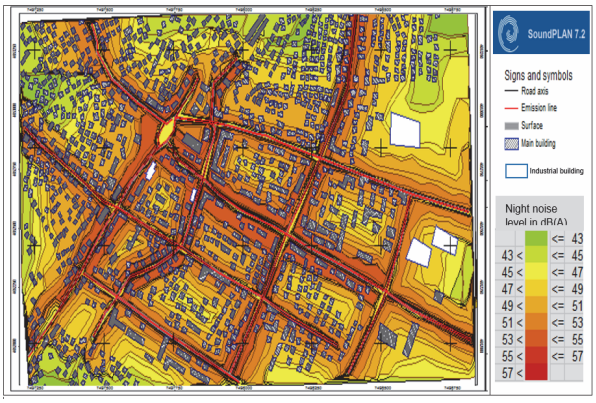


Figure 5. *Night noise map for the central part of Tetovo*

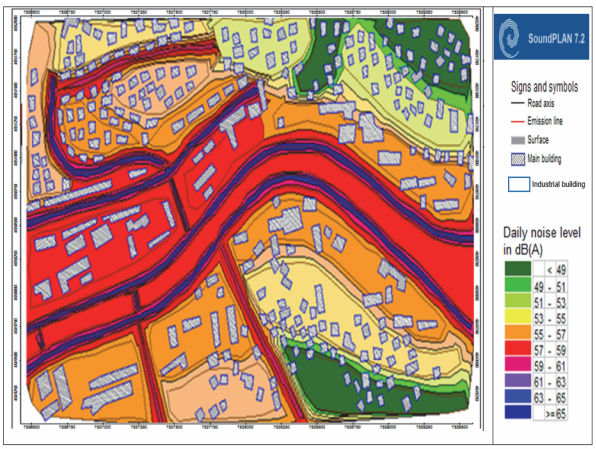


Figure 6. *Daily noise map for the central part of Štip*

The NDMs developed using the SoundPLAN 7.2 noise and air pollution modelling software clearly indicate excellent compliance between modelled and measured data for the three considered urban areas.

According to the Regulation on environmental noise level limit values (2008) regarding the permissible noise levels, the urban areas are divided into four groups, given in Table 3. All three urban areas, Aerodrom district (Skopje), the central part of Tetovo, and the central part of Štip are included in the third level area according to noise level protection.

Table 3. *Division of urban areas*

An area defined according to noise level protection	Noise level in dB		
	L_d	L_e	L_n
First level area	50	50	40
Second level area	55	55	45
Third level area	60	60	50
Fourth level area	70	70	60

Results from the 2-year monitoring of noise levels clearly indicate that the measured noise levels (daily, evening and night noise level) exceed the limit values for all three noise indicators, L_d, L_e, L_n, in accordance with the Regulation on environmental noise level limit values (2008). Exceedance of the permissible noise levels of indicators for daily and evening noise levels ranges from 5 to 7 dB for all measurement points. Significantly higher noise levels compared to the limit values were registered for the indicator of night noise, which exceeds the limit values by 7 to 13 dB. On the other hand, WHO Guidelines strongly recommend reducing noise levels produced by road traffic below 53 dB during day-evening-night time (L_{den}) and below 45 dB during night-time (L_n) (Table 2). If these recommended values according to the WHO Guidelines are exceeded, adverse health effects will occur frequently and a sizeable proportion of the population will become highly annoyed and sleep-disturbed. There is also evidence that the risk of cardiovascular disease will increase (WHO Regional Office for Europe, 2018).

High noise levels in the considered areas resulted primarily from traffic noise, increased number of motor vehicles, malfunction of motor vehicles, damaged roads, inadequate urban planning, bars, and commercial-office buildings.

The developed noise maps can serve as a basis for the preparation of strategic noise maps, which, in accordance with the Regulation on closer contents of strategic noise maps and noise action plans (2010) should contain data about

- Existing, previous or predicted noise conditions expressed through noise indicators;
- Overcoming the permissible noise levels;
- Estimated number of apartments, schools, hospitals, and similar facilities in a given zone exposed to higher noise level indicators;
- Estimated number of people in the area exposed to higher noise levels.

CONCLUSION

The results of two-year noise monitoring clearly indicate that small urban areas, such as Štip, also have a problem with high noise levels, so they need to prepare action plans, including noise level reduction measures, although they have no legal obligation to develop strategic noise maps and action plans for solving noise pollution problems, or to assess health effects related to high noise levels and apply noise reduction measures.

High noise levels and the developed noise dispersion models in the three considered urban areas, Aerodrom district in the City of Skopje, and the central city areas of the Municipalities of Tetovo and Štip, as well as harmful health effects related to high noise levels, clearly point out the necessity of developing a state monitoring network for continuous noise level measurement. Continuous noise level monitoring is necessary for smooth data collection, systematization, processing, establishment of a database, possibility of its usage, determination of the so-called 'hot spots', and development of strategic noise maps for urban areas. Proper urban planning and sound insulation of residential buildings are of particular importance for solving the noise pollution problem.

Considering the harmful health effects of noise (Ising et al., 2004; Van Kamp et al., 2012; Babisch, 2011; Hadzi-Nikolova et al., 2013; ACOEM, 2003; Button et al., 2004; Dalton et al., 2007; Mathews, 2009), the overall goal of an urban noise management and control policy is to ensure that all activities in society are aligned with the residents' wish for a quiet society. The broad operational objectives include requirements for protection, promotion, and improvement of quality of life, i.e. the requirements for environmentally sustainable development, reduction of health risks, and prevention of environmental degradation. Such a policy seeks to promote ecological well-being by preventing and minimizing noise pollution.

ACKNOWLEDGEMENTS

This paper is part of the Project, Monitoring and mapping noise level in urban areas, financially supported by Ministry of Environmental and Physical Planning of Republic of North Macedonia.

REFERENCES

ACOEM Noise and Hearing Conservative Committee. (2003*)*. Noise-induced hearing loss. *Journal of Occupational and Experimental Medicine, 45*, 579–581.

Babisch, W. (2011). *Cardiovascular Effects of Noise*. Noise & Health, 13.

Button, D. C., Behm, D. G., Holmes, M., & Mackinnon, S. N. (2004). Noise and muscle contraction affecting vigilance task performance. *Occupational Ergonomics, 4*, 751–756.

Bunn, F., & Zannin, P. H. T. (2016). Assessment of railway noise in an urban setting. *Appl Acoust, 104*, 16–23.

Dalton, B. H., & Behm, D. G. (2007). Effects of noise and music on human and task performance: A systematic review. *Occupational Ergonomics, 7*, 143–152.

Directive 2002/49/EC. *Directive 2002/49/EC of the European Parliament and of the Council of 25 June 2002 relating to the assessment and management of environmental noise*. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32002L0049

Fiedler, P. E. K., & Zannin, P. H. T. (2015). Evaluation of noise pollution in urban traffic hubs – Noise maps and measurements. *Environ Impact Assess Rev, 2*(51), 1–9.

Hadzi-Nikolova, M. (2013). *Modern approach in control and managing the noise in urban areas*. [Doctoral dissertation, Goce Delčev University, Štip, Republic of Macedonia].

Hadzi-Nikolova, M., Mirakovski, D., Despodov, Z., & Doneva, N. (2013). Traffic noise in small urban areas. *Transport & Logistics, 13*(27), 123-132.

Hadzi-Nikolova, M., Mirakovski, D., Delipetrov, T., & Arsov, P. (2012). Noise Dispersion Modelling in Small Urban Areas with CUSTIC 3.2 Software. *International Journal of Emerging Technology & Advanced Engineering, 2*(12), 84-88.

Hadzi-Nikolova, M., Mirakovski, D., Ristova, E., & Stefanovska Ceravolo, Lj. (2012). Modeling and Mapping of Urban Noise Pollution with SoundPLAN Software. *International Journal for Science, Technics and Innovations for the Industry MTM (Machines, Technologies, Materials),* 38-42.

Hadzi-Nikolova, M., Mirakovski, D., Zdravkovska, M., Angelovska, B., & Doneva, N. (2013). Noise Exposure of School Teachers – Exposure Levels and Health Effects. *Archives of Acoustics, 38*(2), 259-264.

International Organisation for Standardisation. (2017). *Acoustics – Description, measurement and assessment of environmental noise – Part 2: Determination of environmental noise levels*. (ISO Standard No. 1996-2:2017).

Ising, H., Babisch, W., Guski, H., Kruppa, B., & Maschke, C. (2004). *Exposure and Effect Indicators of Environmental Noise.* Berliner Zentrum Public Health.

Lambert, J., & Vallet, M. (1994). *Study related to the preparation of a communication on a future EC noise policy*. Final report. INRETS Report LEN No. 9420. Lyon.

Mathews, R. (2009). *The Effect of Community Noise on Health and Well-being.* [Master's thesis, Auckland University of Technology, New Zealand].

Regulation on agglomerations, main roads, main railways, main airports for which strategic noise maps should be prepared. (2011). Official Gazette of the Republic of Macedonia, No. 15/11.

Regulation on closer contents of strategic noise maps and noise action plans. (2010). Official Gazette of the Republic of Macedonia, No. 133/10.

Regulation on environmental noise level limit values Official. (2008). Gazette of the Republic of Macedonia, No. 147/08.

Regulation on locations of measuring stations and measuring points. (2008s). Official Gazette of the Republic of Macedonia, No. 120/08.

Romeu, J. Genescà, M. Pàmies, & T. Jiménez, S. (2011). Street categorization for the estimation of day levels using short-term measurements. *Appl Acoust, 72*, 569–77, 2011.

Sarantopoulos, G., Lykoudis, S., & Kassomenos, P. (2014). Noise levels in primary schools of medium sized city in Greece. *Sci Total Environ*, *482–483*, 493–500.

Van Kamp, I., Babisch, W., & Brown, A. L. (2012). Environmental Noise and Health. In R. H. Friis (Ed.), *The Praeger Handbook of Environmental Health. Vol. I* (pp. 69-93). ABC-CLIO.

World Health Organization (WHO). (2011). *Burden of disease from environmental noise.* Quantification of healthy life years lost in Europe. Denmark: WHO Regional Office for Europe.

WHO Regional Office for Europe. (2018). Environmental noise guidelines for European Region.

20th International Conference Man and Working Environment
SEMSIE
Safety Engineering & Management – Science, Industry, Education

www.znrfak.ni.ac.rs/semsie

RADOSLAV KURTOV[1]
DEJAN RISTIĆ[2]

[1] Academy at the Ministry of the Interior in Sofia, Fire Safety and Civil Protection
[2] University of Niš, Faculty of Occupational Safety

[1]*r_kurtov@abv.bg*
[2]*dejan.ristic@znrfak.ni.ac.rs*

PROBLEMS WITH ACTIVATION TIME OF JET FANS FOR EXHAUSTING SMOKE AND HEAT IN COVERED GARAGES

Abstract: *The possibility of using jet fans during a fire in closed car parks (garages) is discussed. Special attention is paid to the activation time of the main fans of the SHEVS and the jet fans. The proposal in "TS 12101 Smoke and heat control systems – Part 11: Horizontal flow powered ventilation systems for enclosed car parks regarding the timing of operation of SHEVS" has been revised. A solution has been proposed for timely activation of jet fans from an additional fire alarm installation.*

Keywords: smoke and heat exhaust ventilation systems (SHEVS), jet fans, activation time, TS 12101-11, automatic fire alarm system

INTRODUCTION

The growing tendency to increase and concentrate the population in big cities, as well as the affordable prices of cars, are increasingly affecting the appearance of cities. Vehicles parked on green areas and pavements are a common sight. In order to improve the environment and to 'clean' cities of vehicles parked in inappropriate places, underground and above-ground garages on one or more levels are increasingly being built. And while the problems, from a fire prevention perspective, are limited in the case of above-ground open garages, in the case of underground and closed multi-storey car parks, measures must be taken to secure them.

Due to the small volume of the garages (small height), the maximum permissible concentrations in terms of carbon and nitrogen oxides can be reached very quickly during normal operation, and the space can be filled with smoke products in case of a fire, which will lead to intoxication of the occupants and deterioration of visibility parameters, and thus force evacuation.

This fact is supported by the numerous fires that have occurred in closed garages.

Visibility during a fire in an underground garage with an area of 350 m^2 on Ralevitsa street in the Manastirski Livadi district in Sofia was reduced to such an extent that the reconnaissance team could not find the burning car, given that they were scouting tied to one another with two 20 m ropes. Using a thermal imaging camera, it was found that the burning car was less than 10 m from the entrance.

The fires in the last two years in the underground garage of the Mirage hotel in the city of Burgas were similar. Other garage fires broke out in the city of Pleven (Druzhba complex – destroyed cars and stored materials, damaged walls over an area of 2,500 m^2); in the industrial zone of the town of Nova Zagora (4 cars, computer equipment, 360 m^2 of roof construction, furniture, etc. destroyed); at the Park Hospital in the town of Plovdiv (all patients were evacuated) (Figure 1), etc.

Figure 1. *Fire in the garage of Park Hospital in Plovdiv*

Outside Bulgaria, 21 vehicles were destroyed in a fire in an indoor car park in Neckar Park, Stuttgart. As a result of the high temperature, structural elements were damaged. Also in Stuttgart, 10 vehicles were burnt and 39 people were seriously injured when two motorbikes caught fire in a garage. Losses were estimated at millions of euros. As a result of construction violations, smoke products were released through the door of the stairwell and gassed the building (Figure 2).

Figure 2. *Fires in garages in Stuttgart*

The situation in the event of a fire in garages where there are electric cars could be even more severe and unpredictable. Statistics show that in only one year the number of electric cars in Germany has tripled. Although at a slower pace, Bulgaria and Serbia are also following this trend.

In case of damage (breakdown – thermal runaway) of lithium-ion batteries of electric cars and cars with a hybrid drive, ten times the electrical charge is emitted in the form of heat (Autobild, 2021). Tests show that the temperature exceeds 1,000 °C. Charging stations are also a problem, as they can also be the cause of a fire, due to a technical defect, a cable that caught fire, or previous intent. In both cases, the consequences are serious. For example, approximately 22,000 litres of water are needed to cool the Tesla Model S battery (Autobild, 2021). Bearing in mind that 1,750 l of hot water vapour is released from 1 l of water that falls on the hearth, extinguishment becomes extremely difficult. In an incident in a garage in the town of Alkmaar, the Netherlands, it was necessary to use a fire extinguishing robot due to the released heated smoke products and steam.

SAFETY

The development of fires in confined spaces mostly leads to the formation of large amounts of smoke products (incomplete combustion) and the associated problems with evacuation and firefighting due to reduced visibility.

It is well-known that visibility is basically a function of several main factors:

The smoke-forming ability of substances and materials – m^3/kg;

The optical density of the smoke, i.e. its ability to block the penetration of light;

The illumination, depending on the strength of the light source and the reflective qualities of the environment;

The characteristics of the human eye.

The relationship between these factors is expressed by the coefficient of visibility loss – μ in Eqn. (1) (Grushevsky, 1989):

$$\mu = \frac{D_S M}{V}, \mathrm{m}^{-1}, \quad (1)$$

where:

D_S – optical density of smoke, m^3/kgm (120 for wood; 850 for rubber; 250 for paper);

M – mass of burned materials, kg;

V – volume of the room, m^3.

The results of experiments show that with heavy obscuration (μ=1.4–4.2 m^{-1}), visibility is within 1-2 m. Accordingly, with an average smokiness of μ=0.2-0.6 m^{-1}, the visibility is from 3 to 5 m and with μ less than 0.2, the visibility is from 8 to 15 m.

At the same time, if the smoke products have an eye-irritating effect, the distance at which a person in distress can be distinguished, for example, decreases from 15 to 5 m (with average smoke) (Grushevsky, 1989).

These statements are confirmed by experiments carried out in England, where it was found that approximately 130,000 m^3/h of smoke products are emitted during a car fire. Tests conducted in Austria (1 kg of rubber and polymer materials gasify a volume of approximately 2,500 m^3) and Scotland (burning of 10 kg of rubber and polymer materials fills a volume of approximately 25,000 m^3) also confirm these results (Rasbash, 1967; European Committee for Standardization, 2008).

If we assume that a fire occurs in a car (based on 150 kg of rubber, tire, and polymer materials), in garages with areas of 150, 300, and 750 m^2 and a height of 2.8 m the visibility will be: around 1 m, from 2 to 3 m, and 10-15 m, respectively.

For critical values of the coefficient of visibility loss, the following are assumed:

μ=0.46 m^{-1}, i.e. visibility 3-5 m – for people staying in a room with familiar architecture;

μ=0.1 m-1, i.e. visibility of 15-20 m – for people unfamiliar with the environment (Grushevsky, 1989)

SAFETY REGULATION

In order to ensure good visibility in a closed car park, for the purpose of evacuation of the occupants and correct and timely actions of the firefighters, it is necessary to use ventilation in fire conditions. Table 1 shows the normative requirements for the multiplicity of required ventilation for fire purposes in some countries.

Table 1. *Normative requirements for the multiplicity of required ventilation for fire purposes in some countries*

Country	Airflow for 1 passenger car m^3/h	Multiplicity n, h^{-1}
England		10
Germany		12
Nederland		10
Spain	540	10,8
Portugal	600	12
France	600*-900	12*-18
Turkey		10*-18

Notes:

Multiplicity is calculated on the basis of 50 m^3 volume occupied by one car.

The data with symbol * refer to multiples of air exchange in the presence of a sprinkler installation in the car park.

The analyzed positive aspects of jet fans have led to their increasing application in recent years (Kurtov, 2019). In Europe, only England has developed a standard concerning the basic requirements for them, which can be said to be largely debatable (British Standards Institution, 2013). In 2022, a technical specification on the purpose and operation of jet fans – TS12101-11 – was released for discussion, which contains important requirements, but as described in the preamble of the document, approval and possibly an update, taking into account the experience gained in European countries (European Committee for Standardization, 2022).

DISCUSSION

Much debated and essential to evacuation, visibility and firefighting is the topic of when to activate jet fans during a fire so as to allow for evacuation, provide sufficient visibility for smoke clearance, and rapidly locate the fire. In order to answer this fundamental question, it is necessary to analyse the following questions:

What is the distance from the furthest point in the garage to an escape route? Based on the speed of the spread of smoke products and the speed of movement, this distance should not be more than 40 m;

What is the maximum distance to the main smoke and heat exhaust fans?

What is the possible effective action of the suction field created by the fans at greater distances?

What is the configuration of the room and are 'dead zones' created, from which smoke products cannot be removed?

What are the area, height, and accordingly the volume of the garage, and how long could the smoke fill it, to what level, and for how long?

Are there structural obstacles to the horizontal movement of smoke products, such as beams and the like, and how deep are they?

Is it required to divide the area of the garage into smoke sections?

Obviously, due to the presence of too many questions, it is not possible to give an unequivocal answer to the question regarding the activation time of the jet fans. Therefore, at this stage there is a limited regulatory framework regulating the use of jet fans.

The lack of normative statements and experience related to the short period during which the jet fans are introduced in practice is accompanied in some cases by one main mistake, namely their activation simultaneously with the main suction fans. In order for the smoke and heat removal system to work effectively, however, it is mandatory that the jet fans start with a delay (which is also provided by CEN/TS 12101-11), after the activation of the main fans of the SHEVS.

The signing of CEN/TS 12101-11 from July 2022 provides an opportunity to discuss a firm regulation on activation time. The validity period of this technical specification is initially limited to three years. By 2025, CEN members must make their comments and provide an answer whether it can be implemented in practice, in its form as EN.

In the proposed regulation, the activation time is set to 4 minutes for the start of operation and 5 min for the full capacity of the jet fans (Figure 3). This largely corresponds to the requirements applied so far and the logic of operation of the jets, namely deceleration, in order to avoid destratification and mixing of the smoke, i.e. lowering it to the floor. A delay of 4-5 minutes will help complete the evacuation of the garage and subsequently provide firefighters with visibility of the scene of the fire.

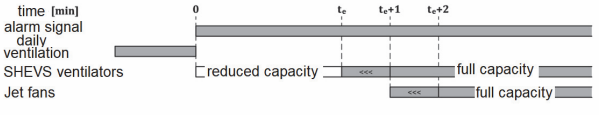


Figure 3. *Smoke ventilation activation sequence,* (European Committee for Standardization, 2022)

The latter position is advocated both in the English Standard (British Standard Institution, 2013) and in CEN/TS 12101-11 (European Committee for Standardization, 2022), where it is emphasized that if the jet fans are put into service too early, they could worsen the evacuation conditions, as they promote smoke circulation and the descent of the smoke layer. This is the reason why their activation is delayed.

It is very important to note that the basic principle that should guide the concerned authorities in this regard is that the jet fans should be put into operation only after the evacuation has taken place and the smoke layer has covered no less than 1/3 of the height of the garage. This essential setting is not considered in CEN/TS 12101-11 (European Committee for Standardization, 2022).

On the other hand, at a theoretical flue gas velocity of approximately 6.4 kg/s or 630 m^3/min (at a temperature of 300 °C), the delay time will be determined by the volume of the flue section served, i.e. of the time

required to fill× 1/3 of its height. In this regard, the larger the smoke section, the longer the delay in turning on the jet fans should be. With a maximum area of the smoke section of 2,600 m^2, the theoretical delay of the activation of the jets should not be less than 4.2 min, calculated on the following theoretical basis for filling 1/3 of the height of the garage:

$$M = 0.19 \times 12 \times 2^{3/2} = 6.4\,\text{kg}/s\,. \qquad (2)$$

At a flue gas temperature of 300°C, this amount will have the following expression in cubic meters:

$$L = \frac{6.4 \times 60}{0.61} = 630\,\text{m}^3/\text{min}\,. \qquad (3)$$

If the smoke section has an area of 2,600 m^2 and a volume of 7,800 m^3, then 1/3 of the volume (2,600 m^3) will be filled in time:

$$\tau = \frac{2600}{630} = 4.2\,\text{min}\,. \qquad (4)$$

Accordingly, if the smoke section has a smaller area, the delay time would be shorter. Thus, for example, for a smoke section with an area of 1,000 m^2, the delay time should not be less than 1.6 min.

If the weight burning rate is taken into account:

0.72 kg/m^2min, for synthetic rubber, 0.9 kg/m^2min, for rubber and polyurethane foam products, and a standard evacuation time of 2 min, they will burn at 1.4-1.8 kg/m^2.;

If it is assumed that 1 kg of these materials gasifies a volume of ~2,500 m^3, then the amount that will burn in ~2 min will fill a volume of about 4,000 m^3. In the case of a garage (smoke section) with an area of 2,600 m^2, i.e. volume of 7,800 m^3, nearly half of it will be filled in 2 minutes, and one third in ~1 min. If the garage has a smaller area, the time required for continuous and efficient operation of the jet fans would be significantly shorter.

In principle, the minimum delay time should be 2 min and it is related to the maximum permissible evacuation time from the premises and one-storey buildings intended for car parks. This time can be increased to 3 min in the presence of an automatic fire extinguishing installation. Adding the time to detect the presence of smoke from the fire alarm installation of 1 minute, the minimum jet activation delay time becomes 3 and 4 minutes, respectively.

It should be borne in mind that the reasoning is also a function of the width of the garage. This is evident from the dependence used in the European recommendations for designing SHEVS (European Committee for Standardization, 2009):

$$d_1 = \left[\frac{M_l T_l}{\gamma \Theta_l^{0,5} W_l} \right]^{2/3}, \qquad (5)$$

where:

γ is a bed factor and is equal to 36 if there is a deep bed or 78 if there is no bed at right angles to the flow;

d_l – minimum depth of the smoke layer in a smoke tank under a flat ceiling;

W_l – width of the garage, m;

It is clear from the presented dependence that the relationship between the thickness of the smoke layer and the width of the garage is inversely proportional, i.e. the narrower the garage, the faster the smoke layer will fall.

Experiments carried out in countries using jet fans to support the work of fire teams show that the delay in the activation of jet fans is in the range of 3 to 15 minutes.

Considering the difference in the methods of determining the activation delay of jet fans compared to the main ones, as well as the variety of factors affecting the spread of smoke products, it is best to determine this delay after playing real tests.

SUGGESTIONS

Apart from the numerous arguments listed on when jet fans should be activated, a major factor that is not taken into account at this stage is related to the question "How big is the fire?" It is essential to determine the activation time whether there is a burning car or, for example, a dustbin in a corner.

In this regard, the most authoritative solution for determining the delay in the time of inclusion of jet fans will be to wait until the plane of equal pressures falls to 1/3 (or even better, to 2/5) of the height of the room, i.e. the jet fans are tightly covered by the smoke layer so as not to promote circulation and mixing of the smoke products and not to further obstruct visibility. Since it is impossible to predict exactly where a possible fire will occur, and in order to avoid 'false' operation of the jet fans, due to misleading phenomena (burnt car gases or deteriorated operation of the fire detectors in unfavourable environments), it is necessary to install an additional fire alarm in the garage (the smoke section) through smoke-optical or another type of sensors, placed scattered on the walls, as far as possible from one another.

The operation of the jet fans should occur when a signal is received from three, four, or more fire detectors farthest from one another (located scattered along walls or columns) on the 'AND' system, i.e. when in reality the plane of equal pressures (the lower level of the smoke layer) falls to 1/3 (2/5) of the height of the room. In this way, 'false activation' will be avoided in a situation where an ignition occurs near the smoke-optical sensor.

A real scheme of operation of fire ventilation systems in the event of a fire in a closed garage would look like this:

The regulated time of 1 minute is waited, during which the point fire detector establishes ignition and sends the signal as intended;

Within 1 minute from the control panel, the elements of the SHEVS are activated: the supply openings are opened (supply fans are activated), the active smoke

barriers are lowered (if provided), and smoke hatches or fans are switched on (with the more powerful fans, the process to recruit full capacity is slightly longer);

Timely evacuation, which should not exceed 2 minutes, is carried out after the fire alarm;

When the plane of equal pressure falls to 1/3 (or 2/5) of the height of the room (depending on the specific conditions) and the detection of the lower level by the smoke-optical (or other type) fire detectors, the jet fans are activated (Figure 4).

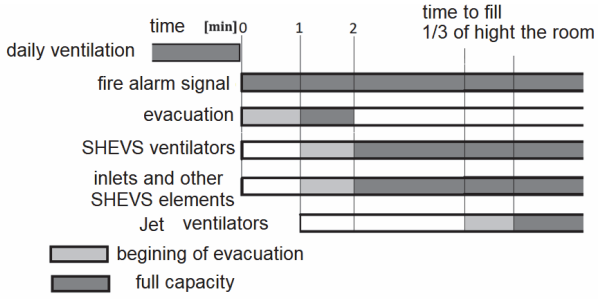


Figure 4. *Suggested sequence of times for activation of anti-smoke ventilation*

The timely detection of the fire and the activation of the EMS is essential. In order to guarantee this and to exclude the risk of false alarms, fire detectors in indoor car parks must be installed above the parking spaces, taking into account the reduction of the concentration of smoke products from the ventilation in the room and those created by movement air currents.

Currently, point heat detectors are most often used in the furnaces, and they give a signal when the temperature rises (usually to 60°C), as well as linear heat detectors (sensor cables or pipe systems with heat sensors).

There are also modern fire detectors that can perform intelligent signal analysis, and their detection methods can be adapted according to environmental conditions. They can be set to respond reliably only to ignitions, without false alarms. Practical experience shows that the ASA neural fire detector can distinguish real fire characteristics from flue gas emissions thanks to signal processing through ASA (Advanced Signal Analysis) (Security, 2016). If such detectors work with correct settings, the risk of unwanted signals and alarms can be practically excluded.

An option to implement the fire alarm is the use of CO sensors. In this way, the ventilation system can be effectively managed for daily ventilation, combined with the use in case of fire. When the concentration threshold is reached in terms of exhaust gases, the jet fans, which operate at a lower speed, are activated. When the concentration reaches the higher threshold, i.e. the fire is present, the frequency of both the main fans and jet fans is increased. In addition, for greater security and in order to avoid the mixing of smoke products, smoke-optical or ASA neural fire detectors should be used, detecting the lower level of the plane of equal pressures (Figure 5).

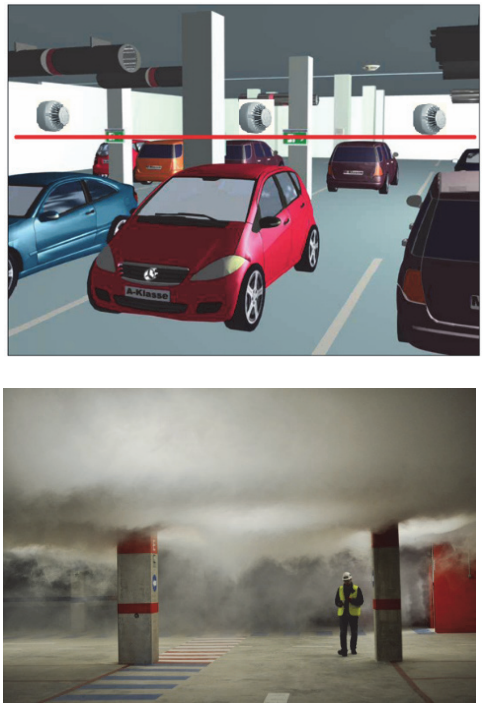


Figure 5. *Proposal for placement of smoke-optical sensors at level 1/3 of the height, to activate jet fans*

Since it is assumed that there are already fire detectors in the garage (point smoke detectors, CO detectors), due to the existence of a smoke extraction system, one of the possible solutions for the described problem in operation would be the installation of line smoke detectors.

The purpose of installing line smoke detectors is to realize a specific time delay in relation to the alarm signal that originated from already existing automatic fire detectors. The time delay for activating individual executive devices is provided by the European standard EN 54-2 Control and indicating equipment.

Two-zone dependence, that is, dependence of two alarm signals, would be used. The European standard EN 54-2 also defines three types of dependency, type A, type B, and type C, which realize a time delay. In this case, type B would be acceptable, which allows a maximum delay of the first alarm signal from the first alarm up to 5 minutes. In type B dependence, the alarm signal comes from two or more automatic fire detectors. Signalling of the alarm state in the system depends on the state of two or more detectors located in the same enclosure. So, in order to signal an alarm, that is, to activate the jet fans, it is necessary that the next alarm signal originate from another detector.

Most line smoke detectors have three alarm threshold settings. Since the goal is to detect when the layer of stratification has a thickness equal to 1/3 of the height of the room, the line smoke detector whose alarm threshold has the highest percentage of obscuration

would be selected. The most common combinations are 25%, 50%, 70% or 25%, 35%, and 50% obscuration.

Line smoke detectors would be sited at the greatest distance from the ceiling that the standard allows, and in this case it would be a third of the height of the room. In this case, the third alarm threshold would be used, i.e. 70% obscuration.

Therefore, the jet fans are activated the moment an alarm is triggered by the line detectors, and no later than 3 minutes after the first alarm, provided the infrared beam obscuration by 70%. The described reaction procedure is shown in the diagram (Figure 6).

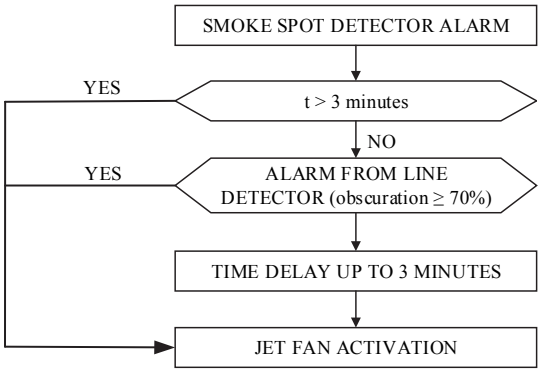


Figure 6. *Reaction procedure when the jet fan is activated*

Bearing in mind that linear smoke detectors cover an area whose dimensions are 7.5 meters to the left and right of the optical axis with a transmitter-receiver distance of 100 m, the number of line detectors required will depend on the complete construction and architectural characteristics of the garage, and, above all, on the distance between the pillars.

REFERENCES

Autobild. (2021). *No. 10-28. Are underground garages safe for electric cars?* https://autobild.bg/безопасни-ли-са-подземните-гаражи-за-е/

British Standards Institution. (2013). BS 7346-7: *Components for smoke and heat control systems – Part 7: Code of practice on functional recommendations and calculation methods for smoke and heat control systems for covered car parks.*

European Committee for Standardization. (2009). *CEN/TR 12101-5 Smoke and heat control systems, Part 5: Guidance on performance recommendations and calculation methods for smoke and heat ventilation systems*

European Committee for Standardization. (2022). *CEN/TS/12101-11 Smoke and heat control systems – Part 11: Horizontal flow powered ventilation systems for enclosed car parks.*

European Committee for Standardization. (2008). *EN 54-2 Fire detection and fire alarm systems / Part 2: Control and indicating equipment.*

Grushevsky, B. V., Yakovlev, A. I., Krivosheev, I. N., & Kudalenkin, V. F. (1985). *Пожарная профилактика в строительстве* [Fire Prevention in Construction]. Moscow, Stroiizdat.

Kurtov, R. (2019). *Application of jet fans in closed garages.* Studios, RIO AMVR.

Organization for Security and Co-operation in Europe. (2016). *Security Community Issue No. 4/2016. Fire safety in parking lots.*

20th International Conference Man and Working Environment
SEMSIE
Safety Engineering & Management – Science, Industry, Education

www.znrfak.ni.ac.rs/semsie

SNJEŽANA KIRIN [1]
MANUELA ŽAKULA [1]
FILIP STEVANOVIĆ [1]

[1]Karlovac University of Applied Sciences
Department of Safety and Security

[1]*snjezana.kirin@vuka.hr*
manuela.zakula@vuka.hr
filip.stevanovic@vuka.hr

INVESTIGATING THE COMFORT OF PROTECTIVE CLOTHING FOR FIREFIGHTERS

Abstract: *The usage of personal protection equipment (PPE) is determined by the nature of the job and responsibilities in the workplace. The HRN EN 469 standard defines how fire protection equipment should be manufactured and what requirements it should satisfy. The experimental part of the study investigated the subjective perception of firefighters and their satisfaction with the protective clothing they use. The results of the survey indicate that firefighters feel safe in the clothes they wear.*

Keywords: firefighter protective clothing, survey, firefighters

INTRODUCTION

Firefighting is a professional and humanitarian activity that involves the prevention of fires and explosions, fire extinguishment, the rescue of persons and property, and the provision of technical aid in accidents and dangerous circumstances. Firefighters are primarily exposed to various physical, chemical, and biological threats that pose a risk to their lives and health. Firefighters are subjected to extreme temperatures, especially while extinguishing fires in restricted areas, as well as different threats such as electric shock, explosions, and collapses (Horvat & Regent, 2009). In a fire to which the surfaces of protective clothing and equipment are exposed, they can reach up to 600°, and fires involving flammable liquids can generate temperatures of up to 1200° degrees (Hursa Šajatović et al., 2013).

Protective clothing for firefighters, and protective clothing in general, is designed to protect the wearer from multiple hazards at the same time. The HRN EN 340:2015 standard defines protective clothing as clothing that covers or changes personal equipment and provides protection against one or more risks that may endanger the safety and health of persons. This standard is complemented by the standard HRN EN 469 protective clothing for firefighters (Hursa Šajatovićet al., 2017; Stevanović, 2021). To be effective and functional, protective clothing must be universal (no distinction between men's and women's clothing), produced in a variety of ready-to-wear sizes, ergonomically designed according to anthropometric measurements of the human body to ensure a high level of comfort and freedom of movement, and specially designed (Čunko &Andrassy, 2005).

There are three types of fire intervention suits:

- Clothing for structural fires
- Clothing for open fires
- Reflective clothing.

The materials used to make protective clothing for firefighters differ from those used to make regular clothing in the composition of the raw material, i.e. the type of fibres used, and in their resistance to mechanical hazards, temperature, chemicals, radiation, biological damage, static electricity, etc. Thus, two to five layers of windproof, waterproof, and perspiration-permeable textile materials make up protective clothing (Zavec Pavlinić, et al., 2013).

The following materials are commonly used in protective clothing for firefighters:

- The outer material (outer shell) is extremely durable and resistant to heat and flames, mechanical influences, most solvents and acids; it must not burn, melt, fracture or disintegrate.
- Waterproof/breathable membrane that protects against the penetration of water from the environment.
- Thermal interlining, a material that slows the flow of heat from the outside of the clothing to the inside.
- An inner lining that shields the material from thermal barriers and adds an extra layer of protection to the user (Hursa Šajatović et al, 2013).

The clothing consists of a jacket, trousers, gloves, a helmet, boots or overalls. Protective jackets are made with additional reinforcements at the elbows and shoulders. The sleeves have a knitted cuff made of aramid fibers, two chest pockets, two side pockets, an elastic band for adjusting the waist circumference, a flame protection collar, a high temperature-resistant zipper, and reflective strips around the body and sleeves. The protective trousers contain elastic, adjustable shoulder straps, elastic waistbands, a zip with Velcro cover, side pockets with flaps, and extra reinforcements for the knees, sides, and sleeves (Hursa Šajatović et al., 2016).

The aim of this research was to investigate firefighters' subjective perceptions of protective clothing and their level of satisfaction while performing assigned tasks.

EXPERIMENTAL PART

An online survey on how comfortable it is to wear firefighters' clothing was undertaken as part of the experimental phase of the work, and the results were processed using MS Excel.

The survey on test subjects' satisfaction and comfort level with fire brigade clothing and equipment involved 107 participants from 9 public fire departments in the following counties: Zagreb (4 surveys), Sisak-Moslavina (4 surveys), Karlovac (24 surveys), Varaždin (4 surveys), Primorsko Goranska (6 surveys), Lička Senj (11 surveys), Virovitica (3 surveys)), Brod Posavina (16 surveys), and Zadar (35 surveys).

RESULTS AND DISCUSSION

All test subjects in the survey were male. Table 1 shows the test subjects by age, and it was found that most of the people interviewed were over 50 years old.

Table 1. *Age of the test subjects*

Age (years)	Number of test subjects
20-30	32
31-40	17
41-50	11
>50	47

Table 2 illustrates the people surveyed in terms of work experience, with the majority of test subjects having 5 to 15 years of work experience.

Table 2. *Work experience of test subjects*

Work experience (years)	Number of test subjects
0-5	24
6-10	25
11-15	24
16-20	15
20-30	15
>30	5

Figure 1 shows how satisfied the test subjects are with the firefighting clothing they wear. The majority of firefighters (48%) are satisfied with their clothing, whereas 24% of test participants had no opinion on the functioning and protection of their clothing.

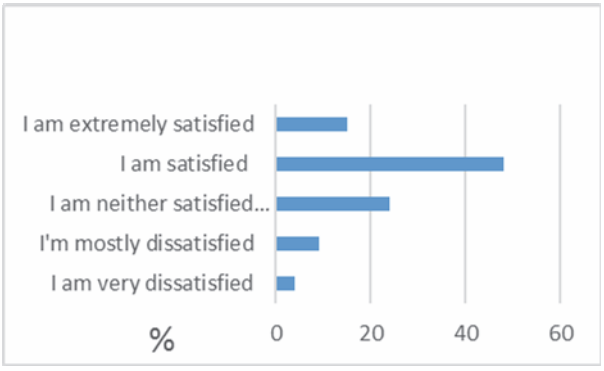


Figure 1. *Presentation of the percentage of firefighters satisfied with the work equipment*

Figure 2 shows the firefighters' grades for work boots. The work boots were rated as grade 4 by 47% and grade 5 by 25%.

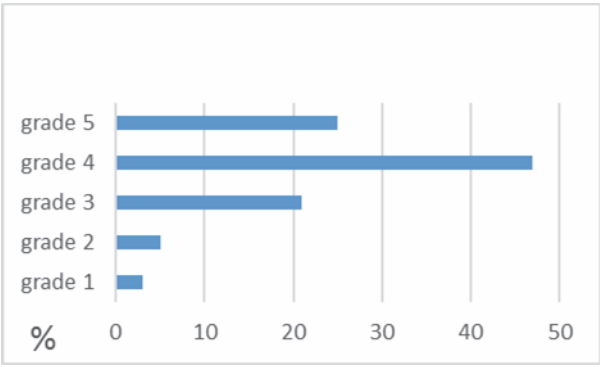


Figure 2. *Presentation of the percentage of firefighters who are satisfied with the firefighter boots*

Figure 3 shows that 48% of firefighters rated suits and gloves as grade 4 and 27% rated them as grade 5.

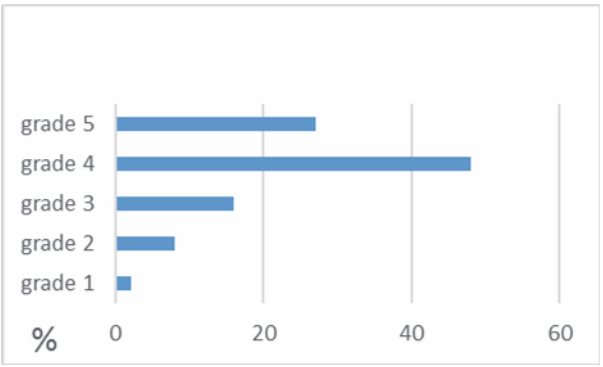


Figure3. *Percentage of firefighters satisfied with the suits and gloves*

Table 3 illustrates the firefighter evaluations of the functionality of the fire department. Based on the presented percentages, it is evident that firefighters give the functionality the highest rating, ranging from three to five. The majority of the test subjects (35%) give the grade 5 for satisfaction with the clothing size. Satisfaction with the comfort of the firefighter's suit is rated 5 by 31% of the test subjects, and satisfaction with thermal comfort is rated 5 by 34% of the subjects. This represents approximately one-third of the test participants who gave the highest grade.

Table 3. *Firefighter suit satisfaction ratings*

Grade [%]	1	2	3	4	5
Satisfaction with the clothing size of the firefighter suit	3	11	22	30	35
Satisfaction with the comfort of the fire suit from a functional point of view	5	5	34	26	31
Satisfaction with the thermal comfort of a firefighter suit	5	9	21	32	34
Satisfaction with the weight of the firefighitng intervention suit	5	12	30	28	25

Table 4 shows the level of satisfaction with the comfort and mobility of the garment on the arms, shoulders,

groin, waist, and knees. It can be seen that the test subjects gave ratings of 3, 4 and 5 with regard to comfort for individual parts of the body. The hand area's comfort and mobility received a satisfaction grade of 5 from 34% of the test subjects. 32% of the test persons gave a 5 for the shoulder area. 25% of test subjects gave a grade of 5 for comfort and mobility in the knee area. One-third of the test subjects who provided the highest grade corresponded to this.

Table 4. *Satisfaction ratings in terms of comfort and mobility of firefighters' suits*

Grade[%] / Comfort	1	2	3	4	5
in the hand area	5	8	24	29	34
in the shoulder area	3	8	25	31	32
in the groin area	4	12	25	33	24
in the waist area	6	7	25	31	30
in the knee area	4	9	26	34	25

Table 5 indicates how satisfied firefighters are with the length of the sleeves and legs of their firefighting intervention suits. It is evident that test participants graded the length of the sleeves and legs from 3 to 5 with most of them assigning a grade of 5. In addition, 37% of test subjects gave a 5 for satisfaction with the length of the sleeves, while 35% of test subjects gave a 5 for the length of the legs. This result corresponds to one-third of the test subjects who are satisfied with the length of the sleeves and legs.

Table 5. *Satisfaction with the length of the sleeves and legs*

Grade [%] / Satisfaction	1	2	3	4	5
with the length of the sleeves	5	9	27	29	37
with the length of the legs	5	14	22	23	35

Figure 4 shows the percentage of test subjects and the care given to the firefighting intervention suits. The results indicate that 76% of the examinees take care of their clothing personally, and 21% in the fire department, while 4% do it either personally or in the fire department.

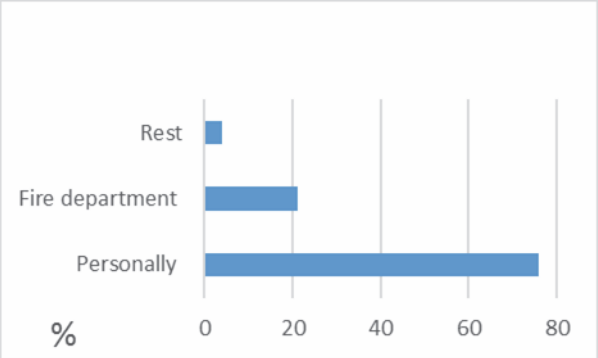


Figure 4. *Methods of taking care of firefighting intervention suits*

Figure 5 shows the percentage of the test subjects who feel safe in a firefighting intervention suit. It suggests that 65% of test subjects feel safe in the firefighting intervention suits with 20% feeling highly safe.

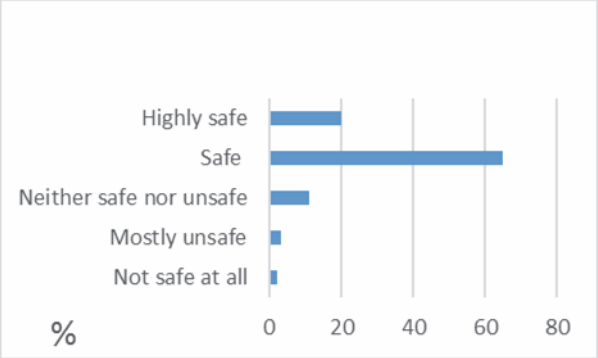


Figure 5. *Feeling of safety in the firefighters' intervention suit*

Figure 6 shows the results of a survey among firefighters about the need to replace firefighting clothing. 21% of test subjects feel that firefighting clothing should be replaced twice a year, 29% believe it should be replaced three times a year, 20% believe it should be replaced four times a year, and 30% believe it should be replaced five times a year.

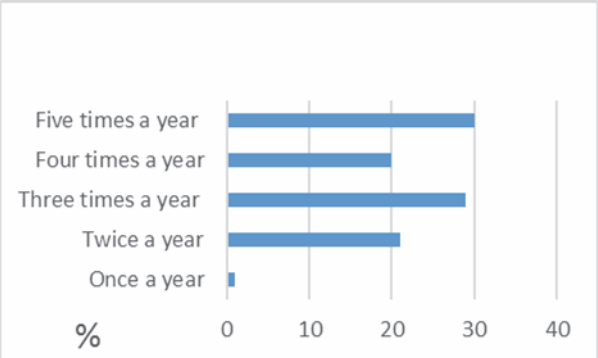


Figure 6. *Opinions regarding how often protective firefighting suits should be replaced*

CONCLUSION

When performing their jobs, firefighters are subject to a variety of risks, especially when fighting fires. Accordingly, firefighters' clothing should provide adequate protection.

The HRN EN 469:2006 standard prescribes the requirements for protective clothing for firefighters when extinguishing fires. The standard's requirements address the functionality and comfort of firefighting clothing when extinguishing fires, as well as methods of testing heat flow and heat transfer, tearing, waterproofing, and chemical penetration. A survey was conducted to determine the basic requirements prescribed by the standard in terms of functionality and comfort for firefighters. The clothing worn by firefighters in public fire stations conforms to the specified standard. The survey collected information on firefighters' subjective perceptions of protective clothing as well as their personal satisfaction with it.

Based on the presented results, most test subjects are satisfied with the size of the suit, its functionality and comfort. Furthermore, the majority of test participants are pleased with the comfort and fit of protective clothing for firefighters. According to the results of the survey, most firefighters wash their clothes in their own households. In order to ensure proper cleaning and maintenance of all types of clothing, fire departments should organize the washing of firefighters' suits. The results of the survey show that the majority of \ firefighters feel comfortable while wearing fire-protective clothing. However, despite the fact that the replacement of fire protection clothing depends on the financial resources of public fire departments, fire protection clothing should be replaced more regularly.

REFERENCES

Čunko, R., Andrassy, M. (2005). Vlakna, Udžbenik Sveučilišta u Zagrebu, ZRINSKI d.d., Čakovec

Horvat, J., Regent, A. (2009). *Osobna zaštitna oprema*, Veleučilište u Rijeci, Rijeka

Hursa Šajatović, A., Zavec Pavlinić, D.&Dragčević, Z. (2013). Vatrogasni odjevni sustavi za zaštitu od topline I plamena, *Tekstil 62 (3-4),* 160-173

Hursa Šajatović, A., Dragčević, Z., Zavec Pavlinić, D.& Čupić,M. (2016). Istraživanje stanja zaštitne odjeće za vatrogasce putem ankete, *Tekstil 65, (11-12*), 378-387

Hursa Šajatović, A., Dragčević, Z.& Zavec Pavlinić, D. (2017). Oblikovanje zaštitne odjeće, obuće I opreme s ergonomskog stajališta, *Sigurnost 59, (3),* 236-236

Zavec Pavlinić, D., Hursa Šajatović, A.&Mekjavić, I:B: (2013). *Sigurnost 55, (2),* 97-106

Stevanović, F. (2021): Zaštitna i radna vatrogasna odjeća, Završni rad, Veleučilište u Karlovcu, Karlovac

20th International Conference Man and Working Environment
SEMSIE
Safety Engineering & Management – Science, Industry, Education

www.znrfak.ni.ac.rs/semsie

JOVICA JOVANOVIĆ[1,2]
MILICA JOVANOVIĆ[2]

[1]Faculty of Medicine,
Faculty of Occupational Safety,
University of Niš
[2]Institute of Occupational Health Niš

[1]joca@medfak.ni.ac.rs
[2]m.jovano1995@gmail.com

IMPORTANCE OF OCCUPATIONAL MEDICINE IN THE MANAGEMENT OF WORKPLACE RISKS

Abstract: *Specialists of occupational medicine, psychiatrists, psychologists, ophthalmologists, and specialists of other branches of medicine are also involved in occupational health services. The leader of the team is a specialist of occupational medicine, which, based on all reviews and analysis, provides the final conclusion and proposal for the protection of each employee's health. In the Republic of Serbia, occupational medicine services are facing numerous problems.*

Keywords: occupational safety engineering, occupational medicine, new occupations

INTRODUCTION

The first knowledge about occupational diseases is old as medicine itself. It is well-known that the slaves who worked on the construction of the pyramids suffered from silicosis. The beginning of the development of occupational medicine is linked to the Italian doctor Bernardino Ramazzini (1633-1714), who published the book *The Morbis Artificum Diatriba* (Diseases of Workers). In 1700, Ramazzini introduced the term 'occupational disease' by observing workers who cleaned garbage and in whom gastro-enteritis was an endemic disease. Ramazzini discovered a connection between their occupation and this disease (Ramazzini, 2001).

Occupational medicine is all about keeping workers healthy and workplaces safe. Employees injured during the course of employment, or who suffer from work-related illnesses or diseases, require specialised care and may be eligible for workers' compensation benefits. These include medical and hospital services, medically necessary equipment and prescribed drugs, partial wage replacement, and rehabilitation services. The concept of occupational medicine implies a multidisciplinary approach focused on protecting and improving the health of employees, control of occupational diseases and injuries, assessment of occupational risks and their elimination, maintenance and development of working capacity, and the physical, mental, and social well-being of employees.

The **subject of study of occupational medicine** is the improvement and maintenance of the highest level of physical, mental, and social well-being of workers in all professions, prevention of any damage to health that could be caused by working conditions, protection of workers from danger due to the presence of harmful factors in the workplace, and adaptation of work to people and of each person to their workplace.

The **objectives of occupational medicine** include reduction, suppression, and prevention of occupational diseases, work-related illnesses, and injuries at work, attainment of the best possible working conditions, rationalisation of human work, and effective technical personal protection measures in order to preserve physical and mental health and work ability, to increase work productivity, and to prolong working life and the overall life span of workers.

The **tasks of occupational medicine** include diagnosis and treatment of occupational diseases, diagnosis of work-related diseases, prevention of occupational and work-related diseases, prevention of injuries at work, assessment of professional risks at work, monitoring of new technologies and their effects, health promotion in the workplace, study of occupational traumatism, prevention of employee disability, evaluation of the working capacity of the employed and the unemployed, health protection of workers employed in workplaces with increased risk, health care for all employees (WHO), and provision of first aid to injured and poisoned persons.

BRANCHES OF OCCUPATIONAL MEDICINE

Occupational medicine has the following branches:

Occupational pathology

Occupational pathology is a special branch and discipline of occupational medicine that studies epidemiology, aetiology, and pathogenesis of occupational and work-related diseases.

Industrial toxicology

Industrial toxicology studies the effects of acute and chronic exposure to toxic substances in the workplace, the mechanisms of their effects, and the degree of their toxicity.

Occupational Psychology

Occupational psychology studies behavioural reactions during work, inclinations and abilities for work, morbidity, and industrial neuroses. It is mainly oriented towards studying the mental health of workers and placing the right worker in the right workplace.

Professional traumatology

Professional traumatology studies the problem of occupational traumatism, medical contraindications for working in certain 'traumatogenic workplaces', psychological aspects of the human factor of injury, as well as the technical aspect of workplace injuries in order to create and maintain the safest possible working conditions (Al Saidi et al., 2023; Cherrie, 2023; Harber et al., 2010).

Occupational (and environmental) hygiene

The task of occupational and environmental hygiene is the prevention of occupational diseases, work-related diseases, injuries at work, fatigue, and exhaustion by creating and maintaining good conditions in the workplace. It defines the maximum allowed concentrations for every professional harm to which workers can be exposed during an eight-hour working time and for the entire working life without causing any damage to their health. Harmfulness in the working environment is constantly measured and preventive measures are proposed.

Occupational physiology

Occupational physiology developed in the time of the First World War (1914-1918), when the largest number of able-bodied people were on the frontlines. At the time, the industry was lacking workforce and it was necessary to increase production and to work at an accelerated pace. It was thought that increasing the working hours to 12 or even 14 hours could lead to an increase in production with the same number of workers. Unfortunately, the results were quite the opposite – a decrease in production, an increase in injuries at work, greater absenteeism from work due to illness, and a very current problem of fatigue and exhaustion appeared, which only then began to be studied from a medical perspective. For many years, work physiology has been identified with the study of the problem of fatigue and exhaustion. In recent times, ergonomics (from the Greek words *ergos* = work and *nomos* = rule), which studies the possibilities of adapting work and machines to the worker, finds the best organisation in the 'man-machine-work environment' system.

Occupational physiology has the following tasks:

- It examines the biochemical changes and processes that take place in the organism, as well as the ways in which individual organs, organic systems, and the organism as a whole adapt to working conditions and working environments.
- It studies how the organism performs the tasks set before it by the production process.
- It studies the physiological bases of work and rest regimes.
- It defines the work requirements of a job.
- It examines the physiological abilities of a person and the amount of effort they can exert to meet the demands of the workplace.
- It studies the problem of fatigue and exhaustion.
- It deals with the problem of professional orientation and selection.
- It studies the problem of occupational stress.
- It studies the nutrition of workers.
- It examines the motivation to work.
- It examines the problems of shift work, problems of night work, work on the conveyer belt, performance-related pay, as well as the problems of older workers.
- It deals with the problems of rest and recreation of workers.

CURRENT ROLE OF OCCUPATIONAL MEDICINE ACCORDING TO THE LAW

In accordance with Article 54 of the Law on Safety and Health at Work for health protection of employees at work, the employer is obligated to hire a healthcare institution that provides occupational medicine services, for which the competent state body has determined that the prescribed conditions for the performance of healthcare activities are fulfilled, in accordance with the law. The healthcare institution that provides occupational medicine services is obligated to perform tasks in accordance with this law, specifically: during the risk assessment procedure, it determines a proposal for health measures for workplaces where harmful effects above the prescribed values have been identified and confirmed; it monitors and studies the working conditions and proposes measures to protect the health of employees in relation to the risks to which the employee is exposed in the workplace and in the working environment; it conducts the training of employees to provide first aid; it determines and examines the causes of occupational and work-related diseases; it evaluates and determines specific health prerequisites that must be met by employees to perform certain tasks in workplaces with increased risk; it performs preliminary and periodic control and targeted medical examinations of employees and issues reports on medical examinations in accordance with the regulations on occupational safety and health; it monitors the employees' health condition in relation to workplace risks; it participates in organising first aid, rescue, and evacuation in case of injury to employees or accidents; it advises the employer when choosing a different suitable job according to the employee's health capacity; it advises the employer on the planning and organisation of work in terms of healthcare; it participates in the development of a program to improve working conditions in the workplace; it participates in the analysis of occupational diseases and work-related diseases; and it directly cooperates with the occupational safety and health officer (La Torre et al, 2023; Leckie, 2015; Raynal, 2015; Samuels, 2003). Preliminary, periodic, and targeted medical examinations of employees may be performed by a health institution that performs occupational medicine activities, for which the competent state authority has

determined that the prescribed conditions for performing health activities have been fulfilled, in accordance with the law.

ETHICAL DILEMMAS IN OCCUPATIONAL MEDICINE

Over the past decades, many new issues have come to the forefront, reflecting changes in the world of work, fragmentation, economic difficulties, demographic shifts, new technologies, and, more generally, the impact of globalisation. The workforce itself is also diversifying, with an increasing participation of women, migrants, and older workers. A growing body of literature on the impact of new forms of work organisation (e.g. changes in management methods, use of contractors and temporary staff, changes in working hours, and increased ability to work away from a fixed workplace or from home) highlighted the negative effects on workers' health and safety. The organisation of work itself can influence the level of psychological stress that workers experience and can increase health problems (e.g. musculoskeletal disorders, cardiovascular disease, and metabolic syndrome and diabetes) related to exposure to occupational hazards, which can lead to injuries or illnesses. These call for radical changes in occupational health, which is considered an important element in the social dimension of working life, in line with a broader concept of global and integrated promotion of well-being at work, giving rise to many new challenges for workers and their representatives, employers, managers, health service providers, government authorities, professional associations, and social partners alike. Although the topic of ethical conflict in occupational health has been discussed since the 1970s and has received increased attention in recent years, there has been no systematic attempt to study the true extent of these problems and how they are resolved in practice. In the process of management and adaptation to the changing world of work, ethics is often ignored even though there are several provisions in an organisation's code of manuals, ethics, and ethical culture. To this end, to deal with the complexity of today's ever-shifting world of work with its new socio-demographic features and new technologies, the logic of an integrated approach must take account of the importance of all three types of ethics: personal (individual), professional, and institutional. Before conducting an analysis, it is usually necessary to map out the situational context and the norms involved. Discussion, analysis, problem solving, and decision making are critical to the ethical resolution of conflicts. It is important to define the problem, obtain a careful analysis of the facts (e.g. stakeholders involved or affected), check on the values involved in any possible decision or try to anticipate the implications of alternative decisions, and evaluate the cost-benefit of an ethical decision. In the coming years, the occupational physicians should be able to act as care providers and experts, decision makers, communicators, counsellors, leaders, advisors, and managers. New challenges and new ways of working will necessitate a review of the competence and capacity of occupational physicians, with implications for future workers' health and safety. The main principles of medical ethics are patient welfare or beneficence (doing good for the patients), non-maleficence (doing no harm), patient autonomy, justice (ensuring fairness), providing the truth or benevolent falsehood, ensuring informed consent, and preserving patients' dignity. The goals of adopting the Code of Ethics are as follows:

- Establishing trust between patient and doctor;
- Ensuring the quality of medical services in the interest of the population's health;
- Preserving the freedom and reputation of the medical profession;
- Developing collegial relationships among doctors;
- Supporting all behaviour befitting the medical profession and preventing that which is unbecoming.

The provisions apply to all doctors who become members of the Serbian Medical Chamber and as such are obliged to familiarise themselves with the Code and to comply with it. It is irrelevant whether a doctor practices within the public or private healthcare sector (Spilchuk, House, & Holness, 2023; Lavicoli et al., 2018; Michel & Guillemin, 2019). The Chamber is also obliged to make sure that every doctor takes a medical oath when entering the register, and signs a statement that they accept the Code as their own.

CONCLUSION

Occupational medicine is one of the oldest areas of medicine. It aims to protect and improve the health of all employees, control professional diseases and work-related injuries, adapting to workplace risks and adapting every person to their workplace, monitor new technologies and their effects on health, and maintain and improve the work ability and the physical, mental, and social welfare of employees. The essential goal of occupational medicine is a healthy worker in a healthy workplace.

REFERENCES

Al Saidi, Y., Al Badri, F., Al-Hakmani, F., & Al-Mahrezi, A. (2023). Oman Vision 2040: Time to Upgrade Occupational Medicine. *Oman Med J. 31; 38*(1), e454. doi: 10.5001/omj.2023.92. PMID: 36873796; PMCID: PMC9975110

Cherrie, J. W. (2023). Occupational exposure science. *Ann Work Expo Health. 21; 67*(8), 915-919. doi: 10.1093/annweh/wxad052. PMID: 37669007.

Harber, P., Rose, S., Bontemps, J., Saechao, K., Liu, Y., Elashoff, D., & Wu, S. (2010). Occupational medicine practice: one specialty or three? *J Occup Environ Med. 52* (7), 672-679. doi: 10.1097/JOM.0b013e3181e36472. PMID: 20595920.

La Torre, G., Shaholli, D., Colaprico, C., Manai, M. V., Ammirati, S., Mantione, G., & Sernia, S. (2023). Occupational Medicine and Prevention of Chronic and Infectious Diseases. *J Clin Med. 15; 12*(16), 5298. doi: 10.3390/jcm12165298. PMID: 37629340; PMCID: PMC10455630.

Lavicoli, S., Valenti, A., Gagliardi, D., & Rantanen, J. (2018). Ethics and Occupational Health in the Contemporary World of Work. *Int J Environ Res Public Health 10; 15*(8):1713. doi: 10.3390/ijerph15081713. PMID: 30103403; PMCID: PMC6121687.

Leckie, A. (2015). Wither or whither now training in occupational medicine? *Occup Med (Lond). 65*(6), 426-428. doi: 10.1093/occmed/kqv117. PMID: 26240123.

Michel, P., & Guillemin, R. (2019). The New Dimensions of Occupational Health. *Health 11*(5). DOI: 10.4236/health.2019.115050

Ramazzini, B. (2001). De morbis artificum diatriba [Diseases of Workers] 1713. *Am J Public Health. 91*(9):1380-2. doi: 10.2105/ajph.91.9.1380. PMID: 11527762; PMCID: PMC1446785.

Raynal, A. (2015). *Occupational medicine is in demise*. BMJ. 11; 351, h5905. doi: 10.1136/bmj.h5905. PMID: 26561457.

Samuels, S. W. (2003). Occupational medicine and its moral discontents. *J Occup Environ Med. 45*(12), 1226-1233. doi: 10.1097/01.jom.0000095003.95440.2d. PMID: 14665808.

Spilchuk, V., House, R., & Holness, D. L. (2023). Assessment of clinical consultations in an academic occupational medicine clinic. *Occup Med (Lond). 14; 73*(1), 26-28. doi: 10.1093/occmed/kqac053. PMID: 35748332.

20th International Conference Man and Working Environment
SEMSIE
Safety Engineering & Management – Science, Industry, Education

www.znrfak.ni.ac.rs/semsie

ANGELINA CVETANOVIĆ[1]
GORAN BOŠKOVIĆ[2]
NEBOJŠA JOVIČIĆ[3]
MILOŠ JOVIČIĆ[4]

[1,2,3] University of Kragujevac, Faculty of Engineering,
[4] The Institute for Artificial Intelligence Research and Development of Serbia, Novi Sad, Serbia

[1] *angelina.pavlovic@uni.kg.ac.rs*
[2] *goran.boskovic@kg.ac.rs*
[3] *njovicic@kg.ac.rs*
[4] *milos.jovicic@ivi.ac.rs*

FORECASTING SUSTAINABLE STEEL SUPPLY CHAINS: A CASE STUDY

Abstract: *To maintain and enhance competitiveness, organizations must monitor market dynamics, conduct comprehensive analyses, and proactively make informed decisions while continually adapting their business strategies to evolving conditions. In the modern business environment, the implementation of business intelligence plays a key role in improving the decision-making processes of management within organizations. This implementation implies the utilization of processes, technologies, and tools that facilitate the transformation of data into actionable information, information into knowledge, and knowledge into strategic plans, ultimately enabling effective decision-making and management. An essential objective of business intelligence is the identification of trends, patterns, and intentions, which advance the formulation of predictive scenarios for future outcomes. Consequently, the aim of this paper is to present a comprehensive approach to quantitative time series prediction and qualitative Delphi prediction techniques. The specific focus of the study centres on forecasting supply chain dynamics, particularly the estimation of raw material consumption within organizations observing circular economy principles. Supply chain management within the circular economy framework involves detailed planning and management of all system activities with a primary goal of reducing resource utilization during production, reducing the amount of material stocks in the plant, and minimising the amount of generated waste. For this research, a specific production organization X was selected, specializing in the manufacture of bodies for motor vehicles, trailers, and semi-trailers, with steel as the predominant raw material. The choice of this organization is justified by the potential for a substantial impact on climate change mitigation through steel flow planning in the production process. Steel industry is recognized as a significant contributor to CO_2 emissions, accounting for approximately 4-5 % of total emissions. By minimizing the use of the analysed raw material, circular economy objectives can be effectively realized. The study highlights substantial disparities between the actual and predicted figures for steel consumption, specifically hot-rolled steel sheets. These variations are attributed to the exceptional circumstances during the SARS-CoV-2 pandemic. Consequently, the research highlights that the historical data from 2019-2020 utilized as the foundation for this study may not be fully representative due to the fact that operations during that period were carried out under an emergency regime prompted by the SARS-CoV-2 pandemic.*

Keywords: circular economy, quantitative forecasting, qualitative forecasting, time series, Delphi method

INTRODUCTION

Rapid and frequent market changes resulting from globalization demands call for a review of how organizations are managed, all with the goal of achieving a predefined business vision within a specified timeframe. Continuous growth of the global population has a direct impact on the increased consumption of goods and services, which, in turn, drives the global economy. However, this surge in global consumption poses significant economic and environmental challenges, such as imbalanced production and consumption, fluctuating prices, and environmental pollution.

The fundamental issue with the current production and consumption of goods and services lies in their connection to a linear economic model, characterized by a one-way flow of energy and materials. To address these challenges, organizations have increasingly embraced sustainable and green practices, aligning with the principles of sustainable development and circular economy (Manavalan & Jayakrishna, 2019).

Transformation of required economic models can be achieved through the adoption of circular economy principles, emphasizing the importance of repairing, reusing, and improving products during their lifecycle, rather than their permanent disposal. This approach not

only conserves resources but also incentivises resource efficiency by connecting industry supply chains.

Effective supply chain management in organizations requires detailed planning to meet customer needs, procure raw materials, manage production, ensure delivery, and facilitate returns of products (Regodić, 2014). According to circular economy principles, managing stocks is a crucial aspect of circular supply chain operations, involving the monitoring of raw materials, semi-finished products, and finished goods. A circular supply chain expands the scope of a closed-loop supply chain by promoting a zero-waste vision, not only within its immediate supply chains but also by collaborating with partner firms in the same or other industrial sectors (Lima & Seuring, 2023).

Accurate forecasting of raw material consumption is essential to proactively address future deviations, enhance raw material management, and adjust business operations when necessary.

Given the rapid technological changes impacting every aspect of modern life, supply chain forecasting aligns with the requirements of Industry 4.0 and facilitates the adoption of a circular economy. This study aims to explore the application of statistical methods in managing raw material supply chains in line with the circular economy principles.

MATERIALS AND METHODS

Today, iron alloys, collectively referred to as technical iron, play an essential role in technical applications. These alloys constitute approximately 95% of the world's total metal production (Jovanović et al., 2003). The widespread use of technical iron is made possible due to significant and easily accessible reserves of iron ore in the Earth's crust, as well as the straightforward processing of iron ore and the diverse physical and mechanical properties of iron alloys (Wondris et al., 2016). Technical irons are classified based on their carbon content into the following categories: pure iron (with very low carbon and other elements), steel (with carbon content typically not exceeding 2%), and cast iron (with carbon content above 2%) (Arsić, 2020).

Steel, available to consumers in various forms, such as hot-rolled, cold-rolled, or cast, has been irreplaceable in societal development for a long time. However, the pressing environmental challenges of the present demand novel approaches and production processes that address climate change and enhance resource efficiency. In order to tackle these challenges, it is imperative to invest in research and development of innovative technologies for producing commonly used resources such as steel. The demand for steel continues to grow, given its fundamental role in society, from infrastructure and construction to transportation. However, steel production is known for its significant energy intensity (World Steel Association, 2012). The steel industry relies heavily on extracting vast quantities of natural materials, such as iron ore (e.g. magnetite) and carbon. Notably, the greenhouse gas most associated with the global steel industry is carbon dioxide (CO_2), with an average emission of 1.41 tons of CO_2 per ton of steel produced (IEA, 2023). The global steel industry is an important emitter of CO_2 and it is considered that it has a 4-5% share in the total emission of CO_2. Consequently, effective management of this raw material is crucial in mitigating climate change.

Long-term reductions in industry emissions require a shift from current production models to new, more environmentally friendly approaches. Steel, being 100% recyclable, can be used repeatedly in a closed loop, aligning with the principles of circular economy. The "4R" concept – reducing the use of steel, reusing it, remanufacturing, and recycling – guides the implementation of circular economy in the steel industry.

Planning and organizing the supply chain for steel are crucial for using this resource in an energy-efficient, environmentally sustainable, and economically viable manner. Given that Serbia ranks 46th among the world's largest steel producers, with 1.9 million tons of steel produced in 2019 (Basson, 2020), and considering steel's suitability for closed-loop management, this research focuses on analysing statistical methods for forecasting the hot-rolled steel (HRS) sheets supply chain in a production organization situated in the city of Kragujevac.

Data collection

To ensure data protection and maintain the confidentiality of the analysed organization, all general information will be anonymised, and the organization will be pseudonymously identified as X throughout this research.

X is a Serbian production organization specializing in the manufacturing of bodies for motor vehicles, trailers, and semi-trailers. Renowned as a leading producer of commercial vehicle bodies, truck enhancements, and specialized vehicles within the Serbian market, X is recognized for its products' quality, innovative design solutions, and long-lasting durability. Within organization X, all products are categorized into two primary groups: the first group comprises cargo boxes with tarpaulin, while the second group includes thermal chambers.

To determine the primary raw material within the organization, which will be the focus of the research, all necessary data was extracted from the company's records to conduct a material flow analysis.

Material flow analysis (MFA) serves as a crucial analytical tool for quantifying materials within a well-defined system, both temporally and spatially, with the objective of achieving a material balance (Brunner & Rechberger, 2017).

Upon analysing material flows within organization X, it was established that the primary input materials encompass steel, aluminium, plywood, insulation materials, tarpaulin, laminate, adhesives, and an input flow of energy. In the production line, the output flows consist of final products, while waste generation and exhaust gases result in emissions.

The MFA reveals that HRS sheets are a frequently utilized raw material in the production process of organization X. This case study focuses on the analysis of HRS sheets, intended for further processing through cold forming and employed in a wide range of

industries, including machinery, vehicles, construction, shipbuilding, industrial equipment manufacturing, metal processing, and construction. HRS sheets refer to carbon-manganese steels with guaranteed elasticity, tensile strength, and satisfactory extensibility.

This study focuses on the consumption of the analysed raw material within organization X during the period from July 2019 to December 2020. The data was gathered through a questionnaire distributed to several production organizations operating in the city of Kragujevac. It is noteworthy that the management of the organization X only expressed interest in participating in this research. Figure 1 illustrates the consumption of HRS sheets and their average specific market price during the observed period.

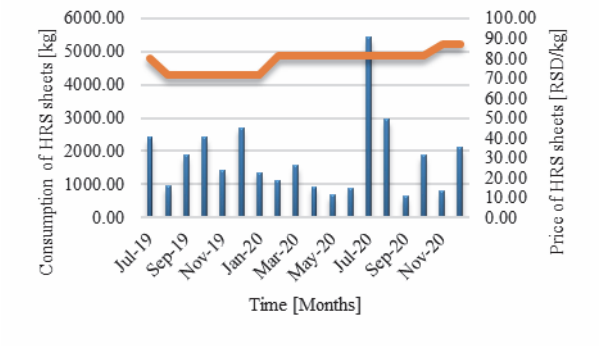


Figure 1. *The influence of fluctuation in the price of HRS sheets on consumption*

Based on Figure 1, it is evident that the price of HRS sheets exerts minimal influence on steel consumption. This assertion can be empirically substantiated using appropriate statistical methods, such as regression and correlation analyses. A comprehensive statistical examination has unveiled a negative (-) correlation coefficient, indicating an inverse, negative relationship. Additionally, the square of the Pearson correlation coefficient, known as the coefficient of determination, quantifies the extent to which variations in one variable can be attributed to changes in another variable. In this instance, the Pearson coefficient showed a value of -0.045. A comparative analysis of this value with literature values (Cvetković, 2015) leads to the conclusion that there exists a weak correlation, often referred to as a low direct correlation, between the consumption of HRS sheets and their price. Specifically, through correlation and regression analysis, it has been established that changes in HRS sheets consumption are only minimally influenced by fluctuations in price.

Forecasting methods

Forecasting can be defined as a systematic and forward-looking participatory process. It facilitates the development and formulation of medium- and long-term policies. Figure 2 illustrates the fundamental components of the basic forecasting model, including input, methodology, and output. This model remains consistent regardless of the specific forecasting technique used.

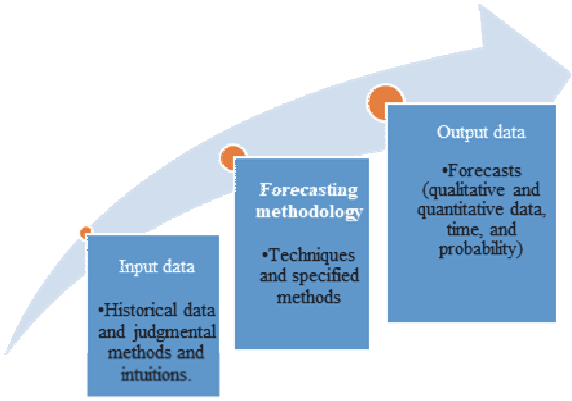


Figure 2. *Forecasting model*

The forecasting process necessitates inputs, specifically data or expert judgment, and the application of specific forecasting techniques. These primary forecasting techniques are divided into three fundamental categories (Walk, 2012):

- Quantitative techniques: These involve the creation of quantitative models based on historical data.
- Qualitative techniques: These rely primarily on non-numerical, descriptive data gathered through expert assessments and opinions.
- Hybrid techniques: These methods combine both qualitative and quantitative approaches using the strengths of both.

In this research, quantitative forecasting methods, specifically time series analysis with a trend component, were employed, alongside qualitative forecasting techniques such as the Delphi method.

Time series analysis has proven to be a valuable tool for forecasting. It allows management to predict the demand for materials for the upcoming months based on historical data, facilitating the planning of production capacities, workforce allocation, raw material stocks, product distribution, and more. It is evident that time series analysis is particularly reliable for short-term forecasting. Most time series data can include several components that contribute to their variations, including trend, seasonality, cyclicality, and random components.

Business intelligence encompasses technologies that empower business users to access, analyse, and utilize data to obtain the essential information required for effective decision-making and management within organizations. Notably, business intelligence technologies also facilitate users in the business to conduct statistical analyses, including forecasting. One of the simplest ways to incorporate business intelligence into the forecasting process in production organizations is by employing various forecasting software solutions. Many forecasters commonly utilize a combination of tools, opting for either Microsoft Excel or specialized forecasting software for their forecasting needs (Syntetos et al., 2016).

In this research, Microsoft Excel software was employed because historical data on a specific variable from organization X's records were available. These

data were utilized to create a forecast using Excel functions such as "forecast" and "trend". As part of this research, these functions were used to validate the values obtained from the previous forecasting method.

The last method utilized in this research was the Delphi method. The Delphi method is a specific, qualitative, and systematic approach that involves gathering and processing the opinions of experts on specific forecasting issues (Vujošević, 1997). Its primary objective is to reach a consensus among experts on a defined topic through a series of surveys (Chan et al., 2001). What sets the Delphi method apart from other qualitative methods are its key characteristics, including anonymity, an iterative process involving rounds of research with feedback, statistical analysis of responses, and a predefined questionnaire (Lang, 1995). These advantages make the Delphi method particularly relevant when applied to research topics with a strong social desirability aspect, such as sustainability and circular economy (Gebhardt et al., 2022).

The Delphi method allows for variations in answers, where participants (known as panellists) can respond to a specific question with one or three answers. If three answers are required, the meanings of the given answers are as follows:

O represents the optimistic answer, signifying a high probability of the event occurring, implying the shortest expected time for the activity's execution.

M corresponds to the expected response, indicating the time when the event is almost certain to take place, representing the most likely time for activity execution.

P stands for the pessimistic answer, suggesting a low probability of the event occurring and representing the longest expected time for the activity to be completed.

In the classical Delphi method, typically only one answer is expected for the corresponding future event or activity. The classic single-answer Delphi method involves panellists providing only the expected response (M). The responses collected from the Delphi questionnaire are predominantly subjected to statistical analysis, which involves the calculation of various parameters, including the median, dispersion, and the probability of the event occurring.

The scheme for forecasting HRS sheets consumption using the Delphi method within organization X is illustrated in Figure 3.

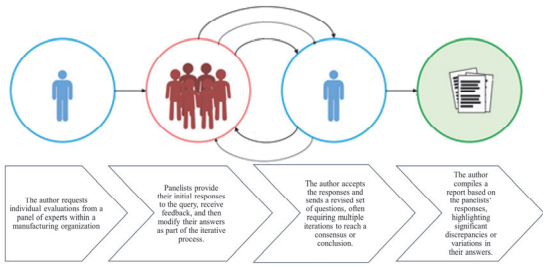


Figure 3. *Forecasting with the Delphi method in a specific organization*

The fundamental steps outlined in the implementation of the Delphi method are in alignment with the recommended methodological framework established in existing literature (Chedi, 2017).

To initiate the Delphi study, experts or respondents were carefully selected to form the expert panel. The number of panellists is a crucial aspect of the Delphi method and typically ranges from 5 to 15 individuals. The selection of these experts for participation in the study was carried out in collaboration with a representative of the production organization X. Once the relevant job positions interested in participating were identified, e-mail addresses were requested from the organization's contact person to facilitate the distribution of the Delphi survey questionnaire. The Delphi survey questionnaire is a fundamental research tool and the main tool in Delphi forecasting.

Creating the questionnaire involves formulating questions related to the relevant area of prediction and defining possible answers to these questions. It is also possible to quantify the responses in the questionnaire, which facilitates subsequent statistical data analysis. The questions within the questionnaire must be clearly understandable and formulated in a way that ensures all panel members interpret them uniformly and correctly, aiming to create the highest quality questionnaire possible. The questionnaire used in this case was structured into two parts. The first part collected general information about the panellists, including their gender, age, educational level, and years of work experience. The second part contained specific questions related to the consumption of the analysed raw material.

The questionnaire comprised two specific questions, each requiring a distinct response related to the consumption of HRS sheets in the production organization X:

(1) Do you assume that the consumption of HRS sheets sheet will be less, greater, or equal to the forecasted value of 1,791.44 kg for the month of January 2021?

(2) In which month of 2021 do you expect the consumption of HRS sheets in your organization to be 1,791.44 kg, which is the forecasted value?

Given the significance of resource efficiency and waste reduction in the context of the circular economy, the panellists were also asked to assess the productivity of using steel as a critical resource in the production process. The productivity of resources in the analysed organization was not previously determined, but for the purposes of this study, it was considered to be low concerning the use of HRS sheets. Consequently, the panellists were asked to respond to the following question:

In which month of 2021 do you expect the productivity of using HRS sheets in your organization to reach 30 %?

As data on the current productivity of HRS sheets usage was not available, a value of 30 % was chosen in collaboration with the management to initiate the Delphi method and obtain a consensus of opinion among a group of experts within the organization. Many researchers halt the survey rounds of Delphi

studies when they achieve a predetermined consensus among the panellists. In this research, a reference value of the variance of 1.2 was established as the criterion for concluding the study. This means that in a given iteration, the variance of a specific response must be less than or equal to the reference value to exclude the question from the subsequent iteration or to terminate the research. This value was chosen based on its frequent use as a benchmark variance value in the literature (Levi-Jakšić et al., 2015).

RESULTS

Fluctuations in the market necessitate organizational management to adapt their approaches in order to attain well-defined business objectives, such as profitability, growth, development, and long-term sustainability. Monitoring business changes is of strategic importance in improving an organization's functioning, allowing for effective analysis and real-time assessment of the current business environment. Consequently, it is imperative to manage organizations effectively, employing activities such as forecasting, organizing, directing, coordinating, and controlling.

Time series forecasting methods

Dynamic analysis is employed in the examination of time series data to ascertain the progression, trends, and rate of change in a variable phenomenon over time. Time statistical series consist of data points gathered and categorized within specific time intervals (Jovetić, 2006). The initial step in time series analysis involves visually representing the data and making a visual assessment. In this research, the consumption of HRS sheets within production organization X is examined over an eighteen-month period (Figure 4). The analysis reveals that this data series displays an impulse pattern.

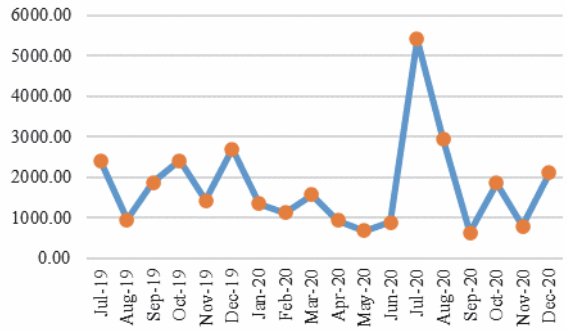


Figure 4. *Time series data characteristics*

This research focuses on analysing the trend component, which is one of the most common variations contributing to changes in time series data. When analysing a particular time series, the application of a linear trend is appropriate if there is a consistent, linear development and movement of the variable.

A key condition for applying a linear trend in time series analysis is that the variable, over the observed time period, should experience approximately the same magnitude of increase or decrease.

Building on the concept of a simple regression function, the linear trend function is defined by Equation 1. In this equation, x represents the independent variable value, which is time in the context of time series analysis, while y_t signifies the trend in the observed phenomenon's value, a indicates the trend's value when x is equal to 0, essentially representing the average of the time series over the observed period, while b is the coefficient indicating the average absolute increase in successive time periods:

$$y_t = a + bx \tag{1}$$

Given that the observed dataset, specifically the consumption of HRS sheets within production organization X, contains an even number of data points, it is necessary to select two data points from the middle of the time series. To these selected data points, values of -0.5 and +0.5 are added, respectively. To forecast the consumption of HRS sheets in the upcoming month for organization X, it is necessary to continue by adding a value of +1 to the independent variable x and repeat this process until it reaches the desired forecasted month. The trend in the consumption of HRS sheets for production organization X can be graphically represented, as shown in Figure 5, with the yellow line on the graph denoting the projected consumption of the analysed raw material for the next 6 months (January 2021 – July 2021). In the first following month of the analysis, the expected consumption (y_{t19}) is projected to be 1,791.44 kg.

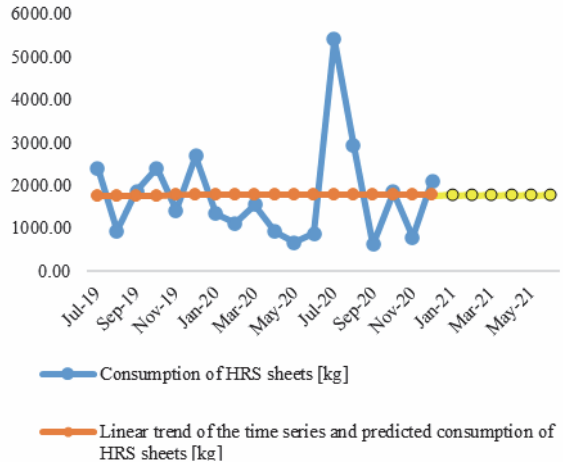


Figure 5. *Linear trend of the time series and predicted consumption of the analysed raw material*

When the central tendencies of a time series do not follow a straight-line pattern, a linear trend may not accurately represent the long-term movement of the phenomenon. In such cases, it becomes necessary to employ alternative trend models, such as parabolic or exponential trends, to better capture and describe the behaviour of the data.

Business intelligence and forecasting

When applying the aforementioned functions within Excel software to forecast the consumption of HRS sheets in the 19th (January 2021) month of analysis, a value of q_{t19} = 1,789.18 kg is obtained. This reveals

certain discrepancies in comparison to the value derived from the time series with a trend component.

Given that the first derived value of 1,791.44 kg for the forecasted consumption of HRS sheets is slightly higher than the Excel-generated value of 1,789.18 kg. The first value is adopted for further analysis. It is essential for further research that the forecasted consumption value, represented as y_{t19} = 1,791.44, belongs to the set of real numbers. However, it is important to note that the model used for this forecast may have limitations because real-world situations are often complex and may not be precisely described with available data. A comprehensive description of a real system frequently requires more detailed data than can be gathered at a single point in time (Zimmermann, 2001). Hence, when defining forecasted consumption values, it is crucial to express the analysed variable using linguistic terms or a language variable. In this particular case study, the expressions used to describe the variable over time are rooted in human reasoning. The terms are defined by the organization's management team on a scale of 1-9, where 1 represents the lowest value (extremely small) of the variable, and 9 signifies the highest value (extremely large) of the variable. The management team has associated specific values with each point on the 1-9 measurement scale, reflecting the range from extremely low to extremely high. The interval size is determined by the range of data and the nature of the feature set. In this instance, the maximum consumption of HRS sheets in the analysed period, y_{max} is 5420 kg, and the minimum consumption y_{min} is 629 kg. With a total of 18 data points n, the interval size i is calculated as 927 kg using Equation 2.

$$i = \frac{y_{\max} - y_{\min}}{1 + 3.322 \cdot \log_n} \quad (2)$$

To gain a deeper understanding of the current consumption of the analysed raw materials within the organization, it is necessary to map the forecasted value y_t to one of the five listed outcomes from Table 1.

Table 1. *Linguistic terms of consumption of the analysed raw material*

Definition	Interval
Extremely low value	[629-1556)
Low value	[1556-2483)
Middle value	[2483-3410)
High value	[3410-4437)
Extremely high value	[4337 <

Based on the comparison of the forecasted value y_{t19} = 1,791.44 kg for the first following month and the intervals shown in Table 1, it is concluded that the forecasted value has a low value.

Forecasting using the Delphi method

Forecasting using the Delphi method in the specific production organization X, which operates in the city of Kragujevac, was carried out following the steps shown in Figure 3.

The Delphi survey questionnaire was transmitted to the panellists via the Internet. One of the significant advantages of using modern media is the expedited feedback process, which is a crucial factor in the Delphi technique. This accelerated communication allows for more rapid iterations and consensus-building among the experts involved in the Delphi process.

In the initial Delphi iteration, the questionnaire was distributed to seven employees at the production organization X, resulting in an initial response rate of 71.43 %. As previously emphasized, the first part of the questionnaire in the initial Delphi round gathered information about the panellists' general data. The general data of the panellists are presented in Table 2.

Table 2. *General data of the panellists*

Feature		Frequency	Percentage of panellists [%]
Gender	Male	3	40
	Female	2	60
	Total	5	100
Feature		Frequency	Percentage of panellists [%]
Age	18-25	1	20
	26-35	1	20
	36-45	2	40
	46-55	1	20
	Over 55	0	0
	Total	5	100
Education level	High School	0	0
	Vocational college	3	60
	Bachelor	2	40
	Master	0	0
	Total	5	100
Years of work experience	Up to 2 years	1	20
	3-5	2	40
	6-15	1	20
	Over 15	1	20
	Total	5	100

The distribution of answers related to the question of whether the consumption of HRS will be less, equal, or greater than the predicted value is illustrated in Figure 6.

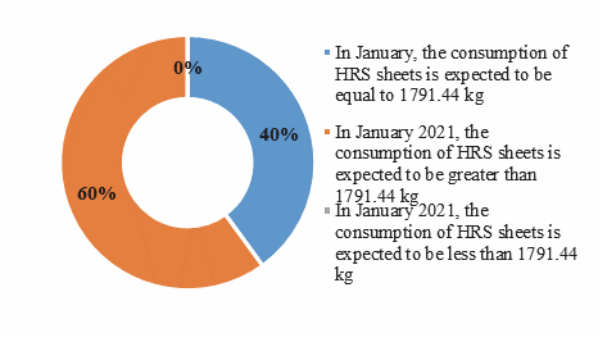


Figure 6. *Distribution of answers regarding the consumption of HRS*

The responses of the panellists to the question regarding the forecasted month in 2021 when the productivity of using HRS sheets will reach 30 % are depicted in Figure 7.

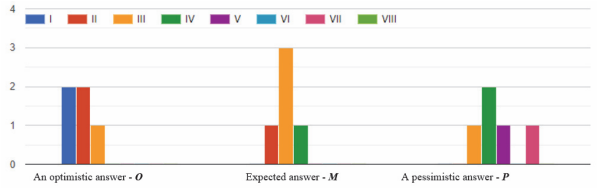


Figure 7. *Distribution of answers regarding the productivity of using HRS sheets*

The panellists were asked to provide answers for the month when there is a high probability of the event occurring, the month when the event is almost certainly expected to occur, and the month when there is a low probability of the event occurring (O, M, and P answer). In such cases, the average time of realization (t_n) of an event is determined according to mathematical relation 3.

$$t_n = \frac{1}{n}\sum_{i=1}^{n} t_i \qquad (3)$$

The individual time (t_i) provided for each panellist is determined on the basis of weights, which are always equal and obtained using the PERT method, while n indicates the total number of panellists.

Based on the answers of the panellists in the first iteration, the productivity of the use of raw materials at 30% in the analysed organization is expected to occur in approximately 2.07 months, which is in the first half of March 2021. A consensus was reached for the said question, as indicated by the received variance value, which is lower than the reference value. Since a consensus has been reached, this question can be omitted in the next iteration.

The panellists were asked to provide their expected answer regarding which month of 2021 (January-August) the consumption of HRS sheets in the organization will be 1,791.44 kg, which is the forecasted value. In this case, where only one answer was required from each panellist, the average time of realization (t_n) of an event is statistically determined using mathematical relation 4:

$$t_n = \frac{1}{n}\sum_{i=1}^{k} t_i f_i \qquad (4)$$

In Equation 4, f_i represents the frequency, which indicates how often the same answer is repeated within a given unit of time. The other parameters in this equation are the same as those in Equation 3.

In the first iteration, the answers were diverse, and no consensus was reached, as the variance exceeded the reference value. Therefore, two additional iterations were conducted (Questionnaire 2 and 3), until the variance matched the reference value. The diversification of responses in all three iterations is shown in Figure 8.

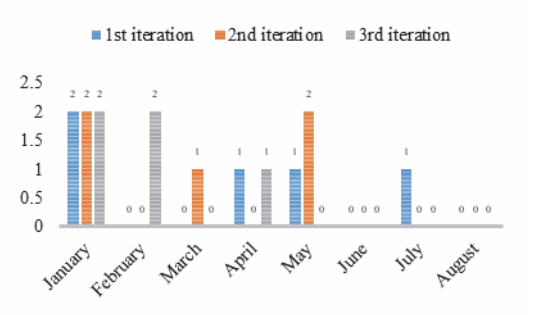
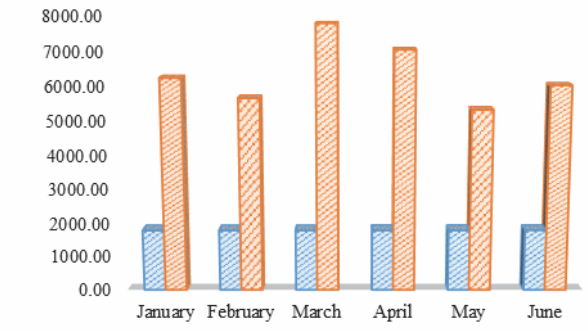


Figure 8. *Distribution of responses in three iterations*

In the initial iteration, based on the responses of the panellists, it was anticipated that the consumption of HRS sheets within the organization would reach 1,791 kg in approximately 2.6 months. Subsequently, in the second iteration, a consensus among the panellists indicated that the forecasted consumption would occur within 2 months. Finally, in the third and concluding iteration, an even stronger consensus was obtained, highlighting that the consumption is expected to reach 1,791 kg in just 1 month. This iteration met the criteria for a satisfactory consensus, as the variance for this question equalled the reference value, emphasizing the conclusion of the Delphi research process.

Evaluating forecast accuracy

To assess the accuracy of the forecasts, it is crucial to calculate the deviation errors between the actual and predicted consumption values of the analysed raw material. As previously noted, quantitative forecasts were made for the period from January to June 2021. Hence, real consumption data for HRS sheets for this specified time range was obtained from the organization's records. A comparison of the actual and predicted consumption of HRS sheets in organization X during this timeframe is presented in Figure 9.



	January	February	March	April	May	June
Forecasted consumption of HRS sheets [kg/month]	1791.44	1792.62	1793.80	1794.97	1796.15	1797.32
Actual consumption of HRS sheets [kg/month]	6241	5665	7787	7042	5327	6029

Figure 9. *Actual and forecasted consumption values*

From the information presented, it is possible to calculate the Mean Absolute Percentage Error (MAPE),

which represents the average of the absolute differences between actual and predicted values expressed as percentages (Equation 5).

$$MAPE = \frac{1}{n}\sum_{t=1}^{n}\left|\frac{A_t - F_t}{A_t}\right| \quad (5)$$

In Equation 5, A_t represents the actual value of the variable, while F_t represents the predicted value of the observed variable. Using this equation, the resulting MAPE of 71.27 % suggests substantial differences between the actual and predicted consumption values of the analysed raw material.

The variance between forecasted consumption of HRS sheets and the actual consumption within production organization X can be attributed to a range of factors, including demand fluctuations (in response to economic conditions, market trends, or seasonality), supply chain disruptions (caused by delays in raw material deliveries), production variability (resulting from machine breakdowns and operational issues), challenges within inventory management (involving overstocking or understocking), quality issues, and economic factors (such as inflation and currency exchange rates). Notably, the COVID-19 pandemic emerges as the most prominent factor during the analysed period. With the spread of SARS-CoV-2 at the end of 2019 – economic, social, commercial, communication, and tourism restrictions were applied in many countries around the world. On 30 January 2020, the World Health Organization declared the COVID-19 pandemic, which was followed by the lockdown of countries. Lockdown has led to disruptions in supply chains and a drop in industrial production. For instance, the steel sector experienced decreased demand in 2020 due to the halt in automotive production, which consequently led to reduced steel consumption compared to 2019. This global trend also affected the specific production organization X under analysis, so it is considered that the increased actual consumption of HRS sheets in the first half of 2021 year is the result of the industry recovery in general.

CONCLUSION

Due to the evident negative environmental outcomes of economic activities, the management of production organizations is under increasing pressure to reduce the harmful effects of their operations on the environment. The costs of prevention and remediation of environmental pollution affect the total costs, and management organizations seek to improve their economic and environmental performance simultaneously. Economic activities heavily rely on natural resources, which are limited. The rising global demand for resources has led to price volatility and the risk of resource scarcity. Addressing these challenges can be achieved through the adoption of a circular economy. Transitioning towards a more sustainable, greener, and circular economy involves reduced resource consumption, investments in environmental practices, and innovation, and can yield significant advantages in terms of competitiveness and job creation.

In line with the principles of circular economy, the goal is to keep raw materials within the economy for as long as possible and minimize waste generation. To achieve this, efficient supply chain management is crucial. Following the circular economy concept, it is essential to plan the quantity of raw materials used in the production process effectively. This can be accomplished through various predictive methods, which can be both qualitative and quantitative. Excessive consumption of metals can disturb the implementation of circular economy. Therefore, this paper focused on a specific case study of production organization X, which specializes in manufacturing bodies for motor vehicles, trailers, and semi-trailers. One of the primary raw materials used in their production process is HRS sheets. To forecast the consumption of HRS sheets in this organization, both quantitative methods (Time series method with a trend component) and qualitative methods (Delphi) were employed.

In the comprehensive analysis conducted in this case study, it was determined that the combination of qualitative and quantitative methods employed was not entirely suitable for forecasting supply chains in alignment with the principles of the circular economy. It is important to note that the historical data used for this analysis may not be fully representative, as the organization was operating under an emergency regime during the specified period. Therefore, this may have affected the accuracy and adequacy of the forecasting methods.

It is imperative to conduct a comprehensive analysis of the aforementioned factors that may contribute to consumption deviations. This analysis is crucial for enhancing forecasting accuracy and aligning supply chain and production processes with the principles of circular economy. While acknowledging the significance of COVID-19 pandemic as a potential driver of observed variations in the analysed period, it is equally vital to account for the broader contextual factors in future research.

REFERENCES

Arsić, D. (2020). *Otpornost na pojavu i širenje prslina u navarenim spojevima termopostojanih čelika*. Fakultet inženjerskih nauka Univerziteta u Kragujevcu.

Basson, E. (2020). *2020 World Steel in Figures*. World Steel Association, Brussels, Belgium, 30.

Brunner, P. H., & Rechberger, H. (2017). *Practical Handbook of Material Flow Analysis for Environmental, Resource and Waste Engineers* (2nd ed.). Taylor & Francis Group/CRC Press.

Chedi, J. M. (2017). A Preliminary Review on Needs Analysis and Delphi Technique: Effective Tools for Data Collection. *Journal of Asian Vocational Education and Training*, *10*, 44-52.

Cvetković, Lj. (2015). *Korelacija i linearna regresija* [Correlation and linear regression]. Retrieved 11 November 2023, from https://people.dmi.uns.ac.rs/~lila/files/V2_ES.pdf

Gebhardt, M., Spieske, A., & Birkel, H. (2022). The future of the circular economy and its effect on supply chain

dependencies: Empirical evidence from a Delphi study. *Transportation Research Part E: Logistics and Transportation Review*, *157*, 102570, https://doi.org/10.1016/j.tre.2021.102570

IEA – International Energy Agency. (2023). *Steel*. Retrieved 10 October 2023, from https://www.iea.org/energy-system/industry/steel

Jovanović, M., Adamović, D., Lazić, V., & Ratković, N. (2003). *Mašinski materijali*. Mašinski fakultet Kragujevac.

Jovetić, S. (2006). *Statistika sa aplikacijom u Excelu*. IP Inter print.

Levi-Jakšić, M., Marinković, S., & Petković, J. (2015). *Menadžment inovacija i tehmološkog razvoja*. Fakultet organizacionih nauka, 432, ISBN: 978-86-7680-309-5.

Lima, F. A. D., & Seuring, S. (2023). A Delphi study examining risk and uncertainty management in circular supply chains, *International Journal of Production Economics, 258*, 108810, https://doi.org/10.1016/j.ijpe.2023.108810

Manavalan, E., & Jayakrishna, K. (2019). An Analysis on Sustainable Supply Chain for Circular Economy. *Procedia Manufacturing*, *33*, 477–484. https://doi.org/10.1016/j.promfg.2019.04.059

Regodić, D. (2014). *Logistika – lanci snabdevanja*. Univerzitet Singidunum, 433, ISBN: 978-86-7912-564-4.

Syntetos, A. A., Babai, Z., Boylan, J. E., Kolassa, S., Nikolopoulos, K. (2016). Supply chain forecasting: Theory, practice, their gap and the future, *European Journal of Operational Research. 252*(1), 1-26, https://doi.org/10.1016/j.ejor.2015.11.010

Vujošević, M. (1997). *Operativni menadžment – kvantitativne metode*. DOPIS, Beograd

Walk, S. (2012). Quantitative Technology Forecasting Techniques. *Technological Change, 6*, 103-124.

Wondris, E. F., Nutting, J., & Wente, E. F. (2016). *Steel*. Encyclopaedia Britannica. Retrieved 6 October 2023, from https://www.britannica.com/technology/steel

World Steel Association. (2012). *The white book of steel*. World Steel Association, Brussels, Belgium, 53.

Zimmermann, H. (2001). *Fuzzy set theory and its applications* (4th ed.). Kluwer Academic Publishers.

20th International Conference Man and Working Environment
SEMSIE
Safety Engineering & Management – Science, Industry, Education

www.znrfak.ni.ac.rs/semsie

ANA VUKADINOVIĆ[1]
JASMINA RADOSAVLJEVIĆ[2]

[1]University of Niš,
Faculty of Occupational Safety
[2]University of Niš,
Faculty of Occupational Safety

[1]*ana.vukadinovic@znrfak.ni.ac.rs*
[2] *jasmina.radosavljevic@znrfak.ni.ac.rs*

GREEN AND SUSTAINABLE THERMAL INSULATION MATERIALS FOR BUILDINGS

Abstract: *Energy consumption in buildings accounts for a large part of total energy consumption and it is mostly used for heating and cooling of buildings. Building thermal insulation affects the reduction of the energy required for heating and cooling. Thermal insulation materials that are currently used in buildings are primarily made of mineral and fossil materials. Due to the depletion of resources and environmental impact, it is necessary to find an alternative to such materials. This research provides a review of the design and production of green and sustainable insulation materials, as well as their properties and application in buildings.*

Keywords: green materials, thermal insulation, buildings

INTRODUCTION

Over the last decades, as building energy consumption has increased, the building sector has been considered energy and resource-intensive (Rabbat et al., 2022). Hence, the building sector is the second-largest emitter of greenhouse gases (GHGs). According to energy demand data for 2017 (Trobiani Di Canto et al., 2023), buildings account for 36% of global energy use and about 39% of the emitted greenhouse gases. To reduce the energy requirements of both old and new buildings, their thermal performance must be improved. All buildings should ensure a sufficient level of thermal comfort with the least amount of energy usage. One of the key features of this design is its potential for thermal insulation (Ajabli et al., 2023). On the other hand, due to the rise of awareness of environmental problems, producing insulation materials from sustainable resources has become a major interest in European countries. Environmental sustainability has been considered a strategic approach that acts as a barrier against the over-exploitation of natural resources, energy consumption, pollutant emissions and waste generation (Ajabli et al., 2023; Rabbat et al., 2022).

THERMAL INSULATION MATERIALS

The goal of thermal insulation systems and materials is to reduce the heat flow through the building thermal envelope. Thermal insulation materials are normally evaluated using thermal conductivity and thermal transmittance. The steady-state heat flow through a unit area of a homogeneous material that is 1 m thick caused by a 1 K temperature differential at the faces is referred to as thermal conductivity. A material is normally regarded as a good insulator if its thermal conductivity is less than 0.07 W/mK. The steady-state heat flow that a 1 K temperature differential creates across a unit surface area is known as thermal transmittance, also known as U-Value (Ajabli et al., 2023). Due to the moisture absorption potential to change the thermal performance of insulation materials, it is required to evaluate thermal conductivity throughout a variety of moisture levels.

Green building insulation materials

Green insulation materials have a smaller carbon footprint and environmental impact and they require less energy for their production. Some environmentally friendly insulating materials are recyclable or biodegradable, which reduces waste and increases the possibility of reuse in various contexts (Ajabli et al., 2023). Green insulation materials also help to improve the indoor air quality. Natural fibers are non-toxic and do not release harmful volatile organic compounds (VOCs) or other chemicals into the air. This can result in improved indoor air quality and a healthier living environment (Ajabli et al., 2023; Zhao et al., 2022). Most of the green materials that are applied in building thermal insulation are derived from:

- Agricultural residues and plant fibers such as hemp, flax, cereal straws and husks,
- Forestry wastes such as cork and wood chips/shavings/fibers,
- Animal by-products such as sheep wool and duck feathers,
- Recycled materials indirectly coming from forestry and agriculture such as newspapers/cardboard and textile wastes. (Rabbat et al., 2022).

Figure 1 shows examples of green building insulation materials derived from various bio-based materials like wood, hemp, straw etc.

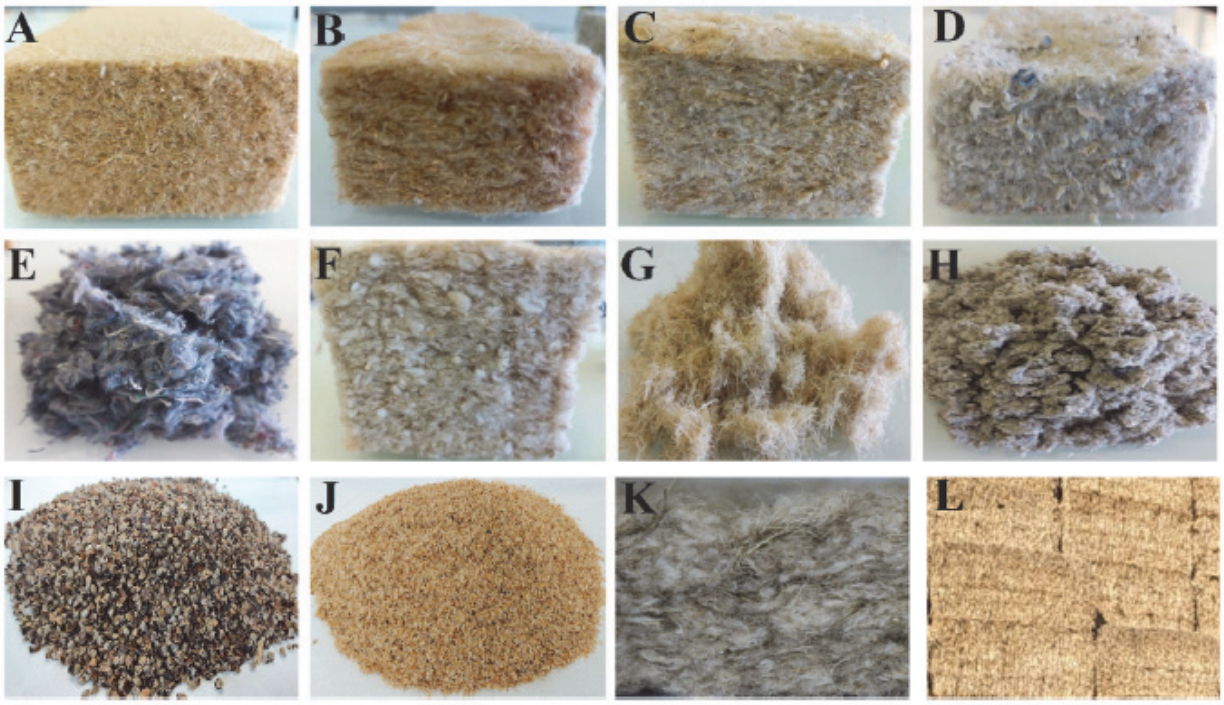


Fig. 1. Various green insulation materials and products:
A) Wood hardboards B) Wood fiberboard C) Hemp panel D) Cellulose wadding panel E) Recycled textiles F) Cotton/flax/hemp panel G) Hemp fibers H) Cellulose wadding I) Buckwheat husks J) Millet husks K) Flax panel L) Wheat straw bales. (Rabbat et al., 2022)

Hemp

Hemp is nontoxic, pest and fire resistant and when combined with lime and water creates hemp concrete, a material that has good thermal insulation properties (0.071 W/m.K conductivity at 340 kg/m^3 density, a specific heat varies with density, ranging from 1000 J/kgK) (Ajabli et al., 2023).

Flax

Flax particleboards can be made out of flax agricultural residue and a binder, usually synthetic glue Urea Formaldehyde Resins (Ajabli et al., 2023). Depending on the density of boards (350-500 kg/m^3) heat conductivity varies from 0.066-0.077 W/mK.

Straw bales

Straw is an excellent construction material recognized by built environment professionals. Straw bales can be used as load-bearing structures or as infill walls (Almusaed & Almssad, 2016). The straw bales layer's measured conductivity is 0.065 W/mK at a density of 100 kg/m^3. For a dense sample of 60 kg/m^{3,} the specific heat capacity was around 600 J/kgK and 0.067 W/mK thermal conductivity (Ajabli et al., 2023).

By using straw, conventional insulation boards for building applications with thermal conductivities of less than 0.045 W/mK can be produced. The applications of straw bale boards are broad, due to their rigidness, strength and low cost. (Almusaed & Almssad, 2016)'.

Bamboo fibers

Insulation panels can be made out of bamboo fibers and bone glue. Bone glue's strong adhesion gives panels good water resistance and high mechanical properties. Insulation panels made of bamboo fibers have thermal conductivity of 0.0582–0.0812 W/mK for 246–534 kg/m^3 densities ranging (Ajabli et al., 2023).

Coconut fibers

Coconut fibers are extracted from the outer shell of a coconut plant that is growing in coastal areas of tropical countries. There are two types of coconut fibers: brown extracted from mature coconuts, strong, thick, and resistant and white fibers from immature coconuts, smoother and finer but also weaker. Thermal conductivity of coconut fiber was investigated and a minimum material thermal conductivity of 0.05 W/mK was found (Almusaed & Almssad, 2016).

Rice

Rice is produced in approximately 95 countries as one of the most important food grains. In Asia, large amounts of rice residues are produced every year. By burning rise residues, a large amount of greenhouse gas emission is produced and it causes a threat to the environment (Almusaed & Almssad, 2016).

Thermal insulation material can be developed from rice straws with a density of 200–350 kg/m^3 and thermal conductivity of 0.051–0.053 W/mK using high-frequency hot-pressing.

Experimental research conducted in two laboratories shows that the thermal conductivity of insulation material made from rice husk ranges from 0.046 to 0.057 W/mK (Almusaed & Almssad, 2016). Without the use of chemical binders, rice husks can be made into hard, high-density boards.

Tomato plant stems

Building envelope materials for thermal insulation made from tomato plant stems and lime were previously investigated with cement, Natural Hydraulic Lime and Natural Hydraulic Lime with sand. Density of those sample materials ranges from 1123.39 kg/m^3 to 523.59 kg/m^3 with a thermal conductivity of 0.097 W/mK to 0.073 W/mK (Ajabli et al., 2023).

Date palm fiber

Date palm is cultivated in arid climate regions. In order to examine the thermal conductivity of date palm fibre, an experimental study was conducted. Date palm fibres were collected from Errachidia in Morocco. Results of the study show that the lowest thermal conductivity of date palm fibre is 0.041 W/mK (Almusaed & Almssad, 2016).

Bagasse

Sugarcane bagasse can be found in tropical countries (Cuba, Brazil, India etc.) Bagasse is managed as waste, burned, or used for animals. In research, bagasse obtained from a sugar factory in Ratchaburi province of Bangkok was used to produce insulation board densities of 250, 350 and 450 kg/m^3 in a laboratory at the Royal Department of Forestry in Thailand. According to the results, the thermal conductivity values of bagasse were in the range from 0.046 to 0.068 W/mK depending on the density of the material (Almusaed & Almssad, 2016).

Pineapple leaves

Pineapple leaves residue is created when pineapples are harvested. Insulation boards made from this material have ranged in density from 178 to 232 kg/m^3 and had a thermal conductivity of 0.035–0.043 W/mK. If pineapple leaves are mixed with natural rubber with a hot pressing technique, insulation boards can be made of a density of 338 kg/m^3 and a thermal conductivity of 0.057 W/mK (Ajabli et al., 2023).

Cotton stalks

Cotton is the most common non-agricultural crop grown primarily for the textile industry. By turning the stalks into fibers without the use of chemical binders, particleboards can be produced. The studied sample's thermal conductivity ranged from 0.0585 to 0.0815 W/mK (Ajabli et al., 2023).

Cork plugs

An environmentally friendly construction material based on cork plugs and natural hydraulic lime. According to the data thermal conductivity of cork plugs was 0.0715 W/mK (Ajabli et al., 2023).

Table 1 shows the comparison between the thermal performance (density and thermal conductivity) of conventional materials and green thermal insulation materials.

Table 1 Comparison of thermal performance characteristics of conventional and green thermal insulation materials (created from data (Ajabli et al., 2023; Almusaed & Almssad, 2016; Rabbat et al., 2022)

	Material name	Density [kg/m^3]	Thermal conductivity [W/mK]
Conventional thermal insulation materials	Expanded Polystyrene (EPS)	15-35	0.031-0.038
	Extruded Polystyrene (XPS)	32-40	0.029-0.039
	Glass wool		0.04
	Rock wool	40-200	0.033-0.045
Green thermal insulation materials	Hemp	340	0.071
	Flax	350-500	0.066–0.077
	Straw bales	60-80	0.067–0.041
	Bamboo fibers	246–534	0.0582–0.0812
	Coconut fibers	174	0.05
	Rice straw	200-350	0.051–0.053
	Rice husk	144-155	0.046–0.057
	Tomato plant stems	1123.39 - 523.59	0.097 - 0.073
	Date palm fiber		0.041
	Bagasse	250-450	0.046-0.068
	Pineapple leaves	178-232	0.035–0.043
	Cotton stalks	150-450	0.0585–0.0815
	Cork plugs	1916	0.0715
	Sheep wool	20-40	0.034–0.050
	Corn cob	212.11	0.139

Sheep wool

The shearing of sheep wool is a pain-free technique carried out to relieve the sheep of discomfort in hot and humid conditions. Depending on the density of the material, the thermal conductivity of sheep wool was found 0.034–0.050 W/mK. Sheep's wool has the potential to be developed into a sustainable, natural and renewable insulation material. According to the Life Cycle Assessment (LCA) approach the GHG emission from 1 m^3 of sheep wool insulation is significantly lower compared with mineral, rock or glass wool (Streimikiene et al., 2020).

Corn cob

Corn cobs are residuals in corn plant processing. It is generally considered agricultural waste. Due to its natural biological origin, corn cob insulation material is heterogeneous. Experimental research on the thermal conductivity of corn cob found that corn cob particle board has a thermal conductivity of 0.139 W/mK. Average density of the randomly picked-up corn cob samples was measured as 212.11 kg/m^3 (Almusaed & Almssad, 2016).

CONCLUSION

This article summarizes the forms of green building insulation materials, their applications, composition, production and installation techniques.

The research shows that green sustainable insulation materials can compete with conventional insulation materials in terms of thermal conductivity performance. By choosing green insulation materials with high thermal performance, energy consumption in buildings will be reduced. Insulation materials that are bio-based can be recycled and they will produce minimal waste and minimise environmental impact.

ACKNOWLEDGEMENTS

The paper is part of the research funded by the Ministry of Education, Science and Technology of the Republic of Serbia according to the Agreement on the implementation and financing of the scientific research work of NIO in the year 2023, Registration number of the Agreement 451-03-47/2023-01/ 200148

REFERENCES

Ajabli, H., Zoubir, A., Elotmani, R., Louzazni, M., Kandoussi, K., & Daya, A. (2023). Review on Eco-friendly insulation material used for indoor comfort in building. *Renewable and Sustainable Energy Reviews*, *185*(July), 113609. https://doi.org/10.1016/j.rser.2023.113609

Almusaed, A., & Almssad, A. (2016). Insulation Materials in Context of Sustainability. In *Insulation Materials in Context of Sustainability*. https://doi.org/10.5772/61361

Rabbat, C., Awad, S., Villot, A., Rollet, D., & Andrès, Y. (2022). Sustainability of biomass-based insulation materials in buildings: Current status in France, end-of-life projections and energy recovery potentials. *Renewable and Sustainable Energy Reviews*, *156*. https://doi.org/10.1016/j.rser.2021.111962

Streimikiene, D., Skulskis, V., Balezentis, T., & Agnusdei, G. P. (2020). Uncertain multi-criteria sustainability assessment of green building insulation materials. *Energy and Buildings*, *219*, 110021. https://doi.org/10.1016/j.enbuild.2020.110021

Trobiani Di Canto, J. A., Malfait, W. J., & Wernery, J. (2023). Turning waste into insulation – A new sustainable thermal insulation board based on wheat bran and banana peels. *Building and Environment*, *244*(July), 110740. https://doi.org/10.1016/j.buildenv.2023.110740

Zhao, J. R., Zheng, R., Tang, J., Sun, H. J., & Wang, J. (2022). A mini-review on building insulation materials from perspective of plastic pollution: Current issues and natural fibres as a possible solution. *Journal of Hazardous Materials*, *438*(February), 129449. https://doi.org/10.1016/j.jhazmat.2022.129449

20th International Conference Man and Working Environment
SEMSIE
Safety Engineering & Management – Science, Industry, Education

www.znrfak.ni.ac.rs/semsie

DANKA MILOJKOVIĆ[1]
HRISTINA MILOJKOVIĆ[2]
KATARINA MILOJKOVIĆ[3]

[1-3]Singidunum University Belgrade,

[1]*dmilojkovic@singidunum.ac.rs*
[2]*hristina.milojkovic.21@singimail.rs*
[3]*katarina.milojkovic.21@singimail.rs*

THE GREEN TOURISM BUSINESS SCHEME (GTBS)

Abstract: *In the coming period, the great growth of tourism is predicted, which will provide excellent opportunities for prosperous development and growth in the world, but at the same time it will be a threat and a challenge to the preservation of the environment and local communities if it is not managed strategically. The paper analysed sustainability in tourism with a special focus on the GTBS tool used in Scotland and its contribution to making tourism and environmental protection policies effective and timely. Analytical methods were used in the work to better understand the purpose of the research, while conclusions and recommendations were formulated using the synthetic method. The author's main finding is that GTBS represents a useful tool for transforming policies into practice. Considering that, the authors recommend GTBS as a tool for achieving a significant impact on state policy through the response of the tourism industry to voluntary initiatives, as well as fostering public-private dialogue and setting common fruitful goals.*

Keywords: certification, environmental protection, strategic management, sustainable tourism, tourism industry

INTRODUCTION

The large growth of tourism that is predicted in the coming years will result in both positive and negative impacts. The bright side of tourism growth will be on the side of economic development and growth, while the dark side will be a shadow that will loom over the environment and local communities whose harmony will be threatened. This threat should be seen as a challenge to the preservation of the environment and local communities through the application of a strategic approach to the management of tourist destinations. Planning, organising, management, and control over a long period are the basic functions of strategic management, for the realization of which it is necessary to develop tools "tailored" for the specific area. To be considered sustainable, strategic management must align with the objectives of sustainable development. Sustainable tourism has minimal impact on the environment and local culture while helping to generate income, create new jobs and protect local ecosystems.

The GTBS tool represents the interactive participation of the tourism industry in an initiative that represents a voluntary environmental certification scheme for tourism companies and contributes to the establishment of public-private dialogue and partnership on various projects, events, and activities.

LITERATURE REVIEW

The leading concept of development in the world is the concept of sustainable development, and the great economic, ecological, and social impact of tourism on the global is directly related to all dimensions of sustainability (Streimikiene et al., 2020, Trišić et al., 2023a; Trišić et al., 2023b). According to Begum's research, sustainable tourism is tourism that is economically sustainable in a way that does not destroy the resources on which the future of tourism depends (Begum, 2021). The fact that there has been a growing interest in the study of the impact of sustainable tourism development on economic growth in the last decade (Leon-Gomez et al., 2021) indicates the need to develop tools to turn theory into practice (Milojković et al., 2021, Milojković & Milojković, 2022a). Berry and Ladkin's research on how sustainable concepts can be translated into feasible practices indicates that despite the willingness of small tourism businesses to engage in sustainable activities, they are engaged in the tourism business and have little understanding of the concept of sustainability, and the reasons for this are a lack of trust in government politics, bad administration and confused channels of communication (Berry & Ladkin, 1997). At the same time, Postma et al. (2017) developed the four scenarios for a sustainable tourism industry by 2040. The four scenarios for a sustainable tourism industry in 2040 are inspirations for tourism businesses to develop a proactive approach and framework strategy for a sustainable and competitive future. Also, for each scenario, strategic issues are listed together with strategic proposals for sustainable development that can be implemented. The Iftikhar et al. (2022) study determined the impact of tourism of 0.351% on sustainable development, where renewable energy sources per capita and income per capita had a significant positive role, while the exchange rate, household consumption, and urbanization harmed sustainable development. Since the 1990s, environmental protection has become a major issue, so tourists are becoming more aware of the environmental problems caused by mass tourism, and as a result, there is a greater demand for environmentally responsible products in the tourism industry (Oonowska & Torre, 2016). Leading tourist destinations are working to preserve the natural environment as well as indigenous culture, and are dedicated to researching sustainable

development strategies and techniques (Hassan, 2000; Milojković & Milojković, 2022b). According to the study of Palacios-Florencio et al. (2021), the development of sustainable tourism can help the tourism industry to be sustainable even in times of pandemics since sustainable tourism is based on uncrowded tourist destinations. Certification programs or quality control tools contribute to the transformation of sustainable tourism into practice (Lesar, 2023). National certificates of sustainable tourism developed to the needs of tourism companies, are used in Finland, Sweden, and Norway, while the role of environment and sustainability in quality is still undefined in Russia (Iivari et al., 2017). Recommendations for the development of tourism include the creation of umbrella labels, certificates, and criteria (Sokolović, 1999a, Sokolović 1999b, Iivari et al., 2017). The EU Eco-Management and Audit Scheme (EMAS) is a tool that enables organisations in the tourism sector to offer environmentally friendly travel so that by choosing accommodations and services registered with EMAS, tourists, authorities and the business community can be sure that the choice and business is responsible (European Commission, 2023). In Serbia, EMAS is partially defined by the Law on Environmental Protection and includes all requirements of the ISO 14001 standard and additional requirements. The global eco-label Green Globe International was established in 1994, includes all types of tourist products and destinations, and consists of 44 criteria and 385 compliance indicators, the application of which depends on the type of certification, geographical location, and the influence of local factors (Green Globe, 2023). The Blue Flag is an international eco-quality standard for the protection of the coastal environment established in 1987 and includes criteria for beaches, marinas, and tourism boats (Blue Flag, 2023). The EMAS, the Green Globe International, and the Blue Flag are world-renowned tools voluntarily.

METHODOLOGY

The research results were obtained using content analysis as an analytical method, while the sample of this method consisted of numerous means of communication such as scientific journals, books, and relevant electronic publications. By applying the synthetic method, the results of the research were summarized and analysed, and conclusions were drawn that indicate the need to apply the GTBS tool to transform state and regional policies in the field of tourism and environmental protection into practice.

RESULTS AND DISCUSSION

The GTBS overview

The GTBS is a leading tool in achieving greater sustainability in tourism development in Scotland. The scheme was established by VisitScotland in 1998 (World Tourism Organization, 2005). It is a voluntary ecological certification scheme for tourism companies and is closely related to Scotland's Tourism and Environment Forum. The Forum was formed four years before the establishment of the scheme and brought together government bodies responsible for tourism development and marketing (VisitScotland), conservation and management of natural heritage (Scottish Natural Heritage), and economic development (Scottish Enterprise and Highlands & Islands Enterprise) (World Tourism Organization, 2005). The establishment of the scheme represented the impact of the Forum as a result of the need to incorporate the needs of the tourism industry into state and regional policies and to put state policies into practice. In addition to the aforementioned agencies, the Forum also gathers representatives of the executive and local authorities, the tourism industry, landownership and land management, conservation, and education. The Forum itself has no legal or statutory powers and acts by influencing its members and others interested in making tourism more sustainable, by gathering the right people at a round table and achieving harmony and synergy of interests (World Tourism Organization, 2005). Currently, more than 2,400 member-tourist companies are registered in the national sustainable tourism certification scheme, the only national certification programme endorsed by the National tourism agencies (Ecolabel Index, 2023). The scheme includes various tourism companies as well as accommodation providers, visitor attractions, activity providers, conference and event venues, corporate offices, and others (Ecolabel Index, 2023). Businesses are awarded bronze, silver, or gold certificates (Green Tourism, 2023) according to their level of sustainability and businesses are promoted through the following websites: Green Tourism (Figure 1), VisitEngland, bookdifferent.com, and Eco Holiday Shop (Yorkshire Dales National Park, 2023).

Figure 1. *The logo of the GTBS*

Member businesses have access to case studies and lists of helpful organisations, and receive monthly newsletters with information on new technologies, legislation, green suppliers, and events.

Ten years after the establishment of the Forum, it focuses on the impact on tourism policies and actions in Scotland, which is partly encouraged by the moves of the governments of Great Britain and Scotland towards more sustainable development, as well as the new requirement of the European Union that development plans undergo a Strategic Environmental Assessment (World Tourism Organization, 2005). During the day-long event, a wide range of stakeholders were divided into working groups, evaluating each goal in terms of relevance and feasibility. In this way, the following seven goals were defined (World Tourism Organization, 2005):

- A more even spread of visitors throughout the year.
- More tourism businesses actively enhancing and protecting the environment, for example by joining the GTBS.
- Greater investment in tourism people and skills.

- A better-integrated quality tourism product that meets visitors' demands and expectations and encourages them to stay longer and spend more.
- A clearer understanding of tourism impacts.
- Greater involvement of communities in tourism planning, development, and marketing.
- Greater use by visitors of Scotland's public transport system.

Based on the aforementioned objectives, each political organization in Scotland was asked to develop the objectives into specific and measurable objectives and to incorporate them into their business plans. Then, following the previous one, there was a revision of the Scottish National Tourism Strategy "Tourism Framework for Action" (World Tourism Organization, 2005). In addition to influencing policy, the Forum contributed to the promotion of numerous initiatives and examples of good practice such as the creation of local partnerships in urban and rural areas for visitor management, the introduction of alternative transport, environmental improvements, traffic management schemes, tourist information and guidance. Also, the Association of Nature and Wildlife Tourism Operators has been established, as well as the Forum's website and newsletter, which is distributed to operators in the private sector, local authorities, departments and agencies at the national level, and the media (World Tourism Organization, 2005).

The scheme contains 145 actions (Ecolabel Index, 2023), most of which are voluntary, and that can be undertaken in the following areas of tourism business: "energy, waste, water, wildlife, transport, support to the local economy, management, and marketing, and customer involvement and information" (World Tourism Organization, 2005, p. 174). The number of actions the tourist company completed determines whether it is eligible for a bronze, silver, or gold award. Tourism companies are obliged to measure and compare their energy and water consumption and waste generation. Inspection supervision is biannual, and the most important indicators of the scheme include the following issues (World Tourism Organization, 2005):

- Quality checks and assessments are carried out by VisitScotland so that requirements such as compliance with health, safety, and other regulations are covered. GTBS is an additional "sustainability" option for quality assessment due to official recognition and credibility.
- During the first inspection supervision, the certification participants are given advice and information. Also, participants receive a regular newsletter with updated information on new ideas, regulations, contacts for more detailed information and help, and structured training. In this way, the inspectors become a team of support and financial assistance.
- The scheme is an excellent communication channel because certification criteria are discussed annually with government agencies, which guarantees a two-way exchange of information.
- Tourist companies - members of the scheme are timely informed about financial assistance such as interest-free loans to small companies for insulation, use of energy-efficient energy sources, and the like. The condition for using financial assistance from some other government schemes is often conditional on membership in GTBS.
- Local authority facilities, such as tourist information centres and the like, have services that are certified through the scheme.
- Tourism businesses in the scheme are featured in official VisitScotland publications and websites, with a green label next to their quality rating, as well as a dedicated green guide and website.
- By being a member of the scheme, tourism businesses realize around 30% savings and 10% higher room occupancy in scheme hotels than in Scotland as a whole.
- Small tourism companies respond more openly to simple and clear criteria

GTBS is run by a private management company "Green Business UK Ltd" on behalf of VisitScotland (Ecolabel Index, 2023). The scheme is financially viable operationally, but the support of VisitScotland and the Forum in promoting the scheme to businesses and consumers in Scotland is essential to its viability (World Tourism Organization, 2005).

An independent quality assessor according to ISO 19011 KMS and EMS audit evaluates the compliance of the tourist company with the standard of the green tourism business scheme and verifies the compliance (Ecolabel Index, 2023).

GTBS is also applicable in other countries in such a way as to be harmonized with the legislation and infrastructure of the specific country. In this way, the tourism industry of that country, with the professional assistance of GTBS, will achieve green business, which will bring those advantages to the global tourism market and will result in the greening of tourist experiences.

The advantages of GTBS are reflected in the tourism industry, in that through the implementation of appropriate goals and policies, businesses effectively and efficiently manage all risks of importance for ecological aspects of the environment. Those businesses use a logical and objective methodology for evaluating ecological aspects based on the importance of their impact on life environment, and direct their management system towards improving and minimizing those significant impacts on the environment. The creation of negative publicity of GTBS implementation is influenced by: the bad experiences of the tourism industry due to extensive administration; the need to adjust or change the company's existing way of doing business to meet the requirements of the scheme, which also contributes to the increase in financial investments, and the overloading of employees who are engaged in the implementation of the scheme.

CONCLUSION

It is possible to turn sustainable development into practice in the field of all tourism activities - from mass tourism to nature tourism and special types of tourism,

using GTBS tools. This is a volunteer-based tool specially designed and implemented in Scotland to help tourism and environmental policies work efficiently and effectively in practice. GTBS is a tool for the implementation of policies on the ground, as well as for gaining influence on state policy from the field.

The model of this scheme can be applied in other countries while respecting the legal regulations and infrastructure of the specific country. In addition to the marketing advantages, as more tourists choose environmentally conscious tourist destinations, tourism companies benefit from expert support in achieving green-friendly business and contributing to greening the tourist experience.

REFERENCES

Begum, M. S.F. (2021). Sustainable tourism. *International Journal of Tourism and Hospitality Management*. https://www.researchgate.net/publication/349636230_SUSTAINABLE_TOURISM#fullTextFileContent

Berry, S., & Ladkin, A. (1997). Sustainable tourism: A regional perspective. *Tourism Management*, *18*(7), 433-440. https://doi.org/10.1016/S0261-5177(97)00053-8

Blue Flag. (2023). Blue Flag's criteria. https://www.blueflag.global/criteria

Ecolabel Index. (2023). *Green Tourism Business Scheme.* https://www.ecolabelindex.com/ecolabel/green-tourism-business-scheme

European Commission. (2023). EMAS for sustainable tourism. https://green-business.ec.europa.eu/eco-management-and-audit-scheme-emas/emas-sustainable-tourism_en

Green Globe. (2023). The global leader in tourism sustainable certification. https://www.greenglobe.com/

Green Tourism. (2023). *Helping businesses improve sustainability. https://green-tourism.com/pages/about-us*

Hassan, S. S. (2000). Determinants of Market Competitiveness in an Environmentally Sustainable Tourism Industry. *Journal of Travel Research*, *38*(3), 239-245. https://doi.org/10.1177/004728750003800305

Iftikhar, H., Pinglu, C., Ullah, S., & Ullah, A. (2022). Impact of tourism on sustainable development in BRI countries: The moderating role of institutional quality. *PLOS ONE*, *17*(4), e0263745. https://doi.org/10.1371/journal.pone.0263745

Iivari, Pekka & Carcia-Rosell, & Hanni-Vaara, Päivi & Linna, & Satokangas, Pasi & Tapaninen, & Tekoniemi-Selkälä,. (2017). Tourism Quality and Sustainability Programmes, Labels and Criteria in the Barents Region.

Leon-Gomez, A., Ruiz-Palomo, D., Fernandez-Gamez, M.A, & Garcia-Revilla, M.R. (2021). Sustainable Tourism Development and Economic Growth: Bibliometric Review and Analysis. *Sustainability*, *13*(4), 2270. https://doi.org/10.3390/su13042270

Lesar, L., Weaver, D. B., & Gardiner, S. (2023). An Updated Framework for Theoretical and Practical Engagement with Sustainable Tourism Quality Control Tools. *Journal of Travel Research*, *62*(2), 271-289. https://doi.org/10.1177/00472875221115177

Milojković, D. & Milojković, H. (2022b). Improving the competitiveness of urban tourism destinations through the smart cities concept, Full Paper, Tourism destination competitiveness – current challenges and future perspectives (electronic version): book of proceedings / SITCON 2022, pp. 71-77. DOI: 10.15308/Sitcon-2022-71-77

Milojković, D. & Milojković, K. (2022a) Improving the business resilience of an organization by applying Agile project management approach, Full Paper, Business resilience in a changing world (electronic version): book of proceedings / FINIZ 2022, pp. 98-103. DOI: 10.15308/finiz-2022-98-103

Milojković, D., Nikolić, M., Čolović, M., Nešić, M, & Ranković, K. (2021) *The role of a cluster in creating the competitive spa and wellness tourism products on the global market in a time of crisis*, Full Paper, Spa&wellness tourism – development, perspectives, and experiences (electronic version): book of proceedings / Singidunum University [VI] International scientific conference SITCON, pp. 22-34. https://doi.org/10.15308/Sitcon-2021-22-34

Oonowska, M. & Torre, D. (2016). Toward a Sustainable Tourism. In: Mariani, M.M., Czakon, W., Buhalis, D., Vitouladiti, O. (Eds.) Tourism Management, Marketing, and Development. Palgrave Macmillan, New York. https://doi.org/10.1057/9781137401854_10

Palacios-Florencio, B., Santos-Roldán, L., Berbel-Pineda, J.M., Castillo-Canalejo, A.M. (2021). Sustainable tourism as a driving force of the tourism industry in a post-covid-19 scenario. *Soc Indic Res. 158*(3):991-1011. Doi: 10.1007/s11205-021-02735-2.

Postma, A., Cavagnaro, E. & Spruyt, E. (2017), "Sustainable tourism 2040", *Journal of Tourism Futures 3*(1), pp. 13-22. https://doi.org/10.1108/JTF-10-2015-0046

Sokolović, D. (1999a). Projekat istraživanja obeležja kvaliteta proizvoda - metodološki pristup. Časopis za unapređenje kvaliteta "KVALITET", izdavač "Poslovna politika" Beograd, ISSN 0354-2408 UDC 006.01:658.5, 47-49 str. (in Serbian)

Sokolović, D. (1999b). Ekologija u sistemu kvaliteta sa osvrtom na standard ISO 14000. Jugoslovenski naučno-stručni časopis "PROCESNA TEHNIKA", izdavač SMEITS Beograd, broj 3, YU ISSN 0352-678X, UDK 574:006.067 BIBLID 0352-678X (1999) 15:3 p. 238-240 (in Serbian)

Streimikiene, D., Svagzdiene, B., Jasinskas, E., & Simanavicius, A. (2020). Sustainable tourism development and competitiveness: The systematic literature review. *Sustainable Development*, *29*(1), 259-271. https://doi.org/10.1002/sd.2133

Trišić, I., Milojković, D., Ristić, V., Nechita, F., Maksin, M., Štetić, S. & Candrea, A.N. (2023a). Sustainable Tourism of Important Plant Areas (IPAs)—A Case of Three Protected Areas of Vojvodina Province. *Land*, 12, 1278. http://doi.org/10.3390/land12071278

Trišić, I., Nechita, F., Milojković, D. & Štetić, S. (2023b). Sustainable Tourism in Protected Areas—Application of the Prism of Sustainability Model. *Sustainability*, 15, 5148. https://doi.org/10.3390/su15065148

World Tourism Organization. (2005). *Making tourism more sustainable – a guide for policy makers (English version).* https://www.e-unwto.org/doi/book/10.18111/9789284408214

Yorkshire Dales National Park. (2023). *Green Tourism Business Scheme.* https://www.yorkshiredales.org.uk/park-authority/living-and-working/tourism-in-the-dales/for-tourism-businesses/our-toolkits-and-handbooks/going-green/green-tourism-business-scheme

20th International Conference Man and Working Environment
SEMSIE
Safety Engineering & Management – Science, Industry, Education
www.znrfak.ni.ac.rs/semsie

MLADEN TODIĆ[1]
SNEŽANA PETKOVIĆ[2]
BILJANA VRANJEŠ[3]
VALENTINA GOLUBOVIĆ BUGARSKI[4]
ALEKSANDAR MAJSTOROVIĆ[5]

[1,2,3,4]University of Banja Luka, Faculty of Mechanical Engineering
[5]City of Banja Luka, Department for Civil Protection and Territorial Professional Fire Fighting Units

[1]mladen.todic@mf.unibl.org
[2]snezana.petkovic@mf.unibl.org
[3]biljana.vranjes@mf.unibl.org
[4]valentina.golubovic-bugarski@mf.unibl.org
[5]aleksandar.majstorovic71@gmail.com

SAFE USE OF LPG FROM MOBILE BOTTLES

Abstract: *LPG (liquefied petroleum gas), is a mixture of propane, C_3H_8, and butane, C_4H_{10}, which is usually stored at elevated pressure when used from mobile bottles, and when the pressure is reduced, both main components change to a gaseous state. The application is very widespread, as it is used in households, the food industry, the drive of internal combustion engines, etc. It is always necessary to remember that LPG is a good servant, but a bad master. Its distribution from producer to consumer can be done continuously or discontinuously. Gas pipelines are used for continuous delivery of gas, while discontinuous delivery is done by tankers and bottles. Compressed gas from bottles has multiple uses, e.g. in households it is used for cooking, water and space heating, as well as for other necessary purposes. Using gas from mobile bottles is very simple and practical. However, when using LPG from bottles, explosions and fires very often occur. The question arises as to what the main causes are that lead to these accidents. In order for the safety level of the use of LPG to be satisfactory, it is necessary to analyse multiple accidents resulting from the use of LPG from mobile bottles. Unfortunately, it is difficult to find the cause of accidents due to inadequate, unprofessional, and unavailable analysis of the cause of accidents. Bottles are made of metal and composite materials. In order to increase safety and reduce the level of consequences of accidents, new materials are introduced in practice for the production of mobile and stable bottles. For the safety of users and their environment, legal regulations and technical instructions for the use of LPG must be observed. Legal regulations must be improved on the basis of scientific research, with the aim of increasing the safety of users and reducing the consequences of accidents.*

Keywords: gas, composite, safety, accident

INTRODUCTION

Fires and explosions occur almost every day somewhere in the world when using gas from mobile cylinders. The bottles usually contain a mixture of propane and butane gases. Their individual share in the mixture depends on the geographical area where it is used and on the legal regulations that prescribe their approximate share. The questions arise: What are the causes that lead to accidents during their use? Are these human or technical factors? The technical causes of accidents include bottles, valves, the hose, and the very device that uses the gas. However, these causes are the result of the human factor. Older versions of mobile bottles were made of steel, and in the last 20 years or so, bottles made of composite materials have taken over. Each designed bottle solution has its advantages and disadvantages. The advantages of bottles made of composite materials are that in the event of an accident, there is no explosion, their mass is 50 to 70% less, the level, i.e. the amount, of LPG in the bottle can be controlled visually, and they are not susceptible to corrosion and explosion. But in the event of a fire, a significant gas leak occurs within two minutes, i.e. degradation of the bottle occurs, which leads to the spread of the fire. The price of composite bottles is higher compared to steel bottles, which initially increases the cost of using gas from composite mobile bottles. The standards for manufacturing and testing bottles are constantly being innovated thanks to the development of techniques and technologies of new materials. However, recommendations and procedures for safe gas use, cylinder use, maintenance, and testing are questionable. There is a very important human factor, which is the most common cause of accidents. A gas leak can occur at any part of the chain (bottle-valve-hose-consumer). Its concentration in the environment leads to a fire and explosion of the bottle itself. In order to avoid accidents, it is necessary to install gas concentration detectors in the area of installation and use of the system, which can significantly reduce the number of accidents in the system of new possible management information systems. These systems can turn on the space ventilation system and warn a specific user (selected person) via mobile phone that the concentration of gas in the space where the system is installed exceeded 1/5 of the permitted gas concentration limit. If no intervention is made, it warns that a fire or explosion will occur and delays the time of a possible accident.

MODULES OF THE LPG USE SYSTEM

The lowest level of safety for the use of gas from mobile cylinders is the one that provides acceptable safety. In this system, the following modules are

important for the safe use of gas: bottle, bottle valve, gas flow regulator, hose, gas consumer, and connections between these modules.

Bottle

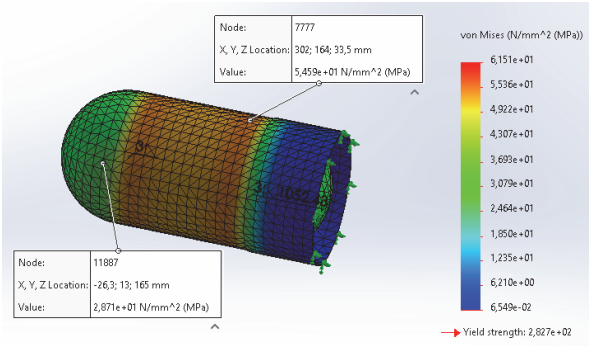
All new solutions to reduce the risk of explosion and fire when using gas from mobile cylinders can only be created by a detailed analysis of the accidents that have occurred. Unfortunately, the detailed causes of accidents are rarely known and analysed in available databases. The most common information is "There was a fire and an explosion caused by a gas cylinder, and the consequences of that accident are...". In order to eliminate the explosion of a gas bottle in the event of a gas leak during its uncontrolled combustion, i.e. the occurrence of a fire, bottles were made of composite materials. They have multiple advantages, especially since in the event of an accident, it is essential that an explosion does not occur, which leads to a reduction in the consequences of a potential accident. But in practice, the reason for avoiding the use of composite bottles is usually their purchase price, which is higher compared to bottles made of steel. Users are not aware of their advantages in the event of an accident. The walls of a steel bottle are single-layered materials, while the walls of composite bottles are made of multi-layered materials, fibres whose layers are bound by a binding material (Figure 1). The intensity of stress-deformation states in the walls of steel bottles depends on the type of material, wall thickness, and mechanical characteristics of the bottle material. However, in composite bottles, this dependence is a function of the number of layers of reinforcing fibre material and the type of reinforcing fibres, i.e. their mechanical characteristics and the type of binding material (Shaikh, 2014; Tripathi et al., 2017). The advantages of multi-layer materials, regardless of whether the wall is made of metallic or non-metallic materials and their combination, can be determined by considering the distribution and intensity of stresses and deformations across the cross section of the bottle wall. In the case of mobile bottles, due to the internal pressure of a maximum of 2.5 MPa or 3 MPa, tangential, radial, and longitudinal stresses occur in the wall. Their effective value is highest on the inner surface and decreases towards the outer surface. In the case of multi-layered materials, or composite layered materials, the change is usually in the form of a saw (it decreases and increases in layers), while in the case of steel, it is in the form of crooked lines. The effective value of dilatation and tension must not exceed the permitted value for the material used.

A steel bottle, when exposed to fire, explodes in about 6 minutes, while a composite bottle degrades in 2 minutes without the occurrence of an explosion, as only gas combustion occurs. The stress-deformation state of composite bottles depends on the number of layers of reinforcing fibres, their direction in the layer, their strength, and the binding material (Tripathi et al., 2017; Dhanunjayaraju, 2015).

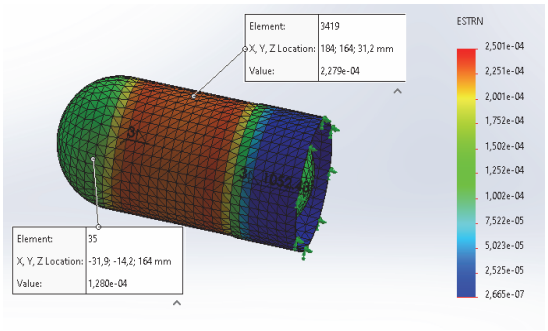
The maximum amount of liquid gas in bottles is about 85% of the volume of the bottle. The bottle is designed in such a way that the position of the bottle when using the gas is determined.

Figure 1. *Mobile bottles made of steel and composite material with a volume of 25.5 l*

To calculate the stress-deformation state in the bottle walls, in the case of steel bottles, it is necessary to know the mechanical characteristics of the material and the shape and the required size of the designed bottle. Most often, the calculation is performed using software for calculating the stress-deformation state of pressure vessels (finite element method), and simulation defines critical points that can be confirmed or disproved experimentally (Figure 2). The authors performed the dilatation check at critical points by detection using strain gauge strips. Deviations were within the permitted engineering accuracy.



(a) Layout of the stress state on the bottle V=25.5



(b) Layout of the deformation state on the bottle V=25.5 l

Figure 2. *Distribution of the stress-strain state on the steel bottle (δ=2.5 mm, p=3 MPa, σ_e=275 MPa)*

The calculation for a steel bottle is usually performed without the segments for protecting the valve and the handle for manipulating the bottle, and the segment for

the proper support of the bottle (Figure 2). However, in addition to protecting the bottle from damage and from damage to the valve on the bottle, they affect the distribution of stress and dilatation connected to the cylinder of the bottle. The same applies to the composite bottle. The protective armour of the composite bottle affects the stress-strain state on the contact surfaces.

Valve

Every cylinder with compressed gas must have a quality valve. The valve allows the cylinder to contain gases, filling or emptying the gas from the bottle. The valve is usually mechanical and it is possible to install an additional electromagnetic valve. It is very important for the safety of using bottled gas that the sealing elements on the valve are periodically changed. It is also necessary to introduce the marking of the inspection period and valve durability (laser) on the valve. The service life of the valve is usually around 15 years, with a change of sealing elements every 5 years, and if it does not have a stamped date of manufacture or assembly, it is difficult to determine its age. This is because after the analysis of the cause of the accident, it was found that the gas leak occurred in the area of the valve due to its malfunction (the sealing elements did not ensure impermeability). An additional electromagnetic valve can significantly reduce the degree of risk of using gas but in a system of modern (smart) management and monitoring of possible gas leaks.

Flow regulator

The basic task of a flow regulator is to regulate the flow of gas towards the consumer due to the difference in gas pressure in bottles and devices that use gas with the necessary operating parameters. Its task is to automatically maintain the pressure on the consumer during gas flow within the limits necessary for the normal operation of the consumer. The maximum outlet pressure and mass flow rate per hour are marked on each gas flow regulator(Figure 3). The diaphragm of the regulator is made of rubber and it is subject to aging, so it is necessary to replace the regulator after the prescribed shelf life. The replacement of the regulator is related to the gas user, i.e. their knowledge of the consequences that may arise when using a faulty regulator.

Figure 3. *Gas flow regulator*

Hose

The hose has the task of transporting gas through it to the consumer from the gas flow regulation valve. It is usually a composite material consisting of a prescribed type of rubber and reinforced with a textile layer, or reinforced with a layer of stainless steel for higher working pressures.

For small consumers, a fibre-reinforced composite rubber hose is used. The ends are additionally reinforced or tightened with special ties. The nominal diameter is usually 8 mm, with a maximum working pressure of 0.06 MPa. Its durability, to which users pay very little attention, is very important for safety, and the time of use is marked on it, for example, UNI 7140 (Figure 4).

Figure 4. *Marking on the hose according to the UNI 7140 standard*

It is necessary to change the hose, after a specified period of use, depending on national and state regulations, if they exist. For example, the shelf life of LPG hoses is not regulated by the Indonesian national standard (SNI) (Mulyono, 2020). The recommended service life of the hose is a function of the basic material from which it is made (MILHDBK- 695-2005). Also, care must be taken not to expose it to accidental damage (contact with sharp edges, small hose bending radius, elevated heat source, etc.) during installation and use of the system.

Consumers

The most common consumers of gas from mobile bottles are gas stoves, furnaces for heating rooms, forklift trucks in closed and open spaces, etc. The level of safety of using LPG from mobile bottles depends on their good working order and professional maintenance.

SOLUTIONS IN COUNTRIES WITH A HIGH DEGREE OF LPG USE

Based on the research of available literature, there are various solutions that are used or recommended for the safe use of LPG. Thus, in the available scientific corpus (Aderibigbe, 2018), quality solutions for safer use of LPG are proposed. These solutions include the following modules:

- Gas concentration detection module;
- Module for detecting the gross mass of the gas bottle;
- Light and sound warning module;
- Module for SMS messages warning that there has been a gas leak;

- Module for removing air with polluted gas from the space where the concentration of gas has increased;
- Module for connection and processing of all parameters from the mentioned modules (microcontrollers).

Display of the block diagram of such a system is shown in Figure 5.

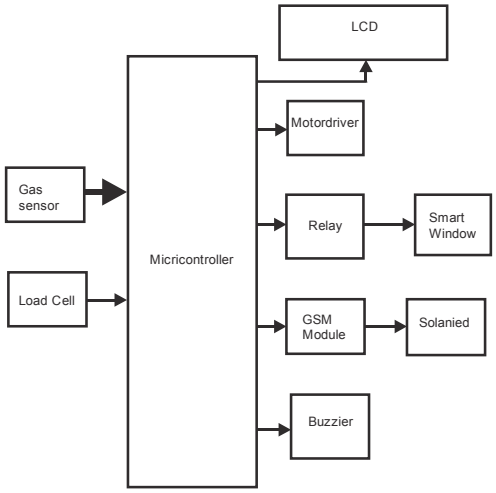


Figure 5. *Block diagram of gas leak detection (Hanchate & Gadgay, 2021)*

SYSTEMS FOR REDUCING THE DEGREE OF EXPLOSION AND FIRE RISK WHEN USING LPG

The risk of an accident is always present when using LPG from mobile bottles. The chain of modules that are most often used when using LPG consists of a bottle with a valve (mechanical or electromagnetic), a flow regulator, a hose, and a consumer. Leaks can occur on any module of the gas use system or on their connection points. In the event of a gas leak, as a consequence of a faulty module or a faulty connection between the modules, the concentration of the amount of gas increases in the environment, the appearance of a spark or flame leads to a fire, and after a certain time an explosion occurs. The consequences can be fatal, the most common among them being the destruction of the environment, serious injuries to users who are in the immediate vicinity, and fires. Unfortunately, all solutions are sought after severe and frequent consequences (standards, regulations, recommendations, etc.). In order to reach a solution, a high-quality analysis of the accidents that have occurred is necessary. However, the analyses are very often the result of inadequate or impossible access to the detection of the factors that led to the accident. Improvements in standards and regulations that affect the reduction of the number and severity of accidents are present in countries where the use of LPG is at a higher level. From the available knowledge bases, it can be seen that detectors with sound and light alarms, which are required by law in rooms where gas is used, were first used. Advances in the technology of mechanical and electrical modules and the use of computer modules and means of communication (smartphones) have resulted in new solutions for increasing the safety of using LPG and reducing the level of risk from its use. These solutions include gas detectors (Zainab, 2014), smoke detectors, GSM modules, microcontrollers (Aderibigbe, 2018), smartphones, ventilators, and various suitable software applications. However, unwanted accidents still occur.

SOLUTIONS FOR REDUCING THE DEGREE OF RISK

The risk of explosion and fire depends on the design of the bottle, valve, hose, gas consumer, system for monitoring possible gas leaks, system maintenance, and the application of modern solutions for monitoring possible gas concentration in the environment. By using bottles made of composite materials, in the event of a fire, the bottle will not explode. In addition, composite bottles are resistant to corrosion. By installing a gas sensor that uses a light or sound signal to warn that the concentration of gas is above the permitted limit, which is a concentration of 1/5 below the LFL (lower flammability limit), the person or persons in that area are prompted to intervene. This intervention includes procedures to prevent further gas leaks or procedures that will eliminate the increase in gas concentration in the room. By installing an air fan with a suitable wireless module and electronic modules for turning it on, the air duct is expelled from the dangerous area, which reduces the concentration of gas in that area. The next module has the option of sending an SMS message to any person with a smartphone. Such systems exist in certain countries where LPG is used intensively. However, the problem is the higher price of these modules, but also the lack of knowledge when maintaining and using the gas system, regardless of the integration of modern modules into the control system and monitoring of possible increased gas concentration. In order to eliminate explosive and fire accidents, it is necessary to implement a smart system in the area of gas use. This system would eliminate the risk of explosion and fire or its value would be at a low level. The built-in fan, which can expel the air polluted with gas from the room, postpones the possibility of fire. In addition, light and sound warnings, as well as an SMS message to a specific person, warn that the gas concentration is above the permitted value and that a fire will occur if further uncontrolled gas leakage continues. (Figure 5). A smart system that would reduce the risk of fire the most or eliminate it completely has to possess gas concentration sensors, an electromagnetic valve, a sensor of the gross mass of the gas bottle, a controller, a fan with variable flow, and possibly light and sound signals. This system works as follows (Figure 6):

- Upon detection of a gas concentration above 1/5 of the lower flammability limit (LFL), it activates the electromagnetic valve, closes the gas flow and turns on the fan;

- If the gas concentration decreases in the space, and the gross mass sensor does not detect a decrease in the gross mass, the fan will work until the concentration is below the LFL, and the system display will show the message that there has been a gas leak behind the electromagnetic valve.

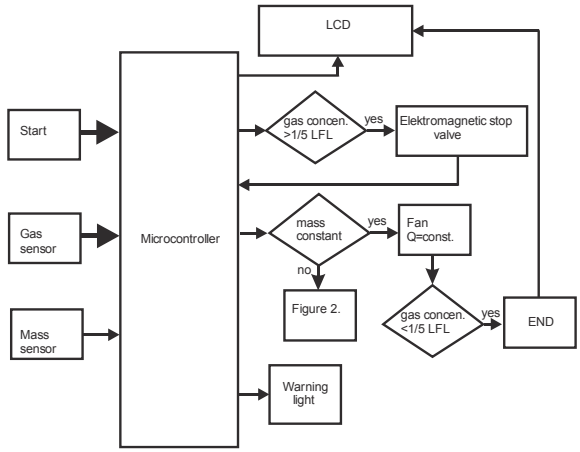


Figure 5. *Intelligent gas concentration control system, phase I*

However, if the signal from the mass sensor shows that the intensity of the gross mass of the bottle decreases, it means that an uncontrolled gas leak has occurred in front of the electro valve. Based on this information, a signal is sent to the fan to increase the maximum flow of polluted air until the system receives a signal that the gross mass is equal to the mass of the bottle and the concentration of polluted air is below 1/5 LFL. The system turns off the fan and leaves a message on the display that gas is leaking in front of the electro valve (Figure 6). With a system in which the intended modules are installed, the degree of risk of explosion and fire is at its lowest level, and the risk of an accident can be reduced to zero, provided that the system is regularly calibrated and well maintained.

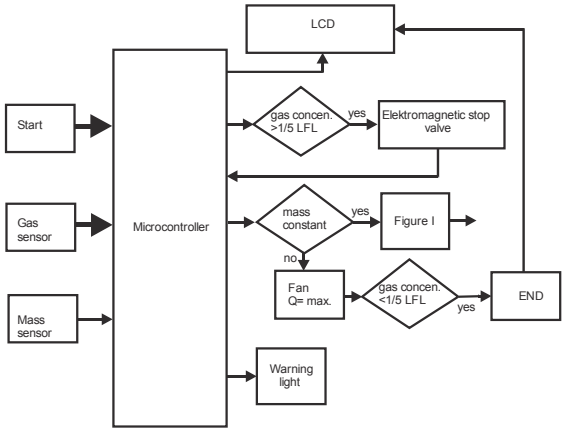


Figure 6. *Intelligent gas concentration control system, phase II*

CONCLUSION

In order to increase the safety of using gas from mobile bottles, it is necessary to act preventively. In order to avoid the risk of explosion, it is necessary to use composite bottles. Deformation states, on certain points of the outer surface of steel and composite bottles manufactured by RAGASCO, do not differ much. The values on the composite bottles are slightly less intense. The risk of fire can be avoided by using a smart system that would keep the risk at a low level or reduce it to a value close to zero, the so-called zero risk value. It is necessary to install the following components in the area where gas is used: a modem for gas concentration detection, a sensor of the gross mass of the bottle, a controllable electric valve, a fan with variable airflow, and an automatic information system, whose task is to close the electromagnetic valve (gas bottle). The system continuously monitors the gas concentration in the area and the gross mass of the gas bottle, and the fan expels the air polluted with gas at a defined flow rate. By further indication of the gross mass sensor, if the gross mass does not change, the constant flow fan runs until the gas sensor reports that the gas concentration is less than 1/5 LFL. In the event that the intensity of the gross mass of the bottle decreases, the conclusion is that there is a gas leak before the electro valve. The system then gives a signal to the fan for the maximum flow of polluted air. The signal comes from the control modem until the gas concentration is reduced to a level below 1/5 LFL and the mass of the bottle has a value equal to the mass of the empty bottle. By further monitoring the gas concentration, until this concentration is below 1/5 LFL, the fan expels the polluted air from the room. After the fan stops working, the message “gas is leaking at part xxxxxx” remains on the security system display. All electronic control components are located in one complex modem. In addition, the functioning of the safety system should be checked once every six months using a special concentration of gas in small bottles. In this way, the risk of explosion and fire will be eliminated. However, there is the issue of the investment price for this system. Any serious accident when using gas has far greater consequences in terms of human life and destruction of property.

REFERENCES

Aderibigbe, I. (2018). A microcontroller based gas leakage detection and evacuation system. *IOP Conf. Series: Materials Science and Engineering, 413*, 012008. https://doi.org/10.1088/1757-899X/413/1/012008

Dhanunjayaraju, M. (2015). Stress analysis of LPG cylinder with composites. *International Journal of Applied Research, 1*(12), 1042-1045.

Hanchate, S. V., & Gadgay, B. (2021). The percentage of detection propane & butane using IOT & wireless technology. *International Research Journal of Engineering and Technology, 8*(8), 4250-4252. https://www.irjet.net/archives/V8/i8/IRJET-V8I8503.pdf

Karnoub, A. (2020). Mechanical properties of composite material laminates reinforced by woven and non-woven glass fibres. *INTERAGROMASH 2020*, *E3S Web of Conferences, 175*. https://doi.org/10.1051/e3sconf/202017512005

Mulyono, A. B. (2020). The expired period of Liquefied Petroleum Gas (LPG) rubber hose supports consumer safety aspects. *IOP Conf. Series: Materials Science and Engineering, 1072*. https://doi.org/10.1088/1757-899X/1072/1/012016

Shaikh, A. (2014). Design of Fibre Reinforced Plastic Pressure Vessel by ASME Section X. *International Journal of Emerging Technology and Advanced Engineering Journal, 4*(11), 523-528.

Tripathi, A., Kumar, A., & Chandrakar, M. (2017). Design and Analysis of a Composite Cylinder for the Storage of Liquefied Gases. *International Journal for Scientific Research & Development, 5*(3), 871-876.

Zainab, Y. (2014). Gas Sensors: A Review. *Sensors & Transducers, 168*(4), 61-75.

20th International Conference Man and Working Environment
SEMSIE
Safety Engineering & Management – Science, Industry, Education

www.znrfak.ni.ac.rs/semsie

ZORICA MIROSAVLJEVIĆ[1]
BOJANA ZORAJA[2]
MILANA ILIĆ MIĆUNOVIĆ[3]

[1,2,3] University of Novi Sad,
Faculty of Technical Sciences

[1]*zoricamirosavljevic@uns.ac.rs*
[2]*bojanazoraja@uns.ac.rs*
[3]*milanai@uns.ac.rs*

STATUS OF PACKAGING GLASS WASTE MANAGEMENT IN SERBIA

Abstract: *Glass, as one of the basic types of materials with a tendency to become waste, is a part of everyday life of most people. In Serbia, the Law on Packaging and Packaging Waste regulates the management of and reporting on packaging and packaging waste, as well as glass packaging. This paper analyses the quantities of glass packaging put on the market and the quantities that have been recycled and compares them with specific goals in Serbia and in Europe, for the 2010-2021 period. The analysis showed that in 2021 the waste glass recycling rate was 47%, while in the EU it was 80.1 %. Serbia, as a developing country and a potential candidate for EU accession, will be obliged to harmonize its legislative framework with the EU legislation and to fulfil the prescribed goals of waste management.*

Keywords: glass waste packaging, recycling rate, waste management

INTRODUCTION

Due to the fact that many environmental and resource management issues faced by developed and developing nations alike are becoming highly uncertain, urgent, complex, and interconnected, we can no longer afford to address individual environmental and social problems in a convenient isolation of their context, or their spatial or temporal scale (Blengini et al., 2012).

Packaging has become a mandatory feature of modern-day products. Packaging materials such as papers, plastics, aluminium, steel cans, and glass/jars are commonly used for enclosing or protecting products during distribution, storage, sale, delivery, and use. The preference and use of such packaging materials depend on the types of products, cost, and packing purpose (Yong-Chul et al., 2020). Despite current efforts directed towards smart packaging that would minimize the quantities of raw materials required for their production and ensure the same function of environmental protection, the overall consumption of packages has increased.

Glass is an ancient material with a rich cultural heritage but it is also more important to modern life than ever before: versatile and easily innovated, it is a potential enabler of the UN Sustainable Development Goals (The European Container Glass Federation (FEVE), 2022a). Because of that, 2022 has been officially declared the UN International Year of Glass to celebrate the extraordinary benefits of glass for businesses, consumers, and the environment alike, with the main objective to champion glass and highlight the central role it has played in our society for thousands of years (The European Container Glass Federation (FEVE), 2022a).

Glass usage has increased globally compared to other kinds of packaging, especially in Turkey, Poland, and Austria (The European Container Glass Federation FEVE, 2022b). Glass is the only packaging material that shows an increased usage trend over the past 3 years (8% higher compared to 3 years ago), globally. In contrast, bags, metal, and plastics are much less used, with use percentages between 24 and 41%. Glass shows a more positive trend than other materials globally, which is particularly the case in Turkey, Poland, Austria, Germany, and Italy. PET is decreasing most noticeably in Austria, while metal cans also show a decrease, particularly in France, Germany, and Portugal.

Glass packaging belongs to the type of waste with a relatively short lifespan, i.e. with a short period of use, before disposal in landfills. Since glass generally has a high chemical and thermal stability, its degradation in landfills is negligible, which, in turn, creates a big problem in landfills because the amount of waste glass increases, unless pre-determined steps are taken to rehabilitate this type of solid waste (for example, reuse or recycling of glass packaging with the aim of obtaining the same or a new product, etc.) (Mirosavljević, 2019).

In Serbia, the management of packaging and packaging waste is regulated by the Law on Packaging and Packaging Waste (2018), which also includes glass packaging. In accordance with this Law and in order to manage this type of waste as effectively as possible, a series of by-laws was adopted in 2010. In addition, the Rulebook on Forms of Reports on the Management of Packaging and Packaging Waste (2018) was adopted, which mandates reporting on the amount of packaging placed on the Serbian market and the management of packaging waste, on the basis of which the reports were created. Taking into account the available data for the previous 12 years, the amount of waste glass packaging will be analysed, with an emphasis on how it is treated. The obtained results will be compared with the existing results of waste glass packaging management in Europe.

METHODOLOGY

The Law on Packaging and Packaging Waste (2018) regulates the management of and reporting on packaging and packaging waste, economic instruments such as product charges, and recovery targets for paper,

plastics, glass, metal, and wood packaging.

On 4 June 2020, the Government of Serbia adopted the Decree on establishing the Plan for the reduction of packaging waste for the period from 2020 to 2024. For the said period, the following national goals for packaging and packaging waste management were set:

- The amount of packaging waste that must be reused;
- The amount of raw materials in packaging waste that must be recycled, within the amount of processed packaging waste;
- The amount of individual materials in the total mass of recyclable materials in packaging waste that must be recycled.

National goals related to reuse and recycling of packaging waste in the period for which this plan was adopted include general and specific goals for recycling packaging waste.

Specific goals for packaging waste recycling in the said period include packaging made of paper/cardboard, plastic, glass, metal, and wood. In this paper, only glass packaging will be considered. Specific national goals for the management of glass packaging from 2020 to 2024 are shown in Table 1.

Table 1. *Specific national goals for packaging glass management (2020-2024) (Serbian Environmental Protection Agency (SEPA), 2010-2021)*

Year	%
2020	44
2021	45
2022	46
2023	47
2024	48

The goals for the recycling of all types of packaging in the EU are 65% by 2025 and 70% by 2030 and they vary depending on the type of packaging material, so a percentage of 75% recycling rate of glass packaging by 2025 and 80% by 2030 is prescribed for glass (European directive, 2017). As can be observed, the stated specific goals for glass packaging recycling rate in Europe for the period up to 2025 are significantly higher than the prescribed specific goals in Serbia.

There are 7 operators licensed to manage packaging waste (Sekopak, Ekostar pak, Delta-pak, Ceneks, Tehno eko pak, Ekopak sistem, and Uni eko pak). Data delivery and processing flow is shown in Figure 1.

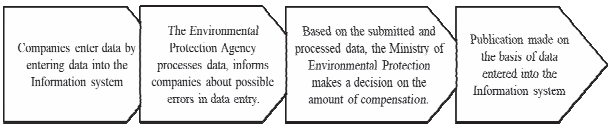


Figure 1. *Data delivery and processing flow*

The amount of packaging glass waste placed on the Serbian market by legal entities or entrepreneurs who transferred their obligations to operators and quantities of recycled waste glass packaging were considered for the period from 2010 to 2021, with the aim of determining the progress of the recycling rate of glass packaging in Serbia (Table 2).

Table 2. *The amount of packaging glass waste placed on the market and quantities of recycled waste glass packaging (Serbian Environmental Protection Agency (SEPA), 2010-2021)*

Year	Amount of packaging glass waste placed on the market (tonnes)	Amount of recycled waste glass packaging (tonnes)
2010	66,214.31	1,068.53
2011	85,928.00	6,865.6
2012	77,978.1	7,700.8
2013	61,496.8	9,023.5
2014	55,236.8	8,947.2
2015	57,115.5	12,188.92
2016	58,155.2	15,359.3
2017	56,602.7	17,874.46
2018	55,400.3	20,705.3
2019	61,979.8	27,743.7
2020	52,280.4	25,155.9
2021	63,813.1	29,723.6

The collected data will be used to determine the recycling rate of glass packaging for the given years and, based on the obtained results, validity will be determined with prescribed specific goals for glass packaging.

RESULTS AND DISCUSSION

According to the Reports on the management of packaging and packaging waste for the period from 2010 to 2021 by the Serbian Environmental Protection Agency (SEPA) (2010-2021), the recycling of waste glass packaging should have been carried out at a minimum of 45% in 2021. According to the results from these Reports from 2010 to 2021, the degree of recycling of waste glass packaging in 2021, the last year for which there are relevant available data, was 47%, with a note that the publication of the results was made based exclusively on the data entered by the user in the information system of the Environmental Protection Agency, which may affect the change, i.e. the reduction of the obtained values representing packaging glass waste recycling. Figure 2 shows the relationship between the amount of glass packaging released on the market and the amount of glass packaging that was recycled or reused.

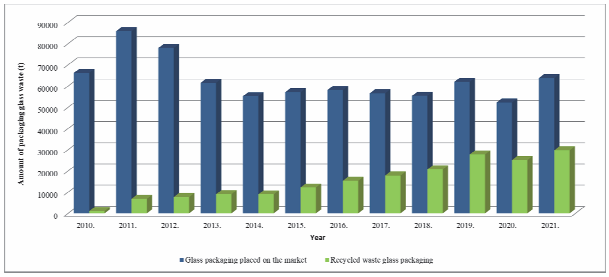


Figure 2. *Relationship between the amount of glass packaging released on the market and the amount of glass packaging that was recycled or reused (2010-2021)*

Figure 3 shows the recycling rate of glass packaging in Serbia for the period from 2010 to 2021 (green colour). A slight increase in the recycling rate can be observed in the period from 2018 to 2021. Given that the specific goals for glass packaging prescribed for the year 2020 is 44% and for the year 2021 45%, the conclusion is that they have been met. The red column indicates the situation in the EU, where the glass packaging recycling rate was 80.1% in 2021 (The European Container Glass Federation (FEVE), 2023), which is incomparably higher than in Serbia.

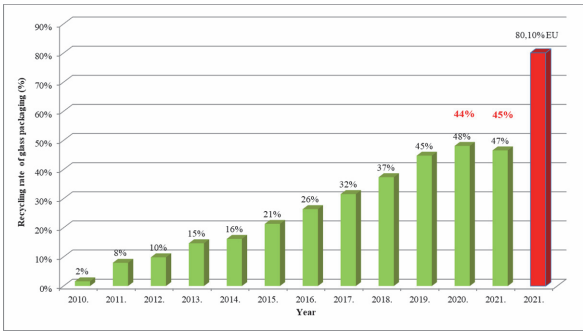


Figure 3. *Recycling rate of glass packaging in Serbia (2010-2021) and in the EU (2023)*

Serbia, as a developing country and a potential candidate for EU accession, will be obliged to harmonize its legislative framework with the EU legislation and to fulfil the prescribed goals of waste management.

Taking into account the presented results, the current percentage of glass packaging recycling in Serbia is significantly lower compared to the represented percentages of recycling in European countries, and the specific goals for the recycling of glass packaging in Europe for the upcoming period are significantly higher than the prescribed specific goals in Serbia. Therefore, it is necessary to investigate and apply new ways of reusing/recycling glass packaging waste, which would contribute to a significant increase in the rate of glass recycling in Serbia in the upcoming period.

CONCLUSION

In Serbia, the reason for the low recycling rate of glass packaging is primarily the low purchase price of glass, the high cost of collecting and transporting waste glass packaging, and the very high costs of sorting glass according to colour, which is necessary in order to use it as a secondary raw material in the production of new glass packaging (closed loop recycling), which, from the aspect of environmental protection, is the best possible option for managing glass packaging. Thus, it is necessary to research and implement new ways of recycling waste glass packaging, which would significantly increase the glass packaging recycling rate in Serbia. According to FEVE literature, glass usage has increased globally compared to other kinds of packaging, especially in Turkey, Poland, and Austria, mainly because of the perceived recyclability of glass and its positive environmental impact. Consumers could be further encouraged to buy glass packages instead of others by working on (perceived) affordability, convenience (lighter packaging), and a good availability of their favourite products in glass packs.

Sustainability and recyclability are the key drivers for glass in the EU. Globally, consumers in developed countries buy more glass because of its recycling properties, and they also consider glass to be better at preserving health than other materials. Taking all of the above into account, more attention should be paid to the management of waste glass packaging, which needs to be viewed as a new resource rather than waste.

REFERENCES

Blengini, G. A., Busto, M., Fantoni, M., & Fino, D. (2012). Eco-efficient waste glass recycling: Integrated waste management and green product development through LCA. *Waste Management, 32*, 1000-1008. https:// doi:10.1016/j.wasman.2011.10.018

European directive. (2017). *Directive 2008/98/EC of the European Parliament and of the Council.*

Law on Packaging and Packaging Waste. (2018). Official Gazette of the RS, No. 36/09 and 95/2018 – other law.

Mirosavljević, Z. (2019). *Model of waste glass containers using as secondary raw material in clay blocks production* [Doctoral dissertation]. University of Novi Sad.

Rulebook on Forms of Reports on the Management of Packaging and Packaging Waste. (2018). Official Gazette of the RS, No. 21/10, 10/13, and 44/18.

Serbian Environmental Protection Agency (SEPA). (2010-2021). *Report on packaging and packaging waste management.*

The European Container Glass Federation (FEVE). (2022a). *Commemorating the international year of glass.* https://feve.org/glass-industry-positions/sustainability-climate-neutral/

The European Container Glass Federation (FEVE). (2022b). *Global report – September 2022.* https://feve.org/glass-industry-positions/circular-economy/packaging-packaging-waste-regulation-ppwr/

The European Container Glass Federation (FEVE). (2023). *Container glass collection for recycling in Europe.* https://feve.org/eu-glass-value-chain-80-collection-rate/

Yong-Chul, J., Gain L., Yuree, K., Jin-hong, L., & Ji-hyun, J. (2020). Recycling and management practices of plastic packaging waste towards a circular economy in South Korea. *Resources, Conservation & Recycling*, *158*, 1-11. https://doi.org/10.1016/j.resconrec2020.104798

20th International Conference Man and Working Environment
SEMSIE
Safety Engineering & Management – Science, Industry, Education

www.znrfak.ni.ac.rs/semsie

TATJANA GOLUBOVIĆ[1]
ANA BIJELIĆ[2]
SRETEN ILIĆ[3]
ALEKSANDAR LAZAREVIĆ[4]

[1,2]University of Niš,
Faculty of Occupational Safety
[3]Military Quality Control, Belgrade
[4]University of Niš, Faculty of
Technology, Leskovac

[1]*tatjana.golubovic@znrfak.ni.ac.rs*
[2]*ana.miltojevic@znrfak.ni.ac.rs*
[3]*sreten.iz@orion.rs*
[4]*acalazarevic92@hotmail.com*

EXPOSURE TO ORGANIC SOLVENTS AT WORK AND RESULTING HEALTH IMPACTS: A CONDENSED REVIEW

Abstract: *Workers around the world are facing a global health crisis due to occupational exposure to toxic substances. In terms of occupational chemical exposures, the most significant chemicals are asbestos, heavy metals, solvents, silica, dyes, manufactured nanomaterials, perfluorinated chemicals, endocrine-disrupting chemicals, and pesticides. Organic solvents as carbon-based substances, capable of dissolving or dispersing one or more other substances, are hazardous chemicals used in considerable amounts in a wide range of occupations. They are used in the production of polymers, plastics, textiles, dyes, printing inks, agricultural products, pharmaceuticals, etc. The most important properties of organic solvents, from a toxicological point of view, are their ability to evaporate and dissolve fats. Due to their high volatility, occupational exposure usually occurs by inhalation of vapours. By dissolving fats, organic solvents can damage hematopoietic tissue, the reproductive system, the nervous system, skin, and all parenchymatous organs rich in fats. Bearing in mind the above-mentioned features, organic solvents can be classified as carcinogens, reproductive hazards, and neurotoxins.*

Keywords: Organic solvents, occupational exposure, toxicity, health effects

INTRODUCTION

Organic solvents are chemically heterogeneous compounds (hydrocarbons, amines, esters, ethers, ketones, nitrated or chlorinated hydrocarbons), capable of dissolving fats, oils, resins, cellulose acetate and cellulose nitrate, which makes them widely used in industry. Most often, organic solvents are used in the production of pesticides, pharmaceutical industry, leather industry, paint and lacquer industries, plastics, explosives, rubber and cellulose industries. Besides, they are components of many products (polymers, plastics, agricultural products, pharmaceuticals, dyes, paints, glues, cleaning agents, etc.). The global solvents market size was evaluated at USD 26.32 billion in 2022 and it is predicted to hit around USD 52.01 billion by 2032 (Clark et al., 2015). In Europe, solvent manufacturers produce 5 million tonnes of solvents annually, contributing 4 billion euros to Europe's economy (ESIG, 2022). Millions of U.S. workers are exposed to organic solvents (International Labour Organization, 2021). High organic solvent exposure occupations include painters, lacquerers, printers, dry cleaners, footwear manufacturers, and occupations in graphics and plastic product works. The level of exposure depends upon the dose, duration, and work being done. Owing to their high volatility occupational exposure usually occurs by inhalation of vapours. Dermal exposure is likewise prevailing in some industries, such as painting and industrial degreasing (Dick 2006). Some tasks, such as spraying, can produce very high exposure levels. Organic solvents are often used in mixed forms in the work environment. In such instances, workers are often simultaneously exposed to more than one solvent vapor in the occupational environment. When two or more substances enter a living body at the same time, interaction may take place at every stage of absorption, excretion, metabolism, protein binding, and subcellular localization (Clark et al., 2015). The toxicity of solvent mixtures varies depending on the toxicity of the individual constituents.

Once the solvent is absorbed, the metabolism, as well as deposition is affected by the exposure pathway and the chemical-physical nature of that solvent. The metabolism and excretion can occur immediately with the liver and lungs, without entering the systemic circulation. The biotransformation of solvents usually forms a biologically less active metabolite, but it can sometimes produce metabolites with toxicity greater than the initial compounds. The solvent that has not been metabolized is distributed mostly in fatty tissue which affects human health on a long-term basis (Joshi, 2019). The central nervous system (CNS) is a primary target organ for the acute toxic effects of organic solvents, because of their rapid entrance capacity to cross the blood-brain barrier. Exposure to organic solvents can also affect the peripheral nervous system, renal, respiratory, cardiovascular, reproductive and hematopoietic system, skin, and mucous membrane (Xiao, 2000, ESIG, 2022).

As awareness of the negative effects of solvent exposure has become obvious, legislation and regulation as well as advances in technology have resulted in decreased use of the hazardous solvents in Europe and the US (Strappaveccia, 2015).

ORGANIC SOLVENTS

Organic solvents, known as carbon-based solvents, comprise a large group of compounds with a variety of chemical structures (alcohols, ketones, ethers, glycols, aldehydes, aliphatic and aromatic saturated and non-saturated hydrocarbons, halogenated hydrocarbons, carbon disulfide, etc.). The structure of common organic solvents is shown in Figure 1.

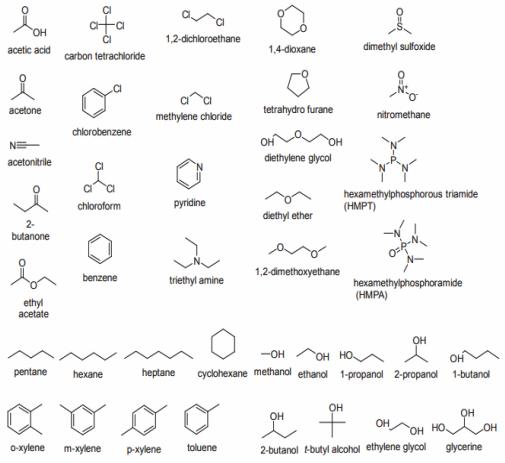


Figure 1. *Structure of common organic solvents*

As the skeleton of organic solvents contains basically carbon and hydrogen, they show high lipophilicity (Xiao, 2000). Lipophilic chemicals exhibit a high affinity for lipids, coupled with a low affinity for water (hydrophobic). Thus, these compounds tend to accumulate in lipid-rich areas. The partition coefficients are an important indicator of solvent behavior in various tissues and depend on the chemical structure and properties of the individual solvent (Xiao, 2000). Also, a very significant property of solvents is their high volatility (Xiao, 2000).

Due to their ability to dissolve and readily disperse fats, oils, waxes, paints, pigments, varnishes, rubber, and many other materials, they are used in a wide range of industries (Fig. 2). Most often organic solvents are used in the production of pesticides, pharmaceutical industry, leather industry, paint and lacquer industries, plastics, explosives, rubber and cellulose industries (Kafferlein, 2000). Besides, they are components of many products (polymers, plastics, agricultural products, pharmaceuticals, dyes, paints, glues, cleaning agents, etc.).

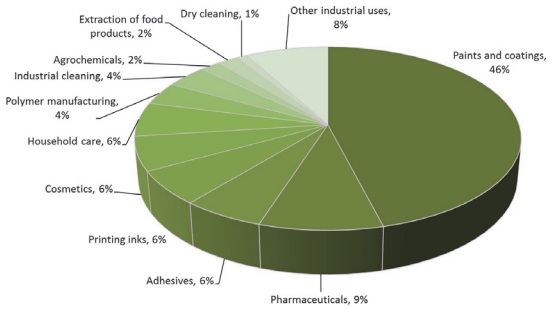


Figure 2. *Solvent use arranged by sector*

OCCUPATIONAL EXPOSURE TO ORGANIC SOLVENTS

The development of industry has increased the need for different solvents. While only a few organic solvents were used at the turn of the last century, their number has today increased to several hundred. Some of the significant applications of organic solvents are shown in Table 1.

Table 1. *Selected sources of solvent exposure*

Sources/processes	Solvents used
Paint and coating	Toluene, xylenes, acetone, methyl ethyl ketone, methyl isobutyl ketone
Manufacturing	Chloroform, o-dichlorobenzene, methylene chloride, 1,1,1-trichloroethane
Metal degreasers	Methylene chloride, perchloroethylene, trichloroethylene,1,1,1-trichloroethane
Paint stripping	Methyl ethyl ketone, methylene chloride, kerosene
Fumigants	p-Dichlorobenzene, ethylene dichloride,1,3-dichloropropane,1,2-dibromo-3-dichloropropane

Occupational exposure

The potential for solvent exposure is common in the home and in many industries. Regardless of the advances in worker protection standards (Fig.3), such exposures remain a health concern to millions of workers throughout the world.

Organic solvents may be absorbed via inhalation, ingestion, and transdermal routes of exposure. Occupational exposure generally occurs by inhalation of vapours. Dermal absorption is important when liquid solvents come into direct contact with the skin, although this route is often overlooked. The ingestion of solvents in clinically significant amounts occurs very rarely in the occupational setting (Xiao, 2000).

High solvent volatility, with the generation of significant airborne concentrations of vapor, lack of appropriate ventilation systems, and relatively high temperature of the work environment may all contribute to increased uptake by inhalation. Solvent uptake through inhalation also depends on air/blood partition coefficients of individual solvents, which are determined by the alveolo-capillary membrane permeability and by the solubility of the selected solvents in blood (Xiao, 2000).

Also, solvent vapours can be absorbed through the skin, whereby the extent varies markedly and depends on the solvent type. The investigations have shown that temperature and humidity have a significant influence on skin hydration and permeability (Boman, 2000). Namely, high temperature (82°C in a sauna) increased skin absorption through enhanced skin blood flow

(Vanakoski, 1996). An important influence on solvent uptake is occlusion. The occlusive process results in the liquid being unable to evaporate from the skin surface, and the quantity of substance absorbed may be as much as five times that from a similar non-occlusive exposure. Factors that can play an important role in determining the degree of uptake include the presence of other materials on the skin (Boman, 2000; Spiker, 2001).

Figure 3. *Application of solvents in industry*

Distribution, biotransformation and excretion of organic solvents

After absorption, organic solvents may be transported by the blood to organs where biotransformation may occur, resulting in the formation of metabolites that can be excreted.

There are significant differences concerning the uptake and potential for adverse effects from solvents, based on exposure pathway. Absorption following ingestion or dermal exposure results in absorption into the venous circulation, from which materials are rapidly transported to the liver where they may be metabolized. Organic solvents absorbed by inhalation exposure, however, are introduced into the arterial circulation via the alveoli. Therefore, a solvent may be distributed widely in the body prior to reaching the liver for metabolism, degradation, and subsequent excretion.

Considering that solvents constitute a heterogeneous group of substances, there are many potential metabolic breakdown pathways. Metabolism of solvents in the body occurs mainly via the P450 oxidase system and the glutathione pathways, by which a water-soluble conjugate is produced (Xiao, 2000; Williams, 2000; Nomiyama, 2001). In the next phase, the metabolites are excreted into the urine or the bile. The biotransformation of solvents usually forms a biologically less active metabolite, but it can sometimes produce metabolites with toxicity greater than the initial compounds. Despite the fact that the metabolism of most solvents occurs primarily in the liver, other organs also manifest an important capacity for biotransformation (e.g., kidney, lung). Some organs may be able of only some of the steps in the process, potentially leading to the accumulation of toxic metabolites if the first steps of the biotransformation pathway are present, but not the subsequent steps. For example, whereas an aldehyde may be metabolized readily in the liver, the same aldehyde may accumulate in the lung and cause pulmonary damage due to a lack of aldehyde dehydrogenase enzyme in that organ (Williams, 2000). Except for the previously mentioned excretion (urine and bile), many solvents may be eliminated in changed or unchanged form by exhalation. This possibility serves as a starting point for the practice of sampling expired air as a measure of possible occupational exposure control in some industrial medical surveillance programs. The most important factor controlling pulmonary excretion is the partition coefficient between air and blood, which is defined as the concentration ratio of a vapor between blood and air at a defined temperature (Sato, 1987).

Health effects of organic solvents

Effects on the central nervous system. Organic solvents act as central nervous system (CNS) depressants, causing general anesthetic effects, inhibiting activity in the brain and the spinal cord, and decreasing functional capacity, render the individual less sensitive to external stimuli, and ultimately may result in unconsciousness or death as the most severe consequence. Organic solvents without, or with few functional groups exhibit some limited degree of CNS-depressant activity. This property increases with the carbon chain length. The CNS-depressant properties of organic solvents are usually improved by increasing the degree of halogenation. When it comes to the effect of solvents on the CNS, it should be emphasized that unsaturated chemical analogs are more potent CNS depressants than their saturated counterparts (Boman, 2000; Hoek, 2001).

Effects on the peripheral nervous system. Some groups of organic solvents (n-hexane, methyl n-butyl ketone, and carbon disulfide) can cause a syndrome known as distal axonal peripheral neuropathy. This disorder has characteristic histologic features that frequently include focal axonal swelling with distal axonal degeneration (Xiao, 2000; Triebig, 1992).

Cardiovascular effects. Cardiovascular disease can be caused by several types of organic solvents. Methylene chloride, through its metabolism to carbon monoxide, and increased carboxyhemoglobin levels has been suggested as a potential risk for myocardial infarction. Aliphatic nitrates (nitroglycerin and ethylene glycol dinitrate) cause cardiac toxicity following withdrawal from exposure among workers habituated to the vasodilation effects of the nitrates. Carbon monoxide, derived from the metabolism of methylene chloride, and aliphatic nitrates may also cause chronic cardiovascular toxicity, as well as carbon disulphide.

Mucous membrane irritation. Organic solvents can cause irritation of the respiratory tract, eyes, and nose, during the exposition to solvent vapors or mists. Also, bronchial and tracheal irritation have been described among solvent-exposed workers.

Dermal effects. Due to their ability to dissolve lipids, many organic solvents, especially aromatics, can cause

severe defatting of the skin, with resulting dermatitis (Fig. 4). Symptoms are more pronounced in conditions of prolonged and repeated skin contact, especially among workers who use solvents for cleaning and degreasing, or who wash hands with solvents to remove glue, plastics, or other material from their skin. These effects are reversible and are preventable by avoiding direct skin contact with solvents by using gloves or barrier creams.

Effects on the renal system. High-level, short-term exposure to selected organic solvents may cause acute tubular necrosis, a potentially life-threatening renal disorder that can lead to acute renal failure. has been suggested to be associated with long-term exposure to solvents.

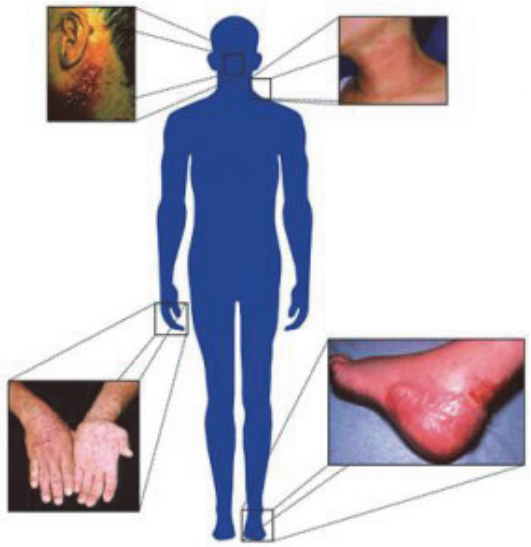


Figure 4. *Different skin diseases*

Carcinogenicity. Benzene is classified by the International Agency for Research on Cancer (IARC) as a group 1 carcinogen. It causes leukemia and other hematopoietic disorders in humans. Epichlorohydrin is classified by the IARC as a group 2A carcinogen (possibly carcinogenic to humans). The suspected carcinogens, according to the IARC, include: carbon tetrachloride, chloroform, trichloroethylene, tetrachloroethylene, ethylene dibromide, 1,2-dibromo-3-chloropropane, ethylene dichloride, and epichlorohydrin (Xiao, 2000; CDC, 2022; Pesch, 2000).

CONCLUSION

Solvent exposure is one of the most common chemical exposures in the workplace, following exposures to gases and dusts. Organic solvents are a potential occupational risk factor for workers who are employed in sectors of production and use of lacquers and paints, chemical industry, engineering industry, wood processing, chemical laboratories, printing houses, specific fields of medicine (diagnostic laboratories, disinfection activities), construction sector, dry cleaners, etc. Handling of solvents is carried out both in small companies and in large and well-organised enterprises. Solvents can be emitted in the work environment air in the form of vapour. Exposition via the respiratory tract is the most prominent exposure to organic solvents. Also, dermal contact may be high in some industries. Solvents should be considered as an occupational health and safety priority, as large numbers of workers are exposed to them worldwide and important health impacts have been identified by scientific data. The organic solvents which pose a serious risk to health should be substituted by less hazardous ones. If this is not possible due to the nature of the work, at least handling conditions should be adjusted so that there is no risk of skin contact and that the concentration of vapour in the air is kept low.

ACKNOWLEDGEMENTS

This research was supported by the Ministry of Education, Science and Technological Development of the Republic of Serbia - Agreements on the implementation and financing of scientific research in 2023 [number 451-03-47/2023-01/ 200148].

REFERENCES

Boman A, Maibach HI. (2000). Percutaneous absorption of organic solvents. *Int J Occup Environ Health*. 6. pp. 93–5.

Centers for Disease Control and Prevention, CDC (2022). *Organic Solvents*, [online], available: https://www.cdc.gov/niosh/topics/organsolv/default.html [Accessed 25 July 2022].

Clark, J.H., Farmer, T.J., Hunt, A.J., Sherwood, J. (2015). Opportunities for Bio-Based Solvents Created as Petrochemical and Fuel Products Transition Towards Renewable Resources, *International Journal of Molecular Sciences*, 16(8), pp. 17101−17159.

Dick, F. D. (2006). "Solvent Neurotoxicity." Occupational and Environmental Medicine. BMJ Publishing Group Ltd.

ESIG, European Solvents Industry Group (2022). *Solvents and ESIG,* [online], available: https://www.esig.org/wp-content/uploads/2020/01/ESIG-advocacy-document-triptic_WEB.pdf [Accessed 25 July 2022].

Fiserova-Bergerova V. (1985). Toxicokinetics of organic solvents. *Scandinavian journal of work, environment & health*, 11 Suppl 1, pp. 7–21.

Hoek, A., Verberk, M., Laan, G., Hageman, G., Ned, G. (2001). Solvent induced chronic encephalophathy; the solvent team project. *Ned Tijdschr Geneeskd*. 145. pp- 256-260.

Joshi, D., Adhikari, N. (2019). An Overview on Common Organic Solvents and Their Toxicity, Journal of Pharmaceutical Research International, 28(3). pp.1-18.

Lim, C., Oh, H. (2023). Organic solvent exposure for the chronic kidney disease: updated systematic review with meta-analysis. *Ann Occup Environ Med.* 35(1). https://doi.org/10.35371/aoem.2023.35.e11

Kafferlein, U., Goen, T., Muller, J., Wrbitzky, R., Angerer, J. (2000). Biological monitoring of workers exposed to N,N-dimethylformamide in the synthetic fibre industry. *Int Arch Occup Environ Health*, 73, pp. 113-120.

Nomiyama, T., Nakashima, H., Sano, Y., Chen, L., Tanaka, S., Miyauchi, H., Yamauchi, T., Sakurai, H., Omae, K. (2001). Does the polymorphism of cytochrome P-450 2E1 affect the metabolism of N,N-dimethylformamide?

Comparison of the half-lives of urinary N-methylformamide. *Arch Toxicol*.,74. pp.755-759.

Occupational Diseases in Workers Exposed to Organic Solvents

Pesch, B., Haerting. J, Ranft, U., Klimpel A., Oelschlagel, B., Schill, W. (2000). Occupational risk factors for urothelial carcinoma: Agent-specific results form a case-control study in Germany. *Int. J. Epidemiol*., 29, pp. 238–247.

Sato, A., Nakajima, T. (1987). Pharmacokinetics of organic solvent vapors in relation to their toxicity. *Scandinavian journal of work, environment & health*, 13(2), pp. 81–93. https://doi.org/10.5271/sjweh.2075

Spiker, C., Morris, B. (2001). Solvents and industrial hygiene. In: Hayes AW (ed) Principles and methods of toxicology, 4th edn. Taylor & Francis, Philadelphia, pp. 531–564.

Strappaveccia, G., Ismalaj, E., Petrucci, C., Lanari, D., Marrocchi, A., Drees, M., Facchetti, A., Vaccaro, L. (2015). A Biomass-Derived Safe Medium to Replace Toxic Dipolar Solvents and Access Cleaner Heck Coupling Reactions, *Green Chemistry*, 17(1), pp. 365–372.

Triebig, G., Barocka, A., Erbguth, F., Holl, R., Lang, C., Lehrl, S. (1992). Neurotoxicity of solvent mixtures in spray painters. II. Neurologic, psychiatric, psychological, and euroradiologic findings. *Int Arch Occup Environ Health*. 64. pp. 361-372.

Vanakoski J, Seppala T, Sievi E, Lunell E. (1996) Exposure to high ambient temperature increases absorption and plasma concentrations of transdermal nicotine. *Clin Pharmacol Ther*., 60. Pp. 308–15.

Williams, P. James, R., Roberts, S. (2000). *Principles of toxicology, Environmental and industrial applications*, A Wiley-Interscience Publication, New York

Xiao, J., Levin, S. (2000). The Diagnosis and Management of Solvent-Related Disorders, *American Journal of Industrial Medicine*,

20th International Conference Man and Working Environment
SEMSIE
Safety Engineering & Management – Science, Industry, Education

www.znrfak.ni.ac.rs/semsie

JELENA MALENOVIĆ–NIKOLIĆ[1]
LIDIJA MILOŠEVIĆ[2]
IVANA ILIĆ KRSTIĆ[3]
UGLJEŠA JOVANOVIĆ[4]
MILAN LUKIĆ[5]

[1,2,3,4] Faculty of Occupational Safety, University of Niš
[5] Baby Food Factory, Dobanovci

[1]*jelena.malenovic@ znrfak.ni.ac.rs*
[2]*dejan.krstic@ znrfak.ni.ac.rs*
[3]*lidija.milosevic@znrfak.ni.ac.rs*
[4]*ivana.ilic@znrfak.ni.ac.rs*
[5]*milanlukic18031@gmail.com*

SAFETY SYSTEM MANAGEMENT AND INJURY ANALYSIS AS A KEY INDICATOR OF WORKER SAFETY

Abstract: *Safety system management based on injury analysis provides an opportunity to assess the actual situation and identify shortcomings in the implementation of occupational safety measures. The analysis of the number of injuries is proposed as a key indicator of workers' safety. The application of sub-indicators significantly contributes to the improvement of the management process. Suitable sub-indicators include the number of filed criminal charges, the number of cases resolved, and the number of cases closed in other ways under the Law on Misdemeanours (warning notices, request denials, dismissals, and release from responsibility of the accused). The analysis of injury data was conducted at the national level, based on official data from the labour reports.*

Keywords: management system, safety indicators, number of injuries, occupational safety

INTRODUCTION

Safety system management, based on the analysis of failures in the implementation of safety measures in critical situations, should also include an analysis of consequences. Occupational injuries are a serious issue, especially when they lead to fatal injuries. Improving the occupational safety system is necessary because Serbia is among the countries where working conditions are not at an adequate level (Malenović Nikolić et al., 2023a). The analysis of risky situations that have occurred and during which a hazardous event was avoided (Malenović Nikolić et al., 2023b) is significant for preventing negative consequences in the work environment.

ANALYSIS OF THE NUMBER OF OCCUPATIONAL INJURIES

The Administration for Occupational Safety and Health within the Ministry of Labour, Employment, Veteran and Social Affairs of the Republic of Serbia (Labour Reports for 2015-2021) analyses the number of minor, major, and fatal injuries. Labour reports (Labour Reports for 2015-2021) also present data from the Ministry of Justice regarding the number of filed requests for initiating misdemeanour proceedings in accordance with the Law on Occupational Safety and Health and the Law on Misdemeanours (Malenović Nikolić et al., 2023b), the number of closed cases, and the number of cases closed in other ways under the Law on Misdemeanours (warning notices, request denials, dismissals, and release from responsibility of the accused). The number of misdemeanour complaints and resolved cases in the public prosecutors' offices of individual cities indicates the functioning of judicial authorities and the occupational safety management system. Labour inspectors conduct inspection supervision upon reports of occupational injuries, and criminal complaints are filed with the prosecutors' offices in Serbia for the failure to implement occupational safety and health measures (Malenović Nikolić et al., 2023b). It is worth noting that cities with intensified inspection supervision record a lower number of occupational injuries (Labour Reports for 2015-2021).

Analysis of the total number of occupational injuries

The analysis of the total number of occupational injuries reveals serious deficiencies in the functioning of the occupational safety system in Serbia (Malenović Nikolić et al., 2023a), as a high number of injuries has been recorded. The situation in Serbia shows that the average number of severe injuries in the four-year period from 2015 to 2018 increased by over 50% in the period from 2019 to 2022 (Labour Reports for 2015-2021). Table 1 presents significant indicators of occupational safety at the global level, showing the number of fatal injuries per 100,000 workers (Bureau of Labor Statistics, 2023).

Table 1. *Rate of fatal occupational injuries by major occupation group (Bureau of Labor Statistics, 2023).*

Event or exposure	Fatalities per 100,000 employees
Transportation	15.9
Construction and extraction	12.2
Installation and maintenance	8.1
Farming and fishing	20.9
Production	2.6
Service	3.3

Analysis of Table 1 shows that a large number of injuries occur in agriculture, transportation, and construction and extraction, which is easily compared by calculating the number of fatal injuries per 100,000 workers.

NUMBER OF CRIMINAL CHARGES AS AN INDICATOR OF OCCUPATIONAL SAFETY

Analysis of the number of filed criminal charges in Serbian cities (Labour Reports for 2016-2022) reveals differences in the functioning of inspection supervision.

Figure 1 shows the number of criminal charges filed with the public prosecutors' offices for the failure to implement occupational safety and health measures.

Analysis of the results (Labour Reports for 2016-2022) presented in Figure 1 shows that the largest number of criminal charges was filed in 2015 and 2019. The largest number of charges was submitted to public prosecutors in Belgrade, Kruševac, Novi Sad, Subotica, and Kraljevo.Niš ranks third in the number of injuries (Labour Reports for 2016-2022), but does not rank significantly in the number of filed criminal charges. It is also characteristic that the fewest criminal charges were filed in 2016 and 2020 (around 640), while the most charges were filed in 2019 and 2015 (around 1,050). Figure 2 shows the number of closed cases by the Serbian prosecutors' offices from 2015 to 2021.

Figure 3 shows the data on the number of unclosed cases from 2015 to 2018, while Figures 4, 5, and 6 show the data for 2019, 2020, and 2021, respectively.

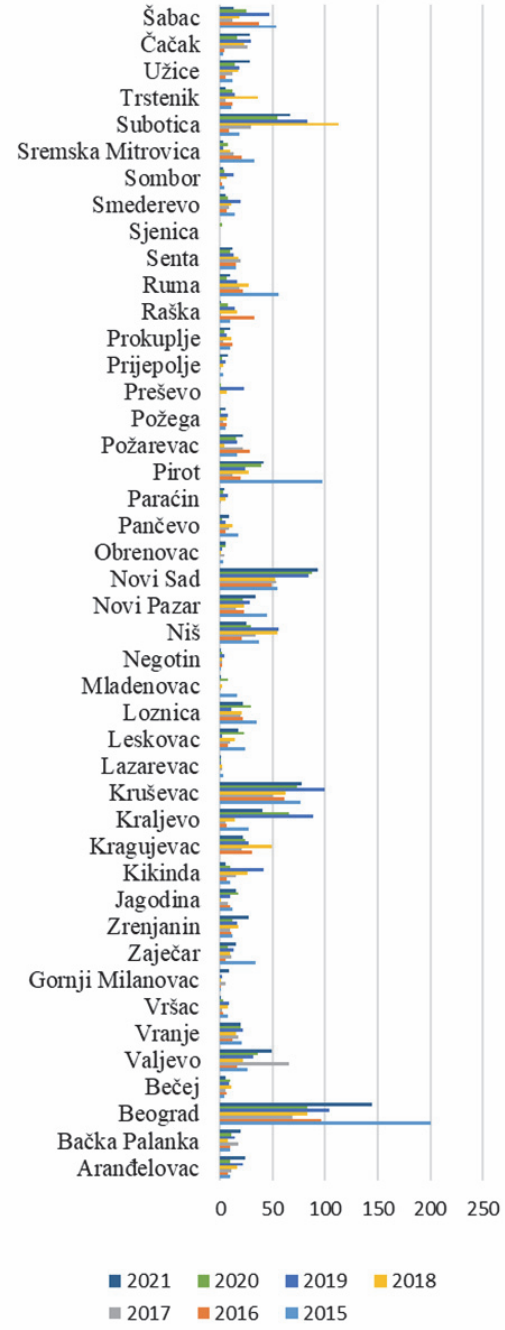


Figure 1. *Number of charges filed*

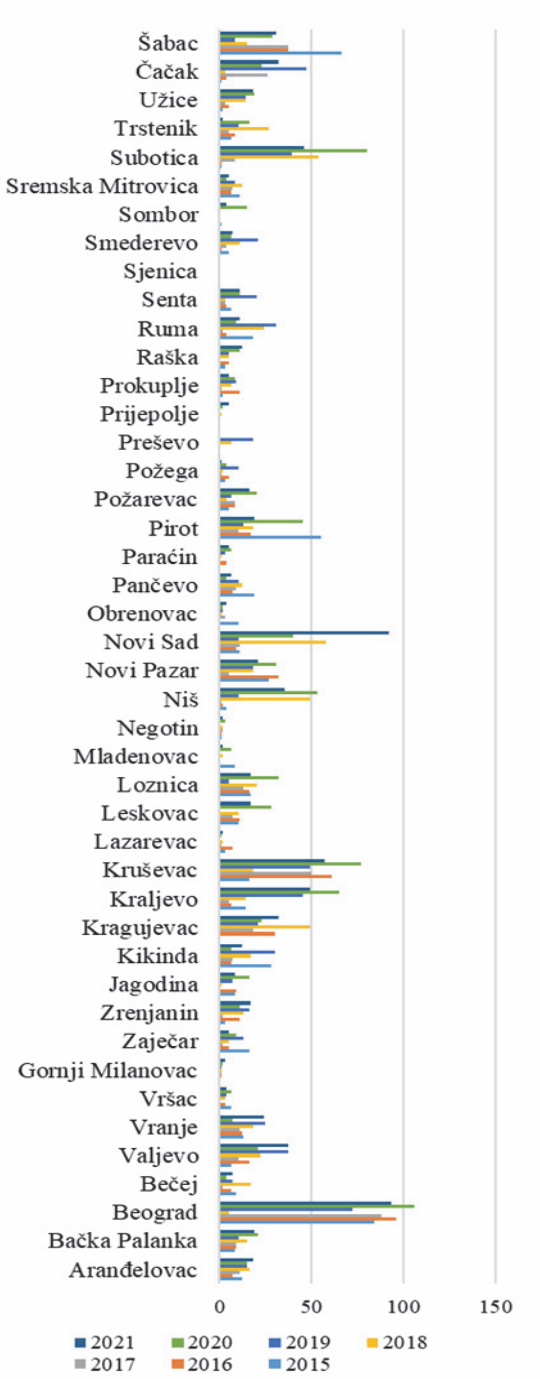


Figure 2. *Number of closed cases*

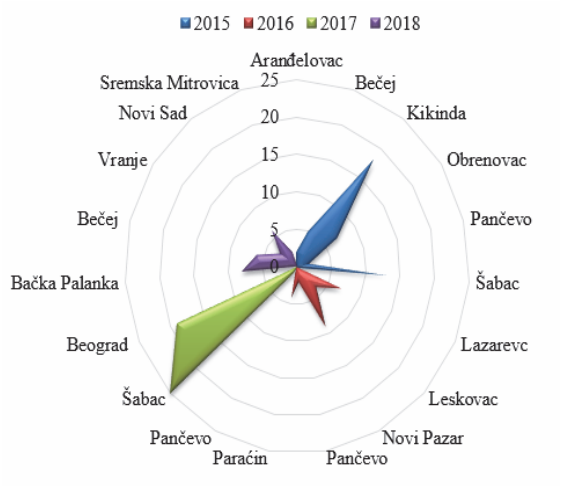


Figure 3. *Number of unclosed cases*

Analysis of Figure 2 shows that the highest number of closed cases was recorded in Belgrade, Kruševac, Novi Sad, Kraljevo, Šabac, and Pirot. The lowest number of closed cases was recorded in 2017 and 2015, while the highest number of cases were closed in 2020 and 2021.

Based on the data in Figure 3, it can be observed that the public prosecutor's office in Šabac stands out in the number of unclosed cases in 2017 and 2015, as well as the office in Novi Pazar in 2016 and in Bela Palanka in 2018.

Figure 4. *Number of unclosed cases in 2019*

Figure 5. *Number of unclosed cases in 2020*

Figure 6. *Number of unclosed cases in 2021*

Figures 7-11 show the data on the number of cases closed in other ways (warning notices, request denials, dismissals, and release from responsibility of the accused).

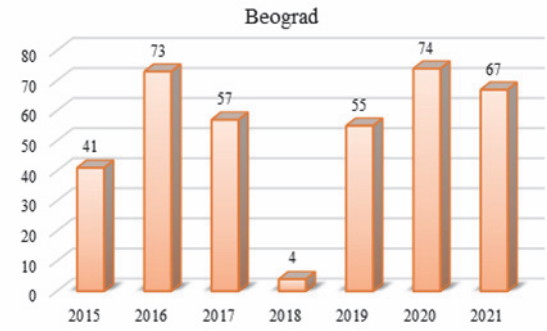


Figure 7. *Number of closed cases in Belgrade*

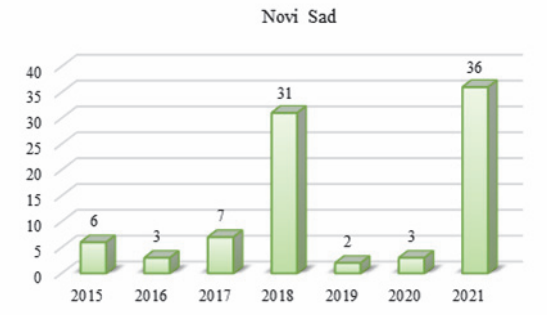


Figure 8. *Number of closed cases in Novi Sad*

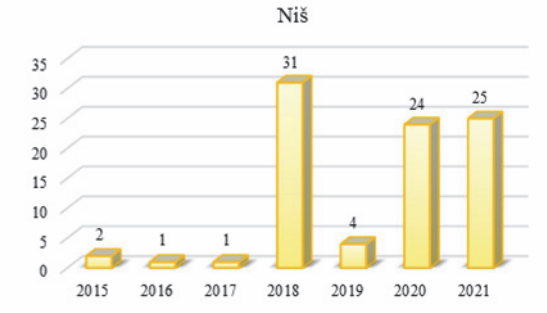


Figure 9. *Number of closed cases in Niš*

Figure 10. *Number of closed cases in Kragujevac*

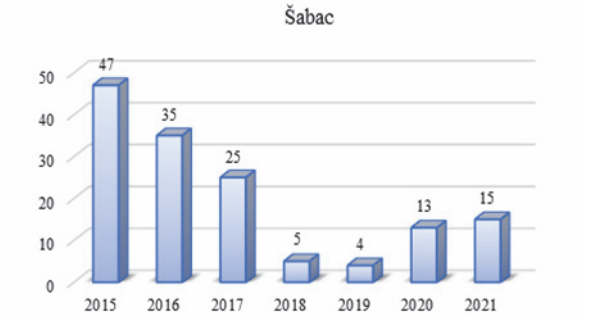


Figure 11. *Number of closed cases in Šabac*

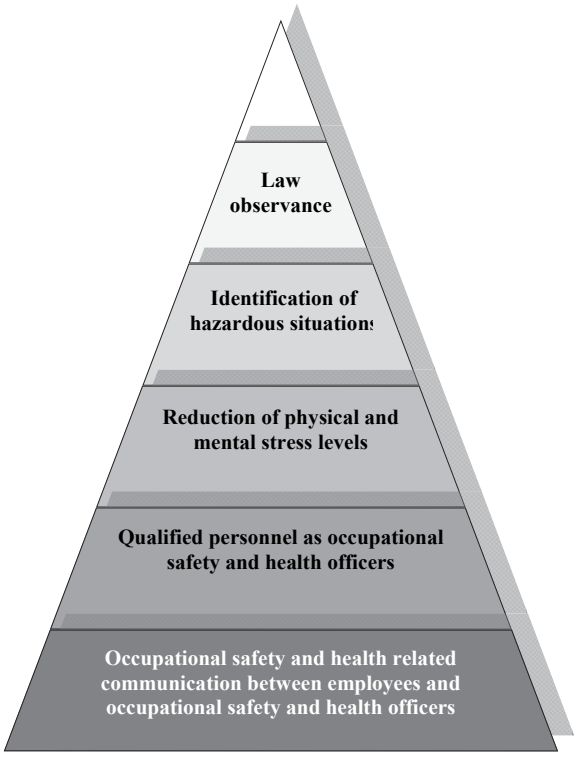
Figures 4-6 reveal that the highest number of unclosed cases was recorded in 2019 in Čačak and Ruma, in 2020 in Belgrade and Niš, and in 2021 in Šabac, Kragujevac, and Niš.

Figures 7-11 indicate that a greater number of cases were closed in other ways according to the Law on Misdemeanours (warning notices, request denials, dismissals, and release from responsibility of the accused) in 2018 in Kragujevac, Novi Sad, and Niš, but also that the same year saw few dismissals in Belgrade and Šabac.

SAFETY SYSTEM MANAGEMENT

Occupational safety system management, based on a multicriteria analysis of conducted activities (Dujman, 2017), involves continuous planning of protective measures and the implementation of corrective actions. The observance of legal regulations raises the level of worker safety, thereby reducing the number of occupational injuries.

The structure of safety management should be set up to enable the reduction of physical and mental stress levels, as well as the number of situations characterized by a high level of risk and harm to workers. Identification of hazardous situations is carried out through procedures conducted beginning with the risk assessment phase, through the examination of work equipment, to the strict implementation of the established working hours. Compliance with regulations is obligatory for both workers and employers. Workers should use machinery and equipment in the prescribed manner, as well as look after their coworkers in the immediate surrounding.



The responsibility for the functioning of the management system lies with the management, both in terms of the overall company (Milovanović, 2011) and in terms of the safety system. Communication in occupational health and safety is regulated by the international standard ISO 45001. It also includes communication during emergencies, which is of great importance for worker safety. Another prerequisite for the proper functioning of the occupational health and safety management system is that occupational health and safety tasks be performed by qualified personnel to ensure a higher level of worker safety through adequate implementation of preventive measures. Modern technical solutions, in addition to planned organizational solutions, should be implemented daily, not just when regular and random inspections are expected. The management system for the health and safety of workers will function properly only if the reduction of occupational injuries is taken into account and if worker safety issues are considered as equally important corporate objectives.

CONCLUSION

The application of safety indicators to improve the safety management system plays a significant role, especially with regard to the impact of the proposed sub-indicators. The number of unclosed cases and dismissed charges can largely contribute to looser implementation of protective measures and the adopted environmental protection policies.

Analysis shows that the highest number of closed cases was recorded in Belgrade, Kruševac, Novi Sad,

Kraljevo, Šabac, and Pirot. Based on the data can be observed that the public prosecutor's office in Novi Pazar and in Bela Palanka stands out in the number of unclosed case.

ACKNOWLEDGEMENTS

This paper was supported by the Ministry of Science, Technological Development and Innovation of the Republic of Serbia, grant no. 451-03-47/2023-01/ 200148.

REFERENCES

Dujman, J. (2017). *Upotreba neparametarske statistike u inženjerskim problemima.* Sveučilište u Zagrebu. Fakultet strojarstva i brodogradnje, Zagreb. https://zir.nsk.hr/ islandora/object/fsb%3A3729

ISO 45001 International Organization for Standardization (ISO) standard for management systems of occupational health and safety (OHS), 2018. https://eshop.liberoservices.org/index.php/list-of-seminar/iso-management-systems/internal-auditor/product/internal-auditor-iso-45001-2018

Labour Reports for 2015-2021. (2016-2022). Ministry of Labour, Employment, Veteran and Social Affairs, Occupational Safety and Health Administration, Republic of Serbia, Belgrade. https://www.minrzs.gov.rs/sr /dokumenti/izvestaji/uprava-za-bezbednost-i-zdravlje-na-radu/izvestaji-o-radu

Malenović Nikolić, J., Krstić, D., Milošević, L., Ilić-Krstić, I., & Jovanović, U. (2023a). *Analysis of the number of occupational injuries as a key element of safety system and energy sector management* [Manuscript submitted for publication]. First international Eurosa conference, EUROSA, Kopaonik.

Malenović Nikolić, J., Krstić, D., Milošević, L., Ilić-Krstić, I., & Lukić, M. (2023b). *Safety system management by analysing occupational injuries and using indicators of state.* [Manuscript submitted for publication]. Scientific Journal-Safety Engineering. Faculty of Occupational Safety, Niš

Number of fatal injuries per 100,000 workers. (2023). Bureau of Labor Statistics. https://www.bls.gov/

Milovanović, R. (2011). *Quality as a Vision of the Future.* 7th Research/Expert Conference with International Participations QUALITY 2011, Neum, Bosnia & Herzegovina, 153–158.

20th International Conference Man and Working Environment
SEMSIE
Safety Engineering & Management – Science, Industry, Education

www.znrfak.ni.ac.rs/semsie

MILENA MANČIĆ[1]
MIOMIR RAOS[1]
MILENA MEDENICA[1]
MARKO MANČIĆ[2]

[1]University of Niš,
Faculty of Occupational Safety
[2]University of Niš, Faculty of
Mechanical Engineering

[1]*milena.mancic@znrfak.ni.ac.rs*
[1]*miomir.raos@znrfak.ni.ac.rs*
[1]*milena.medenica@znrfak.ni.ac.rs*
[1]*markomancic@masfak.ni.ac.rs*

THE IMPORTANCE OF ENERGY BALANCING IN SMALL AND MEDIUM-SIZED ENTERPRISES

Abstract: *The sector of small and medium-sized enterprises is considered particularly important for economic development, as it is the most vital, efficient, and dynamic part of the economy of the Republic of Serbia. Due to the special importance of the sector of small and medium-sized enterprises in the EU and especially in Serbia, there was a need to analyse this sector from the aspect of energy efficiency, as well as to monitor the production process to identify potential problems and possible savings. The applied methodology includes the analysis of the sector of micro, small and medium-sized enterprises in Serbia. Identification of energy-intensive processes, analysis of the environment, and challenges faced by the sector are part of the energy balance. After the identification is completed, an analysis of the dominant energy-intensive processes and equipment is performed, and based on that, applicable energy efficiency measures and applicable technologies for the use of renewable energy sources are selected and described.*

Keywords: energy balancing, small and medium-sized enterprises, decarbonization

INTRODUCTION

The sector of small and medium-sized enterprises (SMEs) is considered particularly important for economic development and solving employment problems, as this sector represents the most vital, efficient, and dynamic part of the economy of the Republic of Serbia (Bahrens et al., 2022). The countries of the Western Balkans, the economies of many of which still depend on fossil resources, signed the Sofia Declaration regardless and committed themselves to becoming climate neutral by 2050. One of the ways to reduce greenhouse gas emissions is to reduce the consumption of energy sources and to migrate to renewable energy sources. Although extensive research is being carried out in the EU and globally, and solutions and paths leading to an energy-independent and decarbonized society are being sought, current technological solutions still depend on the application of conventional technologies for energy transformation, which include combustion and emission of greenhouse gases and the use of nuclear power. Serbia and the Western Balkans have just started their journey towards green energy transition, and at the current level of technological development and with the current energy, financial, and economic resources, the implementation of energy efficiency measures can be considered one of the resources for reducing greenhouse gas emissions, as well as for increasing the competitiveness of the economy.

Due to the special importance of the sector of SMEs in the EU and especially in Serbia, there is a clear need to analyse this sector from the aspect of energy efficiency. The analysis of the sector of micro, small, and medium-sized enterprises in Serbia involves the identification of energy-intensive processes, analysis of the environment and challenges, analysis of dominant energy-intensive processes and equipment, and the selection and description of applicable energy efficiency measures and applicable technology for the use of renewable energy sources.

Serbia continues to face significant challenges in the transition to a sustainable market economy, i.e. towards an economy that is competitive, well-governed, environmentally focused, inclusive, resilient, and integrated. In order to achieve progress in all the abovementioned directions, including in terms of a more energy-efficient environment, it is necessary to strengthen mutual cooperation between employers and workers, regulate legal regulations, increase the participation of state, city, and municipal communities whose common goal is to plan and implement the transition of the economy, private and state-controlled, towards a socially and ecologically sustainable, carbon neutral economy. The energy transition represents a serious challenge for the whole society, but local communities and their inhabitants are affected the most by the transition processes. In order to successfully implement the green energy transition in the Western Balkans, it is necessary to determine the dates for the gradual abolition of fossil fuels in order to enable the planning of investment projects and activities of a just transition. However, in the absence of a decision at the national level, decisions to close individual coal-fired power plants and/or coal mines are always welcome. It is also necessary to approve investment in renewable energy sources and modernize the network infrastructure, conduct a transparent debate on energy, without hiding details behind closed doors, develop energy scenarios at the state level, which determine the limits of plans for the restructuring of thermal power

plants, and conduct exhaustive campaigns to raise public awareness of national as well as regional levels.

Acquainted with the necessity of transition, the European Bank for Reconstruction and Development sets the following priorities for Serbia: improvement of competitiveness and management, which is reflected in the low productivity of unreformed state-owned enterprises and public utilities (European Bank for Reconstruction and Development, 2018), as well as strengthening of integration, which is a key priority of the Western Balkans. Promoting the transition to a green economy is another priority, considering Serbia's high energy consumption in relation to its GDP, as well as its sensitivity to climate change (European Bank for Reconstruction and Development, 2018). It is necessary to support the green economy by encouraging energy efficiency improvements, better use of renewable energy, and promotion of sustainable development, where the goals are to provide financing and support for projects aimed at increasing energy efficiency and using renewable energy, to reduce greenhouse gas emissions, and to reduce sensitivity to climate change.

The share of renewable energy sources in the production of electricity in Serbia is 24%, the largest part being hydropower, while the production of electricity from the sun, wind, and biomass accounts for 4% of the total balance. As the Strategy of the Republic of Serbia foresees that by 2050 the share of renewable energy sources in the total consumption will be 50% (Fresner et al., 2020), and the climate change convention foresees the planning of more efficient application of renewable energy sources and technologies for their application as well as other strategies to reduce the greenhouse gas effect and environmental pollution, it is necessary to consider all energy potentials and needs both at the local and the state level.

OVERVIEW OF THE MICRO, SMALL AND MEDIUM-SIZED ENTERPRISE SECTOR IN SERBIA

According to the Strategy for supporting the development of SMEs (Mustață et al., 2021), in terms of size in the SME sector, micro-enterprises and entrepreneurs are the most numerous, with a share of 96.3% of the total number of SMEs. The relatively low average number of 2.4 employees per business entity indicates one of the key weaknesses of the sector of SMEs compared to that of EU member states, where the average is 4.2. The average values of other business indicators expressed per employee are also significantly lower compared to the EU average, all of which points to excessive fragmentation and weak competitiveness of SMEs in Serbia. The sectoral concentration of SMEs has not changed significantly over the years: the concentration in non-tradable sectors dominates, whereby every third enterprise or entrepreneur from SMEs operates in the field of wholesale and retail trade, followed by services and the manufacturing industry.

The structure of SMEs in the processing industry is dominated by business entities that operate in low-tech areas, with products of little added value and differentiation, which results in their weaker position on the market and low price and profit margins. SMEs are still not sufficiently export-oriented. In the total number of SMEs, exporters make up only 4.3%, and the share of exports in the turnover is a modest 9.1%.

The development of SMEs is of key importance for the development of society and the economy, and it is necessary to create conditions for their development. According to the data from 2017 (Danon & Šormaz, 2020), SMEs have the largest share in the total number of economic entities – 99.9% (357,234), employment – 66.0% (873,462 workers), turnover – 65.6% (7,164 billion RSD), and gross added value – 56.7% (1,325 billion RSD). It should be emphasized that out of the total number of 357,234 economic entities, 99,967 are SMEs, while 257,267 are entrepreneurs.

In Serbia, a growth in demand for green financing can be expected, which will accompany national activities arising from the obligations defined by the Green Deal of the European Union and the Green Agenda for the Western Balkans, which define the basis of Serbia's development strategy in green transition, and within this connection and (environmental) policies of action. The role of the private sector in the transition to a green (circular) economy with low carbon emissions is difficult to assess, and many SMEs have already started investing in energy efficiency. Research conducted on a sample of 146 companies (Fresner et al., 2020; Mancic et al., 2019) showed that the main obstacles to green investments faced by SMEs are lack of capital, lack of necessary skills and information about green technologies and financial products, as well as inadequate support from the regulatory authorities.

Research has indicated the need for financial assistance or subsidies, whereby the preferred support for green projects is 20% of financial assistance or subsidies, but also there is a need for technical assistance, which is considered a key element that would enable green investments (Mancic et al., 2019). In addition, the research pointed to problems arising from the regulatory legal framework and administrative requirements associated with green investments and renewable energy sources.

Based on the analysis of the number of registered economic entities in Serbia, the processing sector was chosen for further analysis, and special attention was paid to energy-intensive subsectors with a significant number of registered economic entities. The measures for improving energy efficiency described in this paper were chosen as applicable in the abovementioned processing sub-sectors, but they are also applicable in other sectors where similar or the same type of equipment is used, i.e. similar processes are performed. A detailed analysis of the processes of all activities performed by SMEs in Serbia is beyond the scope of this paper. Sectors with no production or processing activity most often do not have energy-intensive processes, and energy efficiency measures for these sectors are reduced to the problems of buildings and transport.

Analysis of the situation and problems in the sector of micro, small, and medium-sized enterprises in Serbia pointed to problems with human resources and lack of

specific knowledge and insufficient information, which, among other things, also pertains to the application of energy efficiency measures and the possibility of applying renewable energy sources. In this regard, the priority measure for improving energy efficiency in the sector of SMEs should be to increase the availability of financial assistance for the provision of expert services in the field of energy management, conducting energy audits and preliminary and detailed energy balancing of enterprises. After the implementation of this measure, SMEs will be able to make decisions on investment projects based on relevant data on the energy flows of the enterprises themselves, on the one hand, and investment projects will have the greatest impact of realized energy, environmental and financial benefits per unit of invested money, on the other hand. In other words, it is important to make decisions about investments in energy efficiency after professional energy planning in technically applicable options for improvement, based on analyses carried out by experts.

Based on the Statistical Yearbook of the Republic of Serbia for 2020, in 2018 there were 87,407 active business entities in the Serbia with 1,161,577 employees (of which 1,095,149 were paid employees). The total turnover achieved by business entities in 2018 was 10,379 billion RSD, while the value added by factor costs was 2,134 billion RSD (Simin et al., 2013).

Figure 1 shows the participation of different sectors according to the classification of activities in the total number of business entities. It is notable that the sectors of wholesale and retail trade and repair of motor vehicles had the largest share (35.1%), followed by the manufacturing (processing) industry (18.1%), and professional, scientific, innovative, and technical activities (13.7%).

The manufacturing industry constitutes slightly more than 18% of the total number of business entities and, what is relevant to the present discussion, this sector has a large consumption of energy, which is considered in this paper.

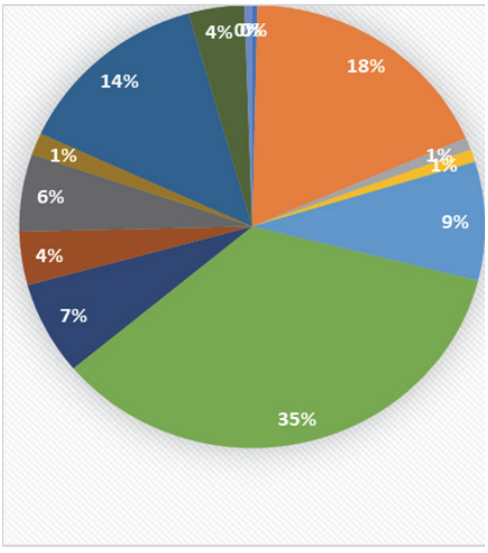


Figure 1. *The participation of different sectors in the total number of business entities*

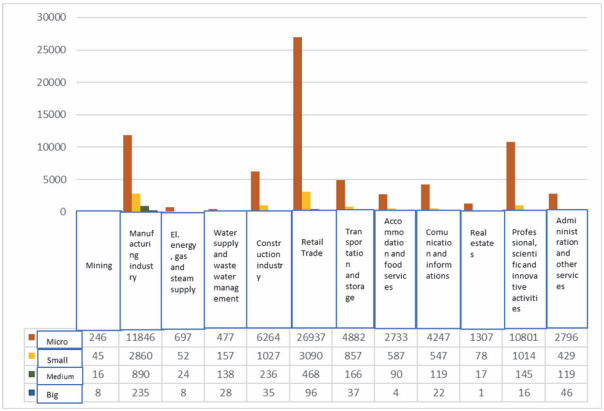


Figure 2. *Number of business entities by size*

Figure 2 shows the number of business entities according to size and sub-sector to which they belong, while Figure 3 shows an overview of the sub-sector of the manufacturing industry, which is considered in the paper.

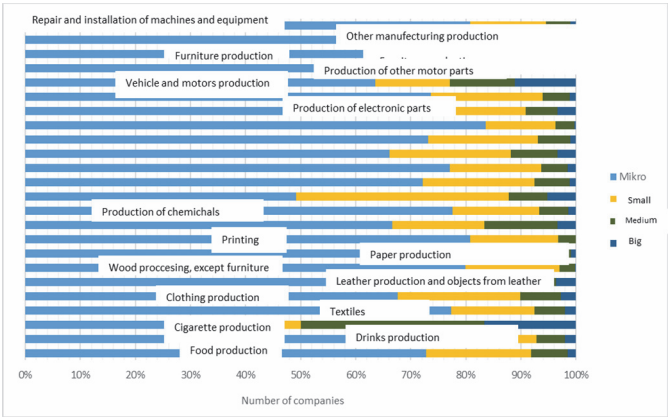


Figure 3. *Overview of the processing industry sector*

Selected sectors of the processing industry by the number of registered business entities with energy-intensive processes are shown in Figure 4.

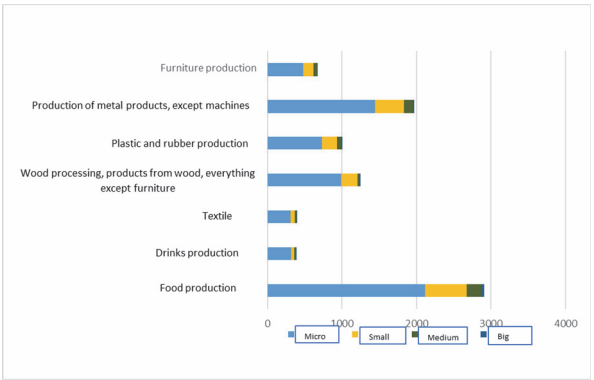


Figure 4. *Business entities with energy-intensive processes*

ENERGY BALANCE

The energy balance represents the monitoring of energy flows from their appearance in the energy economy until delivery to direct consumers (Danon & Šormaz, 2020). Regarding the system of energy statistics, the

most important thing is to form a database of monitored energy processes, which is the basis of the analysis, after which the prediction of energy consumption can be made, as well as the development of future scenarios, and the optimization of energy use by defining the parameters of both energy use and economic indicators. The energy balance has an immeasurable influence on reports and legal acts on environmental impact assessment and the definition of environmental protection measures.

The goals of creating an energy balance are the following: determination of the current energy consumption and the history of energy consumption for the considered process through an overview of the mutual relations of energy delivery and energy needs; an overview of the total energy costs; an overview of the current state of energy efficiency, a proposal for the use of new technologies in order to increase energy efficiency of the facility; and the use of new technologies to achieve a higher degree of utilization of the energy used. Also, one of the goals is to achieve the optimal ratio of economically profitable investments in renewable energy sources and greenhouse gas emissions, as well as to determine measures and activities in terms of energy savings. The energy balance is the basis for the development of investment plans for the considered business facility, as well as for predictive models of energy consumption.

The energy balance of the process is performed for the technological process, as well as for the process whose result is energy production. When creating an energy balance, energy sources are classified according to their renewability, as well as the form in which they are found. Although there are many energy balances, depending on whether they refer to the monitoring of primary energy or final energy, whether it is about monitoring the flow of electricity generation in an electricity production plant, whether it is a municipal, regional, or state energy balance, where the scaling of monitored processes is evidently different, the energy balance that this paper deals with primarily refers to the energy balance of the processes that make up one business entity.

CONCLUSION

Considering the small and medium-sized business sector's unique significance in the EU, particularly in Serbia, it is imperative that this sector be examined from the perspective of energy efficiency. The identification of energy-intensive processes, analysis of the environment and associated challenges, analysis of the equipment and processes that are dominant in the energy-intensive sector, and the description and selection of appropriate energy-efficiency measures and technology for the use of renewable energy sources are all part of the analysis of the micro, small, and medium-sized enterprise sector in Serbia. Regarding the participation of various sectors based on the categorization of activities in the total number of business entities, it was observed that the manufacturing (processing) industry has a share of 18.1% and it is the second largest share in Serbia. The main reason why the manufacturing industry was selected is that its energy consumption level is the highest (both for the manufacturing process and for the distribution), and it is necessary to go through the process of energy balancing and to monitor energy flows. The goals are to determine the current energy consumption and the history of energy consumption for the considered process, to provide an overview of the total energy costs, and to propose the use of new technologies.

ACKNOWLEDGMENTS

This paper is part of the Project No. 451-03-47/2023-01/ 200148, funded by the Ministry of Education, Science and Technological Development of the Republic of Serbia.

REFERENCES

Bahrens A., Lakićević M., Krušković V., Pavlović Z., Petrović Ž., Avignon A., Pešić S., & Perović, S. (2022). *Increasing the share of green financing in the private sector in Serbia in the post-pandemic period*. UNDP.

Danon, M., & Šormaz, N. (2020). *Report on small and medium-sized enterprises and entrepreneurship for 2017*. Ministry of Economy, Sector for the Development of Small and Medium-Sized Enterprises and Entrepreneurship. https://privreda.gov.rs/sites/default/files/documents/2021-08/Izvestaj-MSPP-2018_FIN.pdf

European Bank for Reconstruction and Development. (2018). *Strategy for Serbia 2018 to 2023*. https://www.ebrd.com/documents/strategy-and-policy-coordination/serbia-country-strategy.pdf

Fresner J., Stamenić M., Krenn C., Tanasić N., & Mančić, M. (2020). *Energy efficiency in the food industry sector in the process of obtaining an integrated permit*. University of Belgrade.

Mančić M., Laković M., Janevski J., & Pavlović, J. (2019). Assesment of possibilities of waste utilization in small wood treatment enterprises in the Niš region. *Proceedings of International Conference Interklima*.

Milovanovic Z., Papic Lj., Dumonjic-Milovanovic, S., Milasinovic A., & Knežević, D. (2018). *Chapter 3: Energy balance – energy production and consumption relationship.*

MSPP. (2015). *Strategy for supporting the development of small and medium-sized enterprises, entrepreneurship and competitiveness for the period from 2015 to 2020 with an Action Plan for the implementation of the strategy for supporting the development of small and medium-sized enterprises, entrepreneurship and competitiveness for 2015 with a projection for 2016.* https://privreda.gov.rs/sites/default/files/documents/2021-08/Strategija-I-Plan.pdf

Mustață A., & Shevchuk, V. (2021). *Eight steps towards a just energy transition in the Western Balkans*. https://bankwatch.org/wp-content/uploads/2021/05/EN-Eight-steps-for-a-just-transition-in-the-Western-Balkans-Apr-2021-1.pdf

Simin M., Živkucin S., Aleksić S., & Soleša, D. (2013). State and development of the innovative sector of small and medium-sized enterprises (SMEs) in AP Vojvodina. *Economy, Theory and Practice, 3,* 22-43.

20th International Conference Man and Working Environment
SEMSIE
Safety Engineering & Management – Science, Industry, Education

www.znrfak.ni.ac.rs/semsie

NIKOLA MIŠIĆ[1]
MILAN PROTIĆ[1]
MIOMIR RAOS[1]
MILAN GOCIĆ[2]

[1]University of Niš,
Faculty of Occupational Safety
[2]University of Niš, Faculty of Civil
Engineering and Architecture

[1]nikola.misic@znrfak.ni.ac.rs
[2]milan.protic@znrfak.ni.ac.rs
[3]miomir.raos@znrfak.ni.ac.rs
[4]milan.gocic@gaf.ni.ac.rs

BENCH-SCALE FLAMMABILITY TESTING OF FOREST FUELS: A REVIEW OF METHODS AND APPARATUSES

Abstract: *Forest fires pose a great danger to human life and property, and the characterization of the flammability of forest fuels is the key to understanding fire behaviour. Bench-scale apparatuses are used to study the flammability of forest fuels under controlled conditions. This paper reviews the different bench-scale apparatuses that have been developed for testing the flammability of forest fuels. The paper includes an analysis of methodologies, experimental setups, and measurement parameters that can be obtained from these devices. The literature review found that there is no single bench-scale apparatus that is ideal for all applications. Each apparatus has its advantages and disadvantages, and the choice of apparatus will depend on the specific research question being addressed. By examining the advantages and limitations of different testing platforms, this review aims to provide researchers, fire management agencies, and practitioners with valuable insight into the selection of appropriate tools for assessing the flammability characteristics of forest fuels. Ultimately, the synthesis of existing knowledge on equipment contributes to the improvement of methodologies in fire prevention, prediction, and control in forest ecosystems.*

Keywords: forest fire, forest fuel, bench-scale apparatus, flammability

INTRODUCTION

Customized fire behaviour measurements are essential for addressing specific research questions and supporting decision management. Understanding fire behaviour is closely linked to fundamental physical processes such as combustion, heat transfer, and ignition, as well as to the application of a broad range of fuel types and consideration of environmental conditions in wildlands.

Measurements of fire behaviour can be categorized into two segments: the quantification of data for specific physical processes and the quantification of behaviours of entire fires on a large scale. With the intention of developing models, predicting and understanding fire behaviour, as well as taking into account the cost of large-scale experiments, bench-scale experiments aim to obtain data comparable to those from field-scale fires (Finney et al., 2021).

Laboratory experiments are conducted across a range of scales, spanning from the fuel particle to the fuel bed, and from field plot to stand scales. Small-scale fire testing primarily assesses the flammability of plant parts, while larger-scale tests are employed for the evaluation of whole plants and plant groupings (White & Zipperer, 2010). These experiments aim to broaden the understanding of the relationships between fuel consumption and the processes that drive heat transfer, ignition, flame spread, as well as thermal degradation through flaming and smouldering combustion.

Since it is impossible to measure an entire population in a forest community, a proper sampling design is necessary, which should consider spatial patterns, precision, and timing of measurements. To obtain accurate data, measurement techniques and instrumentation must satisfy two requirements: precision and accuracy. Precision relates to the repeatability of measurements, whereas accuracy pertains to how closely a set of measurements approximates the true quantity. The quality and applicability of experimental results depend on a well-prepared experimental design. It implies a carefully controlled environment and input variables, appropriate ranges of observations, and adequate number of repetitions. In that regard, laboratory bench-scale experiments have the possibility to control the conditions, unlike field experiments.

Regarding the above considerations, this paper aims to review different laboratory apparatuses, devices, and protocols that have been developed for testing the flammability of forest fuels. The paper analyses methodologies, experimental setups, and measurement parameters obtainable from these devices.

DEFINING FOREST FUEL FLAMMABILITY

Considering the definition of forest fuel flammability, Anderson (1970a) and Martin et al. (1993) used four components: ignitability, combustibility, sustainability, and consumability. In this regard, the scientific community has developed numerous approaches, methods, and protocols for assessing the flammability of fine forest fuels (White & Zipperer, 2010). As indicated by Etlinger and Beall (2004), the choice of technique and method depends on the components to be evaluated.

Ignitability is frequently defined as the minimum temperature or heat flux needed for ignition, or as the duration it takes for a plant to catch fire after being exposed to an external heat source. Regarding ignitability, Anderson links it to specific physical properties, such as vegetation density, specific heat, and thickness (Anderson, 1970b). Combustibility follows ignitability and refers to the speed of combustion following ignition, which can be presented as the weight of the test sample divided by the maximum burn rate. Sustainability measures the fire's ability to continue burning, whether with or without an external heat source, in terms of the stability of the remaining burn rate. Consumability can be defined as the quantity of plant material consumed by the fire.

The factors affecting the flammability of forest fuels are directly linked to fuel structure and can be categorized into two groups: (1) physical structure of the fuel, which is based on its configuration (ground fuel (litter, duff), dead and downed woody fuel, shrub, ladder, and canopy fuels), and (2) physiological or chemical elements of the fuel (volatile content, resins, waxes, terpenes, moisture content, etc.). Nevertheless, scientific research investigating the flammability of forest fuels through laboratory experiments often does not consider environmental factors such as weather and wind, temperature, and relative humidity, which significantly contribute to forest fuel flammability.

METHODS FOR MEASURING THE FLAMMABILITY OF FOREST FUELS

To identify, understand, and assess the existing methodologies and experimental setups for testing the flammability of forest fuels, an extensive literature review is necessary. The purpose is to outline specific experimental designs and their outcomes, including measurement parameters characterizing the flammability of forest fuels.

According to the literature review, experimental methods encompass 14 different experimental designs (Table 1).

Table 1. *A review of experimental designs and their outcomes for characterizing the flammability of forest fuels*

		EXPERIMENTAL DESIGNS													
		Cone Calorimeter	Mass Loss Calorimeter	Fire Propagation Apparatus	Full scale room/corner calorimeter	Epiradiator	Low tech device - grill	Muffle Furnace	Oxygen bomb	Steel Ring	FIST Wind Tunnel	Fire Bench	Thermogravimetric Analyser	Ignitability Apparatus	Static Bomb Calorimeter
EXPERIMENTAL OUTCOMES	Heat Release Rate	X	X	X	X									X	
	Total Heat Released	X	X	X	X										
	Time to Ignition	X	X	X	X	X	X	X		X	X	X	X		
	Effective Heat of Combustion	X	X	X	X										
	Mass Loss Rate	X	X	X	X			X			X	X			
	Burning/Combustion Time						X					X			
	Burnt Length						X								
	Burnt Biomass Percentage						X								
	Flame Length					X									
	Flame Height					X						X			
	Flame Depth														
	Flaming Duration/Time	X	X	X	X	X		X		X		X			
	Flame Speed									X		X			
	Temperature						X			X		X			
	Gross Energy Content								X						
	Heat of Combustion								X						
	Higher heating value														X
	Lower heating value														X
	Ember Time														
	Mean Flame Temperature											X			
	Ash content												X		

Numerous methodologies exist for assessing the flammability properties of different materials. The following are standardized methods for assessing the flammability and combustion properties of materials:

- ASTM D 5865 Test method for gross calorific value of coal and coke; the oxygen bomb calorimeter is the most common device for measuring the heat of combustion or calorific value of a material;
- ISO 1716 Reaction to fire tests for building products – determination of the heat of combustion;
- ISO 5657 Reaction to fire tests – ignitability of building products using a radiant heat source;
- ASTM E 2102 Test method for measurement of mass loss and ignitability for screening purposes

using a conical radiant heater; the mass loss calorimeter device meets the test method requirements;

- ASTM D 2863 Test method for measuring the minimum oxygen concentration to support candle-like combustion of plastics (oxygen index); the Oxygen Index technique measures the minimum percentage of oxygen in the test atmosphere that is required to marginally support combustion;
- ASTM E 1354 Test method for heat and visible smoke release rates for materials and products using an oxygen consumption calorimeter, and ISO 5660-1 Reaction to fire tests – heat release, smoke development, and mass loss rate – part 1. Heat release rate (cone calorimeter method); the Cone Calorimeter is a crucial bench-scale instrument in fire testing that complies with these test methods;
- ASTM E 2067 Practice of full-scale oxygen consumption calorimetry fire tests; the full-scale calorimeter is suitable for this fire test;
- ASTM E 1822 Test method for fire testing of stacked chairs; ASTM E 2257 Test method for room fire test of wall and ceiling materials and assemblies; ISO 9705 Fire tests – full scale room test for surface products; these test methods are applied with the room/corner test calorimeter;
- ASTM D 7309 Test method for determining flammability characteristics of plastics and other solid materials using microscale combustion calorimetry.

The dominant mechanisms of heat transfer in forest fires are radiation and convection, with radiation being the primary driver of ignition. The key distinction between convective and radiation heating is that radiation requires a direct line from the heat source, whereas convective heating relies on the flow of air to gather combustible gases necessary for flaming ignition. When considering radiation as a heating source, many experimental designs employ an electric heating element as the radiant heat source, such as Fire Propagation Apparatus, Cone Calorimeter, and Mass Loss Calorimeter. All three devices consist of a conical heater with the capability to set heat flux values and the option of whether to use piloted ignition or not. They also have the ability to measure the heat release rate (HRR), a crucial parameter in fire engineering and the sole significant variable in defining phenomena such as a fire hazard.

By analysing the combustion of pine needle litter, Santoni et al. (2015) utilized the Cone Calorimeter and the Room Corner Test to investigate the impact of scale on heat release rate (HRR). They found that the scale of the experiment is a key factor for the measurement of HRR. The Fire Propagation Apparatus allows air to flow into the combustion chamber, potentially inducing convective cooling. Schemel et al. (2008) conducted the first tests by replacing the standard sample holder with a custom-made one, specifically designed to investigate the flammability characteristics of forest fuels. Madrigal et al. (2013) introduced new methodologies and protocols to enhance the bench-scale measurement of the flammability of live forest fuels using a mass loss calorimeter. Their work provides insights into the interactions between vegetation and fire dynamics. Combustion tests are performed under natural convection and forced airflow. These tests illustrate the processes leading to fuel consumption and provide valuable parameters for numerical modelling.

Studies that use wind tunnels to direct airflow across samples, simulating winds, often employ infrared panels as a heat source for ignition (McAllister et al., 2012). The panels are employed to quantify drag forces in fuel matrices of different compositions and porosities, as well as to comprehend how the associated flow characteristics affect the convective heating of fuel particles. Tests using radiant panels for fuel particle heating are conducted to investigate the role of thermal radiation. The research in Jolly et al. (2012) aimed to measure the impact of fuel moisture and foliar chemistry on the ignitability of lodgepole pine needles during the initial stages of a mountain pine beetle attack.

Several authors made custom-made fire benches to characterize the flammability of forest fuels (de Magalhães & Schwilk, 2012; Kane et al., 2008; Ormeño et al., 2009; Romero & Ganteaume, 2021). Most of them involve a flat surface in which forest fuels are tested for flammability. They use different ignition sources such as firebrands, ignited by an epiradiator, and cotton wicks soaked in a flammable liquid, such as ethanol or xylene. Commonly, their results are summarized in the evaluation of flame characteristics, including flame length, height, depth, duration, and speed. Advanced measurements involve assessing mass loss, utilizing thermocouples for temperature recordings, and employing infrared cameras to capture the temperature structure of the fire plume. Jaureguiberry et al. (2011) introduced similar experimental designs, including a low-tech device for field measurements of the flammability of entire plants. This device and protocol have the potential to efficiently acquire flammability data for numerous species in the field. Parsons et al. (2015) emphasized the significance of analysing the relationship between species-specific leaf traits and flammability based on experimental outputs, including flame height, flaming duration, mass loss, and temperature.

Another method for measuring flammability parameters is to use a muffle furnace. Grootemaat et al. (2015) employ this method to investigate the connection between leaf traits (specific leaf area, moisture content, leaf dry mass, and leaf chemistry) and flammability parameters (time to ignition, flame duration, and smouldering duration).

CONCLUSION

This brief literature review reveals several applied bench-scale devices for investigating the flammability characteristics of various forest fuels. The types, measurement procedures, and testing methodology can affect fire test results. Some of the factors that can influence the results, for example, are the position of thermocouples or the sensitivity of load cells for measuring mass loss rate.

Time to ignition, flaming and smouldering duration, flame height, and temperature are common parameters for quantifying flammability in laboratory experiments, requiring minimal equipment. Mass loss and heat release rate measurements often necessitate precision scales and gas analysers, which are not always available and are expensive. However, these parameters are considered vital for understanding the fire hazard.

The advantage of standardized combustion experiments using devices like the Fire Propagation Apparatus, Cone Calorimeter, or Mass Loss Calorimeter is the control of critical parameters and the repeatability of results. To understand the flammability of wildland fuel, it is essential to assess the heat and mass transfer mechanisms that govern ignition and burning behaviour.

However, determining flammability parameters for vegetative fuels is not straightforward, and a rigorous standardized methodology has yet to be established. In line with the above, these experimental setups aim to establish the most suitable methodology for examining the flammability of forest vegetation, producing data applicable in real field conditions.

At the Faculty of Occupational Safety, University of Niš, a Fire Protection Laboratory was established. This laboratory is dedicated to conducting in-depth research on heat transfer processes and thermal degradation in small fuel beds, utilizing an adaptive mass loss calorimeter. For more information about the laboratory, please visit the following link:

https://www.znrfak.ni.ac.rs/fpl/.

ACKNOWLEDGEMENTS

The paper is part of the research funded by the Ministry of Education, Science and Technology of the Republic of Serbia according to the Agreement on the implementation and financing of the scientific research work of NIO in the year 2023, Registration number of the Agreement 451-03-47/2023-01/ 200148.

REFERENCES

Anderson, H. E. (1970a). Forest fuel ignitibility. *Fire Technology, 6*(4), 312–319. https://doi.org/10.1007/BF02588932

de Magalhães, R. M. Q., & Schwilk, D. W. (2012). Leaf traits and litter flammability: Evidence for non-additive mixture effects in a temperate forest. *Journal of Ecology, 100*(5), 1153–1163. https://doi.org/10.1111/j.1365-2745.2012.01987.x

Etlinger, M. G., & Beall, F. C. (2004). Development of a laboratory protocol for fire performance of landscape plants. *International Journal of Wildland Fire, 13*(4), 479–488. https://doi.org/10.1071/WF04039

Finney, M. A., McAllister, S. S., Grumstrup, T., & Forthofer, J. M. (2021). Measurements in fire behaviour. In: *Wildland Fire Behaviour Dynamics, Principles and Processes* (Ch. 9). SCIRO.

Grootemaat, S., Wright, I. J., van Bodegom, P. M., Cornelissen, J. H. C., & Cornwell, W. K. (2015). Burn or rot: Leaf traits explain why flammability and decomposability are decoupled across species. *Functional Ecology, 29*(11), 1486–1497. https://doi.org/10.1111/1365-2435.12449

Jaureguiberry, P., Bertone, G., & Díaz, S. (2011). Device for the standard measurement of shoot flammability in the field. *Austral Ecology, 36*(7), 821–829. https://doi.org/10.1111/j.1442-9993.2010.02222.x

Jolly, W. M., Parsons, R. A., Hadlow, A. M., Cohn, G. M., McAllister, S. S., Popp, J. B., Hubbard, R. M., & Negron, J. F. (2012). Relationships between moisture, chemistry, and ignition of Pinus contorta needles during the early stages of mountain pine beetle attack. *Forest Ecology and Management, 269*, 52–59. https://doi.org/10.1016/j.foreco.2011.12.022

Kane, J. M., Varner, J. M., & Hiers, J. K. (2008). The burning characteristics of southeastern oaks: Discriminating fire facilitators from fire impeders. *Forest Ecology and Management, 256*(12), 2039–2045. https://doi.org/10.1016/j.foreco.2008.07.039

Madrigal, J., Hernando, C., & Guijarro, M. (2013). A new bench-scale methodology for evaluating the flammability of live forest fuels. *Journal of Fire Sciences, 31*(2), 131–142. https://doi.org/10.1177/0734904112458244

McAllister, S., Grenfell, I., Hadlow, A., Jolly, W. M., Finney, M., & Cohen, J. (2012). Piloted ignition of live forest fuels. *Fire Safety Journal, 51*, 133–142. https://doi.org/10.1016/j.firesaf.2012.04.001

Ormeño, E., Céspedes, B., Sánchez, I. A., Velasco-García, A., Moreno, J. M., Fernandez, C., & Baldy, V. (2009). The relationship between terpenes and flammability of leaf litter. *Forest Ecology and Management, 257*(2), 471–482. https://doi.org/10.1016/j.foreco.2008.09.019

Parsons, A. L., Balch, J. K., De Andrade, R. B., & Brando, P. M. (2015). The role of leaf traits in determining litter flammability of south-eastern Amazon tree species. *International Journal of Wildland Fire, 24*(8), 1143–1153.

https://doi.org/10.1071/WF14182

Martin, R. E., Gordon, D. A., Gutierrez, M. A., Lee, D. S., Molina, D. M., Schroeder, R. A., Sapsis, D. B., & Stephens, S. L. (1993, October 26–28). Assessing the flammability of domestic and wildland vegetation. Proceedings of the 12th Conference on Fire and Forest Meteorology, Jekyll Island, GA, USA, (pp. 130-137). https://doi.org/10.13140/RG.2.1.3999.3680

Romero, B., & Ganteaume, A. (2021). Effect of Fire Frequency on the Flammability of Two Mediterranean Pines: Link with Needle Terpene Content. *Plants, 10*(10), 1–23. https://doi.org/10.3390/plants10102164

Santoni, P. A., Romagnoli, E., Chiaramonti, N., & Barboni, T. (2015). Scale effects on the heat release rate, smoke production rate, and species yields for a vegetation bed. *Journal of Fire Sciences, 33*(4), 290–319. https://doi.org/10.1177/0734904115591176

Schemel, C. F., Simeoni, A., Biteau, H., Rivera, J. D., & Torero, J. L. (2008). A calorimetric study of wildland fuels. *Experimental Thermal and Fluid Science, 32*(7), 1381–1389. https://doi.org/10.1016/j.expthermflusci.2007.11.011

White, R. H., & Zipperer, W. C. (2010). Testing and classification of individual plants for fire behaviour: Plant selection for the wildland urban interface. *International Journal of Wildland Fire, 19*(2), 213–227. https://doi.org/10.1071/WF07128

20th International Conference Man and Working Environment
SEMSIE
Safety Engineering & Management – Science, Industry, Education

www.znrfak.ni.ac.rs/semsie

BOJAN BIJELIĆ[1]
EVICA JOVANOVIĆ[2]

[1,2]University of Niš,
Faculty of Occupational Safety

[1]*bojan.bijelic@znrfak.ni.ac.rs*
[2]*evica.jovanovic@znrfak.ni.ac.rs*

APPLICATION OF DIERS 4DMOTION LAB IN ERGONOMIC RESEARCH

Abstract: *Ergonomics researchers are often faced with certain limitations regarding the research tools that they can use. The main problem lies in the fact that most of the available tools provide unreliable results. To overcome this, it is necessary to include more modern technological solutions in the area of ergonomic research which would lead to an increase in the quality of research. An example of such a solution, DIERS 4Dmotion lab, is presented in this paper.*

Keywords: Ergonomics; DIERS 4Dmotion lab; Musculoskeletal Disorders

INTRODUCTION

Ergonomic research is mainly directed toward finding out how different aspects of work are affecting workers. Most of the negative impact of work is manifested through harm to the workers' musculoskeletal systems. This harm to the musculoskeletal system is referred to as a musculoskeletal disorder (MSD) and can range from a minor injury to a long-term condition. Reliable data on the mechanisms leading to MSD are extremely important.

Exposure to ergonomic risk factors at the workplace is the main reason for the development of MSD. Physical, individual, and psychological risk factors are the three types of ergonomic risk factors (Odebiyi & Okafor, 2023). Assessment of exposure to ergonomic risk factors is needed for determining the risk for MSDs. This assessment can be done by using ergonomic methods such as self-reporting, observational, or direct measurement.

Self-reporting methods are various types of questionnaires that collect data for research, either through interviews or questionnaires (David, 2005). Some of the most widely used self-reporting methods are the Standardized Nordic Questionnaire for the Analysis of Musculoskeletal Symptoms - NMQ (Kuorinka et al., 1987), Risk Factor Questionnaire RFQ (Halpern et al., 2001), Dutch Musculoskeletal Disorders Questionnaire DMQ (Hildebrandt et al. 2001), Cornell University Musculoskeletal Discomfort Questionnaire (CMDQ) (Hedge et al., 1999), Self-Report Ergonomic Risk Assessment Tool (SEAT) (Peres et al., 2017). The main advantage of the self-reporting method is the possibility of simple and inexpensive application to a large number of respondents. However, the results obtained by these methods are often unreliable due to a high degree of subjectivity, which is why they have very limited application for scientific research if used separately.

Observational methods represent the largest group of ergonomic methods for assessing exposure to ergonomic risk factors. These methods are based on observation of the work process and evaluation of the working positions that the worker makes while working. Some of the best-known observation methods are Rapid Upper Limb Assessment RULA (McAtamney and Corlett, 2004), Rapid Entire Body Assessment REBA (Hignett and McAtamney, 2000), Ovako Working Posture Analysis System OWAS (Scott and Lambe, 1996), and revised NIOSH equation (Waters et al., 1993). The majority of observational methods are simple to use and do not require significant resources. The application of observational methods gives reliable results, so these methods are often used in scientific research. The main problem with observational methods is choosing the right one, due to the large number of different methods.

Direct measurement methods are methods that are based on the application of modern technologies for measuring specific parameters needed for ergonomic research. There is a whole range of different parameters that are important for ergonomic research, such as positions of the body and parts of the body during work, muscle activity, brain activity, hand grip force, and the like. The use of these modern devices is becoming increasingly popular and often used in research. Some of the most well-known devices are various types of back position monitoring devices (Nakamoto et al., 2018; Marras et al., 1992), Smart Workwear System (Lind et al., 2020), Inertial measuring suit SIRKA (Lins and Hein, 2022), ErgoArmMeter (Yang et al., 2017). Direct measurement methods are praised for the high accuracy of the obtained results, which makes them extremely useful for research purposes. The main disadvantage of applying these methods is their high cost as they often require expensive instruments.

The need for reliable results in ergonomic research is great. Many research relies on the application of results from self-report and observational methods, which are prone to errors. To achieve the highest level of data reliability used in ergonomic research, it is necessary to apply modern techniques. Several solutions can be used in such research. This paper will present the possibility of using the DIERS 4Dmotion lab in ergonomic research.

DIERS 4DMOTION LAB

DIERS 4Dmotion lab is developed by the German company DIERS, which is mainly focused on producing various biomechanical products used for the evaluation of the human body. The 4Dmotion lab is an all-in-one solution intended for functional analysis of the musculoskeletal system.

Operating principle for DIERS 4Dmotion

The DIERS 4Dmotion lab operates by using a 3D surface topography technique called rasterstereography. Rasterstereography is a non-invasive technique based on the recording of emitted horizontal lines on the surface of the subject's back, these lines are processed to create a three-dimensional image, which is then used to assess the examinee's posture of the spine and existing deformities. (Degenhardt et al., 2017). Rasterstereography as a 3D surface topography technique is often used to analyze the shape of the human body and is a non-contact and non-invasive technique (Wasim et al., 2019). This technique was originally limited only to static measurements, however, further development has enabled dynamic measurements that are of exceptional importance in the diagnosis and treatment of different musculoskeletal disorders, especially in the area of the spinal column (Michalik et al., 2020).

DIERS 4Dmotion lab works by emitting a light grid, a large number of parallel strips of visible light, on the examinee's back (Figure 1). Since the examinee's back is not a perfectly flat surface there will be some distortions between the parallel strips projected on his back. Based on the recorded image of the examinee's back software analyses distortions between the parallel strips and creates a model of the back surface and spinal vertebra (Degenhardt et al., 2020).

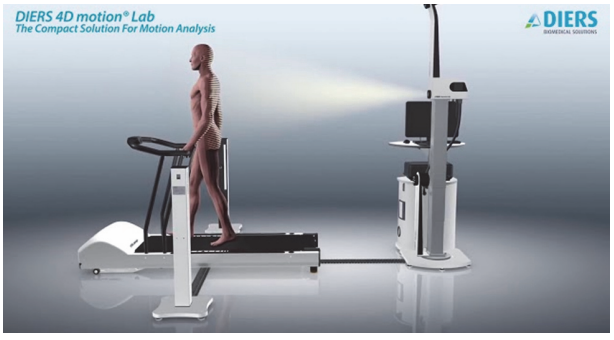


Figure 1. *Analysis in DIERS 4Dmotion lab (DIERS, 2009)*

Benefits of DIERS 4Dmotions lab

One of the main advantages of this lab is that it allows monitoring of the occurrence and progression of postural deformities in subjects in a safe way, without exposing them to harmful radiation that is characteristic of other methods such as X-rays, scanners, and others that used in medicine (Degenhardt et al., 2020). Enabling harm-free check-ups for people with postural deformities was the main idea behind using rasterstereography in such ways. Rasterstereography uses a visible spectrum of lights to create a 3D model of the human spine and therefore significantly reduces the level of exposure to harmful radiation.

As a lab for functional analysis of the musculoskeletal system, DIERS 4Dmotion provides great opportunities for application in ergonomic research. These possibilities are first of all reflected in the observation of early signs of potential postural problems in subjects in a non-invasive way. The literature search shows that DIERS 4Dmotion has not been used in ergonomic research so far, leaving the great potential of this system unused in this area. The application of DIERS 4Dmotion lab in ergonomics will be tested as part of research for a doctoral dissertation at the Faculty of Occupational Safety in Niš.

DIERS 4Dmotion lab parts

DIERS 4Dmotion lab consists of several individual parts with equal importance (Figure 2). The operating unit of the lab is a computer with special software for managing all devices in the lab and for recording and processing all the results. Part of the operating unit is a lifting column equipped with special digital cameras and a light projector. This lifting column is adjustable based on the height of the individual that is analyzed. The lab is equipped with a treadmill with special integrated foot pressure measurement sensors in the belt, which enable dynamic foot pressure measurement as well as gait analysis. The leg axis module allows for the gait pattern and leg axis to be analyzed in the lateral and anterior planes. There is an additional module used for analyzing the range of motion of the cervical spine.

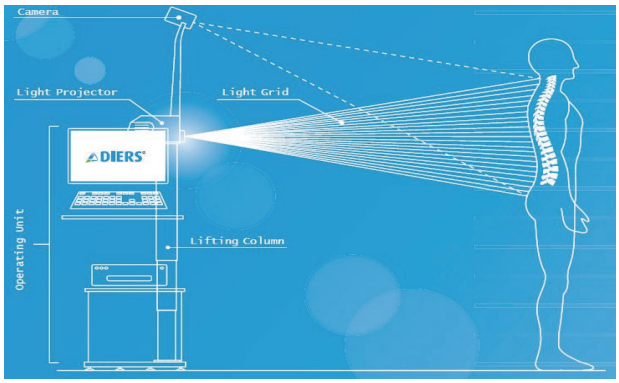


Figure 2. *Diers 4Dmotion lab parts (DIERS, 2009)*

Testing in DIERS 4D motion lab

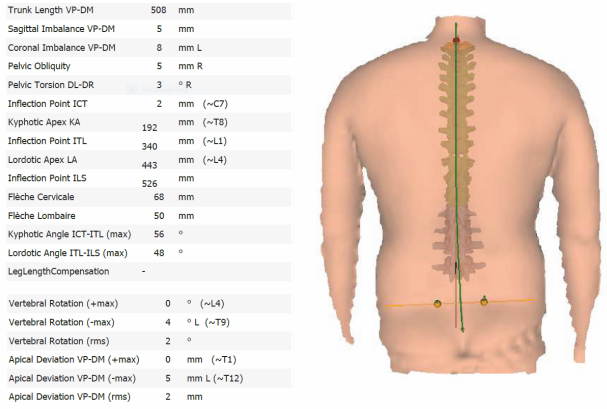
Testing in the lab itself can be performed in static mode when the subject stands still, and in dynamic mode, when the subject is walking on the treadmill. As a result of the testing, more than 40 different parameters are obtained that need to be interpreted to obtain an assessment of the functional state of the subject's musculoskeletal system.

Functional analysis of the musculoskeletal system performed in static and dynamic modes in the DIERS 4Dmotion lab provides a large database that can be used in ergonomic research. The dynamic mode, in which the examinee moves during the measurement, is

particularly important and allows for the observation of the functioning of the musculoskeletal system itself, as opposed to the static mode. Many parameters measured on DIERS 4dmotion lab can be used in ergonomics like kyphotic, lordotic, and scoliosis angle, sagittal and coronal imbalance, pelvic torsion and obliquity, Flèche Cervicale and Flèche Lombaire, etc.

The functional parameters obtained by examination of the musculoskeletal system in the DIERS 4Dmotion lab, the musculoskeletal system of individuals can be evaluated and existing disorders or indications of potential MSDs can be determined. Essentially these results can help in the assessment of ergonomic risk.

An example of the report obtained during the examination is shown in Figure 3 and Figure 4.



Trunk Length VP-DM	508	mm
Sagittal Imbalance VP-DM	5	mm
Coronal Imbalance VP-DM	8	mm L
Pelvic Obliquity	5	mm R
Pelvic Torsion DL-DR	3	° R
Inflection Point ICT	2	mm (~C7)
Kyphotic Apex KA	192	mm (~T8)
Inflection Point ITL	340	mm (~L1)
Lordotic Apex LA	443	mm (~L4)
Inflection Point ILS	526	mm
Flèche Cervicale	68	mm
Flèche Lombaire	50	mm
Kyphotic Angle ICT-ITL (max)	56	°
Lordotic Angle ITL-ILS (max)	48	°
LegLengthCompensation	-	
Vertebral Rotation (+max)	0	° (~L4)
Vertebral Rotation (-max)	4	° L (~T9)
Vertebral Rotation (rms)	2	°
Apical Deviation VP-DM (+max)	0	mm (~T1)
Apical Deviation VP-DM (-max)	5	mm L (~T12)
Apical Deviation VP-DM (rms)	2	mm

Figure 3. *Report overview generated in DIERS 4Dmotion lab*

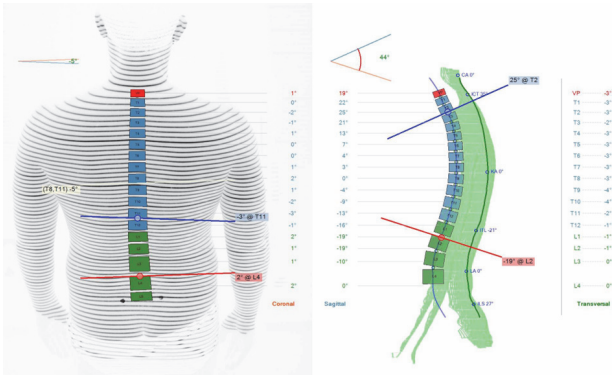


Figure 4. *Scoliosis angle measured in DIERS 4Dmotion lab*

CONCLUSION

DIERS 4D motion lab has shown exceptional results in sports medicine and clinical diagnostics. As it enables early detection of musculoskeletal disorders and monitoring their progression, it can be a very useful tool in occupational medicine and ergonomic research. Due to the comprehensive functional analysis of the musculoskeletal system, this device can be widely used in research related to the musculoskeletal system itself. Increased utilization of the DIERS 4D motion lab in ergonomics will undoubtedly close the gap between the existing state of ergonomic research and the requirement for the application of modern technology. Because of the high demand for the use of new technologies in ergonomic research, it is vital to investigate all possible applications of various existing technological solutions.

ACKNOWLEDGEMENTS

This paper is supported by the Ministry of Science, Technological Development and Innovations, contract no. 451-03-47/2023-01/200148.

REFERENCES

David, G. C. (2005). Ergonomic methods for assessing exposure to risk factors for work-related musculoskeletal disorders. *Occupational medicine*, *55* (3), 190-199. https://doi.org/10.1093/occmed/kqi082

Degenhardt, B. F., Starks, Z., & Bhatia, S. (2020). Reliability of the DIERS Formetric 4D Spine Shape Parameters in Adults without Postural Deformities. *BioMed research international*. https://doi.org/10.1155/2020/1796247

Degenhardt, B., Starks, Z., Bhatia, S., & Franklin, G. A. (2017). Appraisal of the DIERS method for calculating postural measurements: an observational study. *Scoliosis and Spinal Disorders*, *12* (1), 28. https://doi.org/10.1186/s13013-017-0134-y

DIERS International GmbH (2009). DIERS formetric 4D Optical 4D Spine and Posture Analysis.

Halpern, M., Hiebert, R., Nordin, M., Goldsheyder, D., & Crane, M. (2001). The test–retest reliability of a new occupational risk factor questionnaire for outcome studies of low back pain. *Applied Ergonomics*, *32* (1), 39-46. https://doi.org/10.1016/s0003-6870(00)00045-4

Hedge, A., Morimoto, S., & McCrobie, D. (1999). Cornell musculoskeletal discomfort questionnaire. *Ergonomics*. https://doi/10.1037/t60061-000

Hignett, S., & McAtamney, L. (2000). Rapid entire body assessment (REBA). *Applied ergonomics*, *31* (2), 201-205. https://doi.org/10.1016/S0003-6870(99)00039-3

Hildebrandt, V. H., Bongers, P. M., Van Dijk, F. J. H., Kemper, H. C. G., & Dul, J. (2001). Dutch Musculoskeletal Questionnaire: description and basic qualities. *Ergonomics*, *44* (12), 1038-1055. https://doi.org/10.1080/00140130110087437

Kuorinka, I., Jonsson, B., Kilbom, A., Vinterberg, H., Biering-Sørensen, F., Andersson, G., & Jørgensen, K. (1987). Standardised Nordic questionnaires for the analysis of musculoskeletal symptoms. *Applied ergonomics*, *18* (3), 233-237. https://doi.org/10.1016/0003-6870(87)90010-x

Lind, C. M., Diaz-Olivares, J. A., Lindecrantz, K., & Eklund, J. (2020). A wearable sensor system for physical ergonomics interventions using haptic feedback. *Sensors*, *20* (21), 6010. https://doi.org/10.3390/s20216010

Lins, C., & Hein, A. (2022). Classification of body postures using smart workwear. *BMC musculoskeletal disorders*, *23* (1), 921. https://doi.org/10.1186/s12891-022-05821-9

Marras, W. S., Fathallah, F. A., Miller, R. J., Davis, S. W., & Mirka, G. A. (1992). Accuracy of a three-dimensional lumbar motion monitor for recording dynamic trunk motion characteristics. *International Journal of Industrial Ergonomics*, *9* (1), 75-87. https://doi.org/10.1016/0169-8141(92)90078-E

McAtamney, L., & Corlett, N. (2004). Rapid upper limb assessment (RULA). In *Handbook of human factors and ergonomics methods* (pp. 86-96). CRC Press.

Michalik, R., Hamm, J., Quack, V., Eschweiler, J., Gatz, M., & Betsch, M. (2020). Dynamic spinal posture and pelvic position analysis using a rasterstereographic device. *Journal of Orthopaedic Surgery and Research*, *15* (1), 1-7. https://doi.org/10.1186/s13018-020-01825-0

Nakamoto, H., Yamaji, T., Yamamoto, A., Ootaka, H., Bessho, Y., Kobayashi, F., & Ono, R. (2018). Wearable lumbar-motion monitoring device with stretchable strain sensors. *Journal of Sensors*. https://doi.org/10.1155/2018/7480528

Odebiyi, D. O., & Okafor, U. A. C. (2023). Musculoskeletal Disorders, Workplace Ergonomics and Injury Prevention. In *Ergonomics-New Insights*. IntechOpen. https://doi.org/10.5772/intechopen.106031

Peres, S. C., Mehta, R. K., & Ritchey, P. (2017). Assessing ergonomic risks of software: Development of the SEAT. *Applied Ergonomics*, *59*, 377-386. https://doi.org/10.1016/j.apergo.2016.09.014

Scott, G. B., & Lambe, N. R. (1996). Working practices in a perchery system, using the OVAKO Working posture Analysing System (OWAS). *Applied Ergonomics*, *27* (4), 281-284. https://doi.org/10.1016/0003-6870(96)00009-9

Wasim, M., Saeed, F., Aziz, A., & Siddiqui, A. A. (2019). Dotted Raster-Stereography. In *Advanced Methodologies and Technologies in Artificial Intelligence, Computer Simulation, and Human-Computer Interaction* (pp. 93-109). IGI Global. https://doi.org/10.4018/978-1-5225-7368-5.ch008

Waters, T. R., Putz-Anderson, V., Garg, A., & Fine, L. J. (1993). Revised NIOSH equation for the design and evaluation of manual lifting tasks. *Ergonomics*, *36* (7), 749-776. https://doi.org/10.1080/00140139308967940

Yang, L., Grooten, W. J., & Forsman, M. (2017). An iPhone application for upper arm posture and movement measurements. *Applied ergonomics*, *65*, 492-500. https://doi.org/10.1016/j.apergo.2017.02.012

20th International Conference Man and Working Environment
SEMSIE
Safety Engineering & Management – Science, Industry, Education

www.znrfak.ni.ac.rs/semsie

ANĐA STRUGAR[1]
SRĐAN GLIŠOVIĆ[2]
MILENA MEDENICA[3]
MILENA MANČIĆ[4]

[1] Institute for Development and Research in the Field of Occupational Safety in Podgorica
[2,3,4] University of Niš, Faculty of Occupational Safety

[1]*andja.strugar@iti.co.me*
[2]*srdjan.glisovic@znrfak.ni.ac.rs*
[3] *milena.medenica@znrfak.ni.ac.rs*
[4]*milena.mancic@znrfak.ni.ac.rs*

FAST FASHION AND GREENWASHING

Abstract: *The interests of all communities are represented globally by environmental conservation and sustainable development. They have an impact on how the environment changes and how natural resources are used. Sustainability has recently emerged as a significant trend in the textile sector. As a result of improved consumer education and rising expectations for products that are socially and environmentally responsible, the textile sector needs to find sustainable solutions. The textile industry affects climate change, biodiversity, pollution, and increasingly every year, the generation of textile waste. This is primarily a consequence of fast fashion and the production of cheap, low-quality pieces of clothing that do not last long. The production of clothing and footwear ranks fourth in the use of natural resources, immediately after food production, accommodation, and transport. At the same time, another form of consumer mentality is in full swing: the so-called fast fashion model, according to which clothing items are considered to be disposable products. On the other hand, a certain evolution of the understanding of the importance of environmental protection is becoming recognizable, especially among the younger urban population, which probably makes up the largest segment of clothing consumers. In the desire to follow social trends, to 'quiet the conscience' of new consumers and make it easier for them to decide to invest in certain products, companies in the fashion industry are ever more frequently and extensively reaching for greenwashing as a means of achieving profit goals. Greenwashing, in principle, is any attempt to deceive environmentally responsible consumers of goods, or users of services, to whom, through marketing tricks, announcements, labels, advertisements, or in any other way, it is unfoundedly or falsely suggested that a certain product is environmentally friendly, or that the company that produces it (or provides a corresponding service) is committed to preserving the environment and health.*

Keywords: fast fashion, greenwashing, textile industry, environment

INTRODUCTION

Environmental protection and sustainable development are closely related and represent the interests of all communities at the global level. They affect all the changes that occur in the environment and the use of natural resources. For this reason, the consequences of climate change ensue.

One of the biggest polluters of the environment is the textile industry. It affects climate change, biodiversity, pollution and, increasingly every year, the generation of textile waste. This is primarily a consequence of fast fashion and the production of cheap, low-quality pieces of clothing that do not last long. The fast fashion model in the fashion industry implies the production of trendy clothing items that have a short storage time and are available to customers at affordable prices. However, such a production method could potentially increase the amount of textile waste (Adamkiewicz et al., 2022). Big businesses are experimenting with the fast fashion trend, which involves updating the selection of their retail stores' clothing every fifteen days, giving them access to fresh collections in a flash, and providing all of this at competitive prices for customers (Shirvanimoghaddam et al., 2020). This phenomenon can also be described as a business strategy that aims to decrease expenses, particularly in production and customer delivery, by putting finished goods in warehouses as soon as feasible.

One of the world's major polluters is the fashion sector, which includes the production of textiles, apparel, and footwear. Fast fashion has become popular as a result of consumerism, in which we all participate and where transience is one of the dominant ideas of the day. Fast manufacturing cycles and low-cost, subpar products define this phenomenon (Colasante & D'Adamo, 2021).

It should be known that the textile industry and fast fashion are among the industries that harm the environment the most; the production of apparel alone is responsible for 10% of the world's CO_2 emissions. Millions of litres of water are consumed in the creation of clothing, and tonnes of waste are dumped into the ocean in addition to the high levels of CO_2 emissions produced by the manufacturing of clothing (Colasante & D'Adamo, 2021).

At the same time, another form of consumer mentality is in full swing: the so-called fast fashion model, according to which clothing items are considered to be disposable products. On the other hand, a certain evolution of the understanding of the importance of

environmental protection is becoming recognizable, especially among the younger urban population, which probably makes up the largest segment of clothing consumers. In the desire to follow social trends, to 'quiet the conscience' of new consumers and make it easier for them to decide to invest in certain products, companies in the fashion industry are ever more frequently and extensively reaching for greenwashing as a means of achieving profit goals.

Greenwashing refers to the practice of falsely promoting organizations as green, consuming more resources than they promote (Becker-Olsen et al., 2013). However, greenwashing and the circular economy are in constant conflict. The goal of circular fashion is to create items (textiles) that are recyclable and biodegradable by using the 'cradle to cradle' philosophy. Although it should be mentioned that these materials still have an impact on the environment, the manufacturing of sustainable textiles, i.e. natural fibres such as cotton, hemp, linen, wool, and silk, is once again dominating the sustainable fashion business. Consumers need to be aware of all these detrimental effects because they are primarily manifested in the usage of land, landfills, fertilizers, greenhouse gas emissions, etc. (Micklethwaite, 2019).

FAST FASHION AND ENVIRONMENTAL IMPACT

With the growth of technology and the textile industry in the late 1990s and early 2000s, the fashion industry, or the fast fashion phenomenon, was established. Fast fashion refers to the mass production of inexpensive, disposable clothing that is done mindlessly and frequently without consideration for the environment or the working conditions of the workers. Consequently, this model has a detrimental effect on the ecosystem (Back, 2017).

The textile sector pollutes the environment heavily when producing clothing and it also depletes water supplies. Additionally, people who purchase apparel at low costs tend to discard it after seven or eight wears, producing a significant amount of textile waste that must be disposed of in a landfill (Adamkiewicz et al., 2022).

According to Shirvanimoghaddam et al. (2020), it is estimated that roughly 85% of the textiles produced in a given year end up as waste. According to the same research, the biggest issues facing this industry are increased water consumption, pollution of rivers and oceans, the generation of large amounts of solid waste, the use of chemicals, and an increase in the greenhouse effect. These issues are caused directly or indirectly by mass production and improper disposal of clothing and textiles.

The textile and apparel sectors are major consumers of water, which contributes to water contamination. An estimated 1.5 billion tonnes of water are used annually for this process, and one ton of coloured cloth requires roughly 200 tonnes of water to dye and finish. For instance, 7,500 litres of water are needed to produce one pair of trousers, and 2,600 litres are needed to produce one short-sleeved T-shirt (Shirvanimoghaddam et al., 2020).

In third-world countries, there are no legal regulations, which is why the largest production of clothes is precisely in those countries. As a result, there is a lot of water pollution, meaning that harmful elements, such as arsenic, mercury, and lead, are present in large quantities in the water. As a result, river species are at risk, which threatens the health of humans, since they enter the food chain and disturb the ecosystem as a whole (Adamkiewicz et al., 2022).

In order to produce one tonne of clothing, one tonne of these hazardous chemicals must be utilized in the production, dyeing, and bleaching of fabrics. Different fertilizers used to grow cotton as a raw material for clothing produce a variety of chemicals (Micklethwaite, 2019).

The average family is thought to produce roughly 30 kg of textile waste annually, of which only a small portion is recycled and the majority ends up in landfills. The majority of clothing is made of synthetic fibres, which also contain plastic, which takes more than 200 years to degrade (Adamkiewicz et al., 2022).

The production and shipping of goods produce a significant quantity of greenhouse gases, and the textile and apparel business is responsible for up to 10% of global carbon emissions. Additionally, significant amounts of fossil fuel reserves are consumed in the production of synthetic materials such as nylon and polyester. On the other hand, the procedures involved in clearing forests damaged green spaces, which could have solved the issue by releasing a significant amount of greenhouse gases. They are consequently trapped in the atmosphere for a longer duration, which causes global warming (Shirvanimoghaddam et al., 2020).

TEXTILE WASTE IN SERBIA

In Serbian landfills, 5.5% of the total amount of waste is waste clothing. In the last 20 years, the consumption of clothing has increased by 1,000%. Every month, over 1,200 tonnes of textile waste enter our landfills, up to 70% of which are synthetic textiles with a decomposition time comparable to that of plastic bottles (hundreds of years) (Petrovic et al., 2011). Additionally, many landfills 'burn eternally' after catching fire from landfill gas, turning all of these fabrics into chemical warfare agents. Additionally, recycling textiles is not as profitable as recycling plastic, iron, or paper.

Serbia has over 200 serious clothing manufacturers, but only 11 legally dispose of their textile waste by handing it in for recycling, while the others annually throw over 1,800 tonnes of waste into landfills. Part of the waste has value, but for some, recycling has to be paid for even though it is harmless (Petrovic et al., 2011).

Manufacturers in industrialized nations pay up to 500 euros per tonne to recycle their textile waste from the apparel manufacturing process. In Serbia, producers just take the waste to a landfill to fix this issue for 20

euros per tonne. This type of waste can be recycled by a number of companies, and domestic recycling costs are substantially lower than those abroad. Only a few small manufacturers with advanced recycling practices submit their waste, while the industry giants continue to carelessly discharge industrial textile waste in Serbia in large quantities. The most crucial thing is that this waste does not end up in a landfill. Fibres are generated from waste textiles from the creation of garments through recycling, as fillers and other decorative canvases.

Data from the Centre for Environmental Improvement (Petrovic et al., 2011) show that Serbia sells more than 80,000 tonnes of clothing annually, or roughly 12 kg per person. These fragments end up in landfills, where they cause environmental pollution. According to experts, there is currently no solution for this waste. In Australia, 27 kilograms of clothing are consumed per person annually, compared to 22 kg in Western Europe and 37 kg in North America (Back, 2017).

GREENWASHING AND CONSUMER PERCEPTION

Greenwashing, in principle, is any attempt to deceive environmentally responsible consumers of goods or users of services, to whom, through marketing tricks, announcements, labels, advertisements, or in any other way, it is unfoundedly or falsely suggested that a specific product is environmentally friendly or that the company that produces it (or provides a corresponding service) is committed to preserving the environment and health.

There are numerous studies related to consumer attitudes towards greenwashing and eco-marketing (Halverson, 2018) or to the credibility of eco-labelling (Parguel et al., 2011). In one of the studies, an attempt was made to look at consumer perspectives regarding greenwashing by investigating the aspect of trust (Brouwer, 2016). The authors of this study, like the authors of some earlier ones, discovered that consumers view marketing messages with scepticism, especially when they refer to environmental aspects, but that despite such an attitude, they did not completely stop believing them (Schmuck et al., 2018). In other words, consumers, despite their pronounced scepticism, assumed that the information they received was at least partially true, which would justify their trust. Respondents were surprised and shocked when they discovered that the eco-label was false or that the product did not have the expected characteristics. On the other hand, the results of this study revealed that, in recent times, consumers have become more sceptical of environmental labelling (Chen & Chang, 2013), which indicates that awareness of the problem is developing among consumers. However, another study showed that consumers are not too distrustful and lack adequate awareness of products and claims related to them (Brouwer, 2016). Eco-labels have been found to be very effective in persuading consumers, even when consumers are aware of the phenomenon of greenwashing (Brouwer, 2016).

Figure 1. *Example of a greenwashing label (Halverson, 2018)*

As different studies show quite different results, there is room for further research in this area. Many studies have shown that consumers view green marketing with scepticism, which led to the need to investigate the question of whether global consumers are able to identify and differentiate between environmentally friendly products and products that are rebranded under the influence of greenwashing. Studies have shown that consumers are often unable to identify advertisements that rely on greenwashing as misleading (Newell et al., 1998). It is also claimed that, despite being sceptical about greenwashing, consumers still consider eco-labels environmentally friendly (Halverson, 2018). There is also the claim that greenwashing has little impact on consumers or that the impact on them is not significantly increased by resorting to unsubstantiated environmental claims (Krafft, 2014). Therefore, it follows that consumer awareness regarding greenwashing is still quite underdeveloped. Also, the authors of the same study found that, after exposure to eco-marketing, consumers are more likely to buy a particular product (Krafft, 2014). Interestingly, there was also an earlier study that claimed that there was no correlation between environmental concerns and the ability to identify greenwashing (Newell et al., 1998). Another study found that consumers will maintain a positive attitude towards eco-marketing until they discover the deception (Stokes, 2009), suggesting that consumers remain ignorant until they directly perceive the deception in one way or another. It also turns out that being sceptical and aware of the problem is not the same thing. Greenwashing will be more difficult to use when consumers are aware of the phenomenon, but it will still work with consumers who are only labelled as sceptical (Halverson, 2018).

In one of the studies, it was concluded that greenwashing is not a particularly effective and useful strategy, because it does not significantly affect the purchase intentions of consumers (De Jong et al., 2018). It is claimed that sales increase only when companies show a real and genuine interest in protecting the environment. Greenwashing has also been reported to have a positive impact on a company's perceived environmental performance but a negative

impact on the perceived integrity of its communication with the public (De Jong et al., 2018). It is obvious that this area requires further research because there is still no complete agreement and knowledge about how consumers actually react to eco-marketing and eco-labelling of industrial products, as well as to what extent they are able to succumb to greenwashing.

FAST FASHION AND ENVIRONMENTAL IMPACT

The so-called fast fashion model, which views clothing as disposable, is another type of consumer mindset that is currently quite popular. However, a certain evolution in the recognition of the significance of environmental conservation is emerging, particularly among younger urban residents, who likely comprise the greatest proportion of clothing consumers. Fashion firms are increasingly resorting to greenwashing as a means of meeting profit targets, primarily due to their desire to follow social trends, to 'quiet the conscience' of potential customers, and to facilitate their decision to invest in specific products.

A number of large fashion brands, including H&M, Primark, and Zara, have been accused of greenwashing several times. For this reason, the Changing Markets Foundation analysed the 12 largest European fashion brands and their sustainability declarations in their report. The brands Asos, Boohoo, Forever21, George at ASDA, Gucci, H&M, Louis Vuitton, Marks & Spencer, Uniqlo, Walmart, Zalando, and Zara were analysed (Micklethwaite, 2019). The study found that 60% of environmental claims could be classified as greenwashing. Brands that were not found to be greenwashing were also found to make no sustainability claims about their products (Muthu, 2016). In terms of declarations that were usually in line with the sustainability principles, Marks & Spencer, Zara, and Gucci were the top-ranked companies.

Figure 2. *Products made from recycled materials (Becker-Olsen & Potucek, 2013)*

It is thought that less than 1% of the material used to make clothes is recycled into new clothes. It is also estimated that 80% of discarded textiles globally are incinerated or landfilled, and only 20% are reused or recycled (Muthu, 2016). Research has shown that most fashion brands that present themselves as sustainable are classified in the 'red zone', because none of them provided information on the total use of synthetic materials during the year, what percentage of their products contain synthetics, or whether the use of synthetics is decreasing or increasing (Muthu & Gardetti, 2017).

Several companies have been shown to provide information that is inconsistent with that which is publicly available on their brands' websites. This group includes Primark, Target, Walmart, Uniqlo, Wrangler, Burberry, Gap, Patagonia, The North Face, and Timberland. Nike's environmental impact report states that the company used more than 152,000 tons of polyester and 111,490 tons of rubber in 2020 (Muthu & Gardetti, 2017).

Without a more detailed analysis of the behaviour of a certain company in the supply chain (but also its attitude towards the treatment of the residues of its own and other people's related products), it is usually not easy, or not possible, to recognize greenwashing, and even less to claim that this phenomenon is involved in any specific case. A special problem arises in multinational companies, where, in addition to the problem of data protection, the so-called trade secret, it is even more difficult to cover the flow and schedule of their work operations geographically (Becker-Olsen & Potucek, 2013). Nevertheless, credible environmental organizations, institutes, social groups, and even prominent individuals often highlight and document knowledge about the environmental behaviour of well-known brands on their Internet portals, so part of the knowledge obtained in this way should be taken into account with a certain amount of caution. The most common way of manipulating consumers in the fashion industry is by deliberately confusing customers through inappropriate use of fundamentally different terms, such as *recyclable, recycled, biodegradable, organic, organically grown*, etc.

Therefore, the question arises if there truly are any fashion industries that can comply with the regulations and make truly green products. Recently, many fashion industries have been pushing the use of natural materials such as cotton, hemp, linen, wool, and silk, and it should be noted that these materials are not exempt from negative environmental impacts, which are mostly reflected in the use of land, landfills, fertilizers, emissions of greenhouse gases, etc., and consumers should be aware of all these negative impacts (Micklethwaite, 2019).

CONCLUSION

Although every initiative of the corporate sector towards applying the principles of circular economy is to be commended (example of some companies that collect remnants of old clothes with appropriate (non)monetary incentives that they later recycle), there are doubts (and some evidence) that many companies do not actually use secondary raw materials for the expected purpose but only export them to less economically developed countries, where a good part of the textile waste becomes cheap and

environmentally very harmful fuel for heating individual households.

We know it is impossible to remove clothes from our lives in an attempt to save the planet; however, that does not mean we cannot cut back on fast fashion consumption and find alternatives that are much more sustainable. The solution to this increasingly widespread phenomenon must be a combination of improving the fundamental ecological information of consumers, strengthening their social and ecological awareness, and modernizing legislation in the field of environmental protection. As these are mostly multinational companies, whose business operations exceed the national borders of the country in which they are incorporated, it is necessary for international bodies, such as the EU Commission, to take a stand and adopt modern regulations regarding the treatment and export of textile waste.

ACKNOWLEDGEMENTS

This research was financially supported by the Ministry of Education, Science and Technological Development of the Republic of Serbia, according to contract No. 451-03-47/2023-01/ 200148.

REFERENCES

Adamkiewicz, J., Kochańska, E., Adamkiewicz, I., & Łukasik, M. R. (2022). Greenwashing and sustainable fashion industry. *Current Opinion in Green and Sustainable Chemistry, 38*. https://doi.org/10.1016/j.cogsc.2022.100710

Back, J. (2017). *Sustainable and ethical practices for the fast fashion industry.* Occidental College, UEP Student Scholarship. http://scholar.oxy.edu/uep_student/4?utm_source=scholar.oxy.edu%2Fuep_student%2F4&utm_medium=PDF&utm_campaign=PDFCoverPages

Becker-Olsen K., & Potucek, S. (2013). Greenwashing. In S. O. Idowu, N. Capaldi, L. Zu & A. D. Gupta (Eds.), *Encyclopedia of Corporate Social Responsibility* (pp. 1318–1323). Springer. https://doi.org/10.1007/978-3-642-28036-8_104

Brouwer, A. (2016). Revealing greenwashing: A consumers' perspective. In P. Kommers, To. Issa, Th. Issa, E. McKay, & P. Isias (Eds.), *Proceedings of the International Conferences on Internet Technologies & Society (ITS), Education Technologies (ICEduTECH), and Sustainability, Technology and Education (STE)* (pp. 245–252). International Association for Development of the Information Society. https://files.eric.ed.gov/fulltext/ED571577.pdf

Chen, Y.-S., & Chang, C.-H. (2013). Greenwash and green trust: the mediation effects of green consumer confusion and green perceived risk. *Journal of Business Ethics, 114*(3), 489–500. https://doi.org/10.1007/s10551-012-1360-0

Colasante, A, & D'Adamo, I. (2021). The circular economy and bioeconomy in the fashion sector: emergence of a "sustainability bias". *Journal of Cleaner Production, 329*. https://doi.org/10.1016/j.jclepro.2021.129774

De Jong, M. D. T., Harkink, K. M., & Barth, S. (2018). Making green stuff? Effects of corporate greenwashing on consumers. *Journal of Business and Technical Communication, 32*(1), 77–112. https://doi.org/10.1177/1050651917729863

Halverson, R. (2018). *Consumer perceptions of greenwashing: understanding awareness, trust, and effectiveness.* [Bachelor's Thesis, University of Colorado].

Krafft, J. (2014). *Greenwashing: An experimental study about the effects of misleading and deceptive environmental claims in advertising.* [Bachelor's Thesis, University of Gothenburg].

Micklethwaite, P. (2019). Design against consumerism. In A. Massey (Ed.), *A Companion to Contemporary Design Since 1945* (Ch. 21, pp. 436–456). John Wiley & Sons, Inc. https://doi.org/10.1002/9781119112297.ch21

Muthu, S. S., & Gardetti, M. A. (2016). *Green fashion – Sustainable fibres for fashion industry.* Springer.

Muthu, S. S. (2017). *Textile and clothing sustainability – Sustainable technologies*. Springer.

Newell, S. J., Goldsmith, R. E., & Banzhaf, E. J. (1998). The effect of misleading environmental claims on consumer perceptions of advertisements. *Journal of Marketing Theory and Practice, 6*(2), 48–60. https://doi.org/10.1080/10696679.1998.11501795

Parguel, B., Benoît-Moreau, F., & Larceneux, F. (2011). How sustainability ratings might deter greenwashing: A closer look at ethical corporate communication. *Journal of Business Ethics, 102*(1), 15–28. https://doi.org/10.1007/s10551-011-0901-2

Petrović, V., Stepanović, J., Stamenković, M., Skoko, I., & Stefanović, S. (2011). Životni ciklus i reciklaža tekstilija. *Tekstilna industrija, 59*(3), 34-39.

Schmuck, D., Matthes, J., & Naderer, B. (2018). Misleading consumers with green advertising? An affect–reason–involvement account of greenwashing effects in environmental advertising. *Journal of Advertising, 47*(1), 127–145. https://doi.org/10.1080/00913367.2018.1452652

Shirvanimoghaddam, K., Motamed, B., Ramakrishna, S., & Naebe, M. (2020). Death by waste: fashion and textile circular economy. *Science of the Total Environment, 719*. https://doi.org/10.1016/j.scitotenv.2020.137317

Stokes, S. A. (2009). *Deception in environmental advertising: Consumers' reactions to greenwashing*. [Master's Thesis, Kansas State University].

20th International Conference Man and Working Environment
SEMSIE
Safety Engineering & Management – Science, Industry, Education
www.znrfak.ni.ac.rs/semsie

TOXICITY OF PPIX INDUCED BY HAZARDOUS CHEMICALS

ALEKSANDAR LAZAREVIĆ[1]
SANJA PETROVIĆ[2]
JELENA ZVEZDANOVIĆ[3]
BOJANA DANILOVIĆ[4]
DRAGAN CVETKOVIĆ[5]
TATJANA ANĐELKOVIĆ[6]
TATJANA GOLUBOVIĆ[7]

[1,2,3,4,5]University of Niš, Faculty of Technology, Leskovac
[6]University of Niš, Department of Chemistry, Faculty of Science and Mathematics
[7]University of Niš, Faculty of Occupational Safety

[1]*acalazarevic92@hotmail.com*
[2]*milenkovic_sanja@yahoo.com*
[3]*jelite74@yahoo.com*
[4]*bojana_d@yahoo.com*
[5]*dragancvetkovic1977@yahoo.com*
[6]*tatjana.andjelkovic@outlook.com*
[3]*tatjana.golubovic@znrfak.ni.ac.rs*

Abstract: *Occupational safety and health (OSH) is a cross-disciplinary area and it is concerned with protecting the safety, health and welfare of people engaged or employed. Chemical hazards and toxic substances are widely used in different industries and can seriously impact the environment and human health. Exposure to chemicals commonly used in workplaces can lead to a variety of short- and long-term health effects such as poisoning, skin rashes and disorders of the lungs, kidneys and liver. One of the diseases that can be caused by hazardous chemicals is porphyria. Porphyria is a genetic family of diseases, that mainly affect the skin or nervous system and it can be manifested as the accumulation of protoporphyrin IX (PPIX) due to the inhibition of enzyme ferrochelatase (FECH), responsible for the insertion of iron into PPIX to form heme. It is known that overaccumulation of PPIX, mainly in the liver and erythrocytes, leads to dermal phototoxicity with symptoms such as itching and burning, followed by increasingly severe pain, erythema, and edema after light exposure. Preclinical studies showed that many drugs and chemicals such as barbiturates, glutethimide, 2-propyl-2-isopropylacetamide, salicylic acid, ethylenediaminetetraacetic acid, metals (lead, gallium, copper, cadmium, mercury, and aluminum ions) can induce porphyria and PPIX accumulation and toxicity. Some of the chemicals such as fungicide hexachlorobenzene (HCB) and 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) cause toxicity later on, and abnormalities in porhyrin may not manifest for years after the initial incident. Patients with porphyrias usually alter their activities and lifestyles to avoid sunlight, which can limit employment opportunities and/or cause depression and a significant decrease in quality of life. Because of that, it is very important to prevent the influence of hazardous chemicals on people's health.*

Keywords: occupational safety and health, chemicals, toxicity, protoporphyrin IX

IINTRODUCTION

Occupational safety and health (OSH) deals with all aspects of health and safety in the workplace and has a strong focus on primary prevention of hazards. Since safe working conditions are a fundamental human right, occupational safety and health are a top priority of decent work. Health is associated with the physical conditions of both the mind and body of all people included at the workplace and their protection from injury or disease. Safety is related to the physical condition at the workplace which includes a safe working environment, safe equipment, policies and procedures in order to ensure workers' safety. One of the most common dangers in the workplace in many industries comes from chemical hazards. It is common knowledge that chemicals surround us, from the everyday goods we use to the industrial operations that drive our economies. A chemical hazard is any substance that can potentially cause physical and health hazards to people, or can result in harm to the environment. Chemical hazards can occur in many settings, from many industries including manufacturing, construction, healthcare, food industries, etc., to homes, to transport and disposal. Chemical hazards can be classified based on their properties, such as flammability, explosiveness, reactivity, corrosivity, and toxicity. Examples of some of the most commonly used hazardous chemicals in workplaces include gasoline, methanol, glues, detergents, pesticides, cosmetics, and heavy metals including lead, cadmium and mercury. Exposure to chemicals commonly used in workplaces can lead to a variety of short- and long-term health effects such as headache, difficulty in breathing, poisoning, skin rashes and irritation, and disorders of the lungs, kidneys and liver. One of the diseases that can be caused by chemicals is porphyria.

PORPHYRIA

Porphyria is a genetic family of diseases, a group of metabolic disorders caused by defects in the heme biosynthetic pathway (Anderson, 2003). The heme is an essential component of a variety of compounds such as hemoglobin – the iron-containing oxygen-transport protein present in erythrocytes, myoglobin, catalase, respiratory cytochromes, and cytochrome P450

enzymes. Heme synthesis is a biochemical pathway that requires a number of steps, substrates and enzymes and it is mainly made in the bone marrow and the liver (Ogun et al., 2019). A deficiency in some enzyme or substrate leads to the accumulation of intermediates of heme synthesis in blood, tissues and urine leading to porphyrias. Porphyrias are mainly categorized according to the source of excess production of heme precursors, porphyrins, as hepatic or erythropoietic but also they can be acute or cutaneous *(Anderson, 2003; Ogun et al., 2019).* Acute porphyrias most often affect the nervous system and cutaneous affect only skin. Acute and cutaneous porphyrias are divided into two subgroups, dependent on which specific heme pathway enzyme missing and to major clinical features (Table 1 and 2) (www.niddk.nih.gov).

Table 1. *Type of acute porphyria (taken from: www.niddk.nih.gov)*

Type of acute porphyria	Affected part of the body	Precursors build-up
acute intermittent porphyria	nervous system	liver
variegate porphyria	nervous system and skin	liver
hereditary coproporphyria	nervous system and skin	liver
delta-aminolevulinic acid (ALA) dehydratase deficiency porphyria	nervous system	liver

Table 2. *Type of cutaneous porphyria (taken from: www.niddk.nih.gov)*

Type of cutaneous porphyria	Affected part of the body	Precursors build up
porphyria cutanea tarda	skin	liver
protoporphyrias: erythropoietic protoporphyria and x-linked protoporphyria	skin	bone marrow
congenital erythropoietic porphyria	skin	bone marrow
hepatoerythropoietic porphyria	skin	liver

The symptoms of porphyria vary depending on type and can range from mild to severe. Some people with porphyrias have no symptoms but in some cases, it can be life-threatening. People with cutaneous types of porphyria often have symptoms including oversensitivity to sunlight, itching, swelling of skin exposed to sun, blisters on the skin, and scarring of sun-exposed areas of the skin leading to fragile skin. People with acute types of porphyrias mainly have symptoms that generally occur suddenly but usually last a short period of time and some of them are pain in the abdomen, chest, arms, legs or back, constipation, urinary retention, confusion and hallucinations, muscle weakness (my.clevelandclinic.org).

Among these types of porphyria, one of the most common is erythropoietic porphyria (Ramanujam and Anderson, 2015). This type of porphyria occurs due to a deficiency in ferrochelatase (FECH), the enzyme responsible for the final formation of heme in the biosynthesis pathway by combining protoporphyrin IX (PPIX) and ferrous iron. Deficiency of FECH results in the accumulation of PPIX in the bone marrow, where erythrocytes are developed, and in the liver. PPIX, unlike other porphyrins, is water insoluble and therefore can be removed from the body through hepatic excretion into bile or feces leads to dermal phototoxicity (Rüfenacht et al., 1998, Samuel et al., 1988*).*

PROTOPORPHYRIN IX TOXICITY

PPIX is a heterocyclic organic compound consisting of four pyrrole rings. PPIX is mainly produced in the bone marrow (85%) and secondarily in the liver, as the final intermediate in the heme biosynthesis pathway.

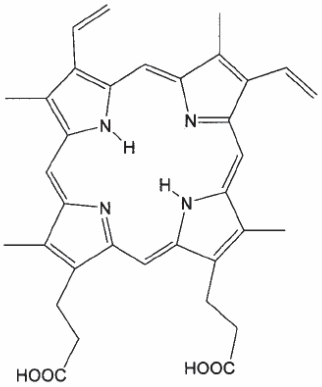


Figure 1. *Protoporphyrin IX*

Under normal physiological conditions, amounts of PPIX in cells actively synthesizing heme remain low, because the amount supplied does not exceed what is needed for heme synthesis (Brun and Sandberg, 1991). Accumulation of free-PPIX in the erythrocytes, and secondarily in other tissues same as in biological fluids (skin, liver, bile, stools) leads to painful photosensitivity and in a small percentage of patients, it can cause severe liver diseases. This is often manifested as a burning sensation in the skin on exposure to light, which can occur alone or followed by swelling, redness, and purpura (Figure 2)(Murphy, 2003). Repeated reactions to sunlight can result in more symptoms such as waxy thickening of the skin, especially over the knuckles, hands, nose and cheeks, and mild scarring (Horner et al., 2013). Further, patients with high concentrations of PPIX often have a deficiency of vitamin D, due to avoiding sunlight

exposure (Wahlin et al., 2011). Among these symptoms, definitely, the most serious clinical manifestation caused by PPIX accumulation is liver damage, which occurs in less than 5% of patients with porphyria and can be life-threatening and often require liver transplantation. Large amounts of PPIX are hepatotoxic but the liver is the only route for excretion of this large hydrophobic molecule that cannot be excreted by the kidneys (Jonker et al., 2007). PPIX-mediated liver damage can have two possible ways of clinical manifestation. Symptoms can progress slowly often indicated by mild and abnormal liver function tests followed by an inflammation process, or advance rapidly to hepatic failure with evidence of both acute and chronic liver disease (Anstey et al., 2007; Bruguera et al., 2005). Additionally, some early medical research indicated that PPIX or products of PPIX may be neurotoxic under some conditions with motor neuropathy as the main symptom (Rank et al., 1993).

Figure 2. *Phototoxic burning caused by PPIX accumulation (picture taken from Murphy, 2003)*

Phototoxicity of PPIX is related to its heterocyclic ring structure which provides it to absorb visible and UV light, generating excited states. When excessive PPIX and other porphyrin compound concentrations are exposed to light they produce free radicals, which in turn cause lipid peroxidation and protein cross-linking. As a consequence, this causes damage and death of cell membranes. (Murphy, 2003).

CHEMICAL INDUCED PORPHYRIA

Porphyria and related overproduction of porphyrins and the most common protoporphyrin IX can occur under the influence of some toxins. In these cases, exposure to certain chemicals in people who have no evident genetic predisposition can cause biochemical and clinical manifestations of the disease. Many chemicals can cause porphyria because the heme pathway is highly sensitive to inhibition by a number of inorganic agents such as lead, mercury, gallium, copper, arsenicals and aluminum ions, as well as organic compounds such as the chlorinates benzenes and alcohols (Fowler, 2001). Preclinical studies showed that many other chemicals such as barbiturates, glutethimide, 2-propyl-2-isopropylacetamide and salicylic can cause PPIX accumulation (Hamilton et al., 1988, Gupta et al., 2013). In addition, there are some chemicals that can potentiate PPIX-induced phototoxicity. Some of them are medications such as amiodarone, chlorpromazine, doxycycline, etc. (Blakely et al., 2019). Many reported findings have generally been linked to long-term industrial exposures to some hazardous chemicals, industrial accidents, or environmental exposures to chemicals that were in much higher concentrations than usual.

Hexachlorobenzene

Hexachlorobenzene (HCB), organochlorine pesticide, caused one of the most known cases of chemical-induced porphyria that occurred in Turkey during the late 1950s. HCB was widely used as a pesticide but it is no longer in use after finding its toxic effect on humans (wwwn.cdc.gov). Reports say that in 1959, several thousand people who consumed grain treated with fungicide containing HCB developed porphyria. The syndrome commonly consisted of weight loss, muscle wasting, weakness, arthritic changes, gross porphyrinuria and photosensitive dermopathy (Daniell et al., 1997, Schmid, 1960). According to reports, the dermopathy was usually hyperpigmented and complicated by infections and often left depigmented scars. Skin lesions often recur subsequently, even in the absence of any new exposure to HCB (Schmid, 1960).

Dioxin

Tetrachlorodibenzodioxin (TCDD) is one of a family of isomers known chemically as dibenzo-p-dioxins and a member of a group of chemical compounds that are persistent organic pollutants (POPs) in the environment. These chemicals are mostly byproducts of burning or other industrial processes (wwwn.cdc.gov). Laboratory experiments have demonstrated that TCDD in animals causes various systemic effects including tumorigenesis, immunological dysfunction, and teratogenesis in a wide range of concentrations (Goldstein et al., 1982; wwwn.cdc.gov). Studies of humans exposed to TCDD-contaminated materials suggest that TCDD is the cause of observed metabolic disorders such as porphyria and also they are suggestive of TCDD's ability to cause cancer (wwwn.cdc.gov). TCDD occurs as a contaminant of some industrial materials like 2- (2,4,5-trichlorophenoxy) propionic acid (silvex), and workers' exposure may occur through contact with these materials during use or from the past contamination of worksites. The American National Institute for Occupational Safety and Health (NIOSH) recommends that TCDD be regarded as a potential occupational carcinogen (wwwn.cdc.gov). Some early studies have shown that Vietnam veterans developed porphyria because TCDD was widely used in Vietnam during the war. Also known exposure to TCDD in a chemical plant near Seveso, Italy, led to the development of porphyria (Strik et al., 1980, Webb et al., 1986).

Lead and other metals

Chronic and acute lead absorption is well documented to affect heme synthesis. Lead causes the accumulation of zinc-protoporphyrin in erythrocytes but also increases concentrations of alanine (ALA) and coproporphyrin in urine. Lead intoxication is generally classified as a secondary porphyrinuria rather than an acquired porphyria (Rossi et al., 1993). Arsenic, as well as mercury exposures, are also reported to affect heme synthesis in humans but the levels of porphyrinuria are lower than those seen with lead. Some very early studies noticed that workers exposed to inorganic and organic mercury had higher concentrations of porphyrins. Similarly, studies showed that arsenic-exposed smelter workers also had higher concentrations of these compounds related to porphyrias (Goldwaier et al., 1967; Telolahy et al., 1993). In the work of Downey, it was reported a case of porphyria caused by dental prostheses containing 76% palladium and 10% copper (Downey, 1992).

CONCLUSIONS

Some chemicals, drugs and pesticides are known to interfere with heme synthesis causing porphyria, which often is manifested with PPIX accumulation. Patients with porphyrias usually alter their activities and lifestyles to avoid sunlight, which can limit employment opportunities and/or cause depression and a significant decrease in quality of life. Further, many patients develop hepatic dysfunctions and the continued progression of liver damage can lead to death due to cirrhosis or liver failure. Because of that, it is very important for occupational health specialists to maintain the safety and health of employees by preventing or reducing the influence of hazardous chemicals.

ACKNOWLEDGEMENTS

This paper is part of the project supported by the Ministry of Education, Science and Technological Development of the Republic of Serbia under the Program of financing scientific research work, number 451-03-47/2023-01/200133.

REFERENCES

Anderson, K. E. (2000). Approaches to Treatment and 94 Prevention of Human Porphyrias. *The Porphyrin Handbook: Medical Aspects of Porphyrins*, *14*, 247.

Anstey, A. V., & Hift, R. J. (2007). Liver disease in erythropoietic protoporphyria: insights and implications for management. *Postgraduate medical journal*, *83*(986), 739-748.

Blakely, K. M., Drucker, A. M., & Rosen, C. F. (2019). Drug-induced photosensitivity—an update: culprit drugs, prevention and management. *Drug safety*, *42*, 827-847.

Bruguera, M., & Herrero, C. (2005). Liver disease in erythropoietic protoporphyria. *Gastroenterologia y hepatologia*, *28*(10), 632-636.

Brun, A., & Sandberg, S. (1991). Mechanisms of photosensitivity in porphyric patients with special emphasis on erythropoietic protoporphyria. *Journal of Photochemistry and Photobiology B: Biology*, *10*(4), 285-302.

Daniell, W. E., Stockbridge, H. L., Labbe, R. F., Woods, J. S., Anderson, K. E., Bissell, D. M., ... & Franklin, G. M. (1997). Environmental chemical exposures and disturbances of heme synthesis. *Environmental Health Perspectives*, *105*(suppl 1), 37-53.

Downey, D. (1992). Porphyria induced by palladium-copper dental prostheses: a clinical report. *The Journal of Prosthetic Dentistry*, *67*(1), 5-6.

Fowler, B. A. (2001). Porphyrinurias induced by mercury and other metals. *Toxicological Sciences*, *61*(2), 197-198.

Goldstein, J. A., Linko, P., & Bergman, H. (1982). Induction of porphyria in the rat by chronic versus acute exposure to 2, 3, 7, 8-tetrachlorodibenzo-p-dioxin. *Biochemical Pharmacology*, *31*(8), 1607-1613.

Goldwaier, L. J., & Joselow, M. M. (1967). Absorption and excretion of mercury in man: XIII. Effects of mercury exposure on urinary excretion of coproporphyrin and delta-aminolevulinic acid. *Archives of Environmental Health: An International Journal*, *15*(3), 327-331.

Gupta, V., Liu, S., Ando, H., Ishii, R., Tateno, S., Kaneko, Y., ... & Handa, H. (2013). Salicylic acid induces mitochondrial injury by inhibiting ferrochelatase heme biosynthesis activity. *Molecular Pharmacology*, *84*(6), 824-833.

Hamilton, J. W., Bement, W. J., Sinclair, P. R., Sinclair, J. F., & Wetterhahn, K. E. (1988). Expression of 5-aminolaevulinate synthase and cytochrome P-450 mRNAs in chicken embryo hepatocytes in vivo and in culture. Effect of porphyrinogenic drugs and haem. *Biochemical Journal*, *255*(1), 267.

Horner, M. E., Alikhan, A., Tintle, S., Tortorelli, S., Davis, D. M. R., & Hand, J. L. (2013). Cutaneous porphyrias part I: epidemiology, pathogenesis, presentation, diagnosis, and histopathology. *International journal of dermatology*, *52*(12), 1464-1480.

https://my.clevelandclinic.org/health/diseases/17760-porphyria

https://www.niddk.nih.gov/health-information/liver-disease/porphyria

https://wwwn.cdc.gov/TSP/PHS/PHS.aspx?phsid=625&toxid=115

Jonker, J. W., Musters, S., Vlaming, M. L., Plosch, T., Gooijert, K. E., Hillebrand, M. J., ... & Schinkel, A. H. (2007). Breast cancer resistance protein (Bcrp1/Abcg2) is expressed in the harderian gland and mediates transport of conjugated protoporphyrin IX. *American Journal of Physiology-Cell Physiology*, *292*(6), C2204-C2212.

Murphy, G. M. (2003). Diagnosis and management of the erythropoietic porphyrias. *Dermatologic therapy*, *16*(1), 57-64.

Ogun, A. S., Joy, N. V., & Valentine, M. (2019). Biochemistry, heme synthesis.

Ramanujam, V. M. S., & Anderson, K. E. (2015). Porphyria diagnostics—part 1: a brief overview of the porphyrias. *Current protocols in human genetics*, *86*(1), 17-20.

Rank, J. M., Carithers, R., & Bloomer, J. (1993). Evidence for neurological dysfunction in end□stage protoporphyric liver disease. *Hepatology*, *18*(6), 1404-1409.

Rossi, E., Taketani, S., & Garcia□Webb, P. (1993). Lead and the terminal mitochondrial enzymes of haem biosynthesis. *Biomedical Chromatography*, *7*(1), 1-6.

Rüfenacht, U. B., Gouya, L., Schneider-Yin, X., Puy, H., Schäfer, B. W., Aquaron, R., ... & Deybach, J. C. (1998).

Systematic analysis of molecular defects in the ferrochelatase gene from patients with erythropoietic protoporphyria. *The American Journal of Human Genetics*, *62*(6), 1341-1352.

Samuel, D., Boboc, B., Bernuau, J., Bismuth, H., & Benhamou, J. P. (1988). Liver transplantation for protoporphyria: evidence for the predominant role of the erythropoietic tissue in protoporphyrin overproduction. *Gastroenterology*, *95*(3), 816-819.

Schmid, R. (1960). Cutaneous porphyria in Turkey. *New England Journal of Medicine*, *263*(8), 397-398.

Strik, J. J. T. W. A., Janssen, M. T., & Colombi, A. M. (1980). The incidence of chronic hepatic porphyria in an Italian family. *International journal of biochemistry*, *12*(5-6), 879-881.

Telolahy, P., Javelaud, B., Cluet, J., De Ceaurriz, J., & Boudene, C. (1993). Urinary excretion of porphyrins by smelter workers chronically exposed to arsenic dust. *Toxicology letters*, *66*(1), 89-95.

Wahlin, S., Floderus, Y., Stål, P., & Harper, P. (2011). Erythropoietic protoporphyria in Sweden: demographic, clinical, biochemical and genetic characteristics. *Journal of internal medicine*, *269*(3), 278-288.

Webb, K. B., Ayres, S. M., Mikes, J., & Evans, R. G. (1986). The diagnosis of dioxin-associated illness. *American Journal of Preventive Medicine*, *2*(2), 103-108.

20th International Conference Man and Working Environment
SEMSIE
Safety Engineering & Management – Science, Industry, Education

www.znrfak.ni.ac.rs/semsie

MILORAD GILJAČA[1]
MILOŠ TODOROVIĆ [2]
SNEŽANA ŽIVKOVIĆ [3]

[1] Protection and Rescue Service, Municipality of Tivat, Montenegro

[2] Faculty of Technical Studies, University of Travnik, Bosnia and Hercegovina

[3] Faculty of Occupational Safety, University of Niš, Serbia

[1]*gix147@yahoo.com*
[2]*todor.timprotekt@gmail.com*
[3]*snezana.zivkovic@znrfak.ni.ac.rs*

APPLICATION OF VIDEO SURVEILLANCE IN THE PREVENTION AND PROTECTION AGAINST FOREST FIRES

Abstract: *Increasing the efficiency, speed and simplification of work in protection and rescue services is one of the biggest challenges facing both highly developed and developing countries. One of the key aspects that determine the readiness of units to intervene quickly and in a timely manner during fires and similar accidents is the accurate, precise and rapid reporting of the fire scene (or similar accidents and incidents). This is important in order to determine the basic characteristics of the fire and for the protection and rescue group members to act quickly and efficiently. In Montenegro, a developing country, an obvious problem is the lack of system solutions for monitoring, reporting and intervention, appropriate software, and other solutions that could successfully detect and solve this issue. It is obvious that outdated reporting and alerting procedures, which rely mainly, or sometimes only, on human elements, need to be replaced by automatic reporting, alerting and intervention systems, as well as systems that include video surveillance and control and combine modern sensor systems with artificial intelligence, etc. The efficiency of the use of such automatic systems could be ranked from best to worst, so that the implementation of such devices, sensors and equipment, i.e. hardware and software (algorithms) and their combination, can provide the members of the intervention teams with the most important data about time, location, coverage of fires or other accidents, conditions, determination of the required number of people, intervention plan, etc., which are not known to the members of the intervention teams with the existing outdated alerting and reporting systems until they arrive at the scene.*

This paper aims to show the advantages of theoretical explanation and practical implementation of automatic video and other, combined and systemic methods and procedures of monitoring, observation, alerting and reporting in case of fire, for the purpose of pointing out the shortcomings of the existing monitoring, reporting and alerting systems used in Montenegro, improving efficiency and increasing the operational speed of intervention teams – protection and rescue forces, as well as reducing costs and damages caused by fires or other accidents and incidents.

Keywords: video surveillance, forest fires, prevention

INTRODUCTION

According to the Britannica definition, a "forest fire" is an uncontrolled fire that starts in vegetation more than 1.8 metres high. These fires often reach wildfire proportions and are sometimes fuelled by the burn and heat from surface and ground fires. A large forest fire can spread rapidly through the upper branches of trees before reaching the understory or forest floor. As a result, forest fires often produce violent gusts that can take on the appearance of a firestorm (Britannica, 2023).

Forest fires not only cause tragic loss of life and valuable natural and private property, including thousands of hectares of forest and hundreds of homes, but also pose a major threat to ecologically healthy forests and environmental protection. Every year, thousands of forest fires around the world cause disasters with dire consequences. This paper provides an overview of a problem that has preoccupied researchers for dozens, if not hundreds, of years. The paper analyses the use of video surveillance in the prevention and protection against forest fires.

The situation of the protection and rescue system in Montenegro as a developing country, and also in the countries of the region, is accompanied by a number of problems related to the method of reporting fires, e.g. when reporting fires or other emergency problems and accidents, citizens can call (only) one telephone number (123).

After receiving the call, the members of the response team of the protection and rescue service go to the

scene, very often without information about the exact location, time, extent and cause of the fire, data about the degree and spread of the fire or other information that would facilitate the members of the response team during the firefighting or rescue and prepare them for all possible situations.

Montenegro, like most countries in the region (Serbia, Bosnia and Herzegovina, Croatia, Albania, Greece, etc.), is generally located in an area dominated by forests (open spaces), with significantly fewer fires in residential and/or industrial areas.

The systems for reporting, extinguishing and alerting fires in residential and/or industrial areas have developed technically disproportionately faster than the systems for reporting, extinguishing and alerting forest fires. However, statistically, according to the data available to us (Montenegro as well as the municipality of Tivat and its surroundings), this ratio is on average 5:1 on an annual/monthly basis, which means that forest fires are five times more frequent than fires in residential and/or industrial buildings and facilities.

The specificity of fire detection systems for residential and/or industrial buildings and facilities is reflected in the equipment of these buildings with video surveillance systems, which rely primarily on fire detectors (thermal, ionising and others). As a result, video surveillance is often used only as a means of confirming a fire alarm.

On the other hand, the installation of fire detectors and video surveillance systems in open spaces and forests is much more complex, delicate, expensive and demanding because of a completely different approach, technology and methodology, although there are trials for this as well. Microsystems and sensors for monitoring and reporting can be installed, for example, in the tips of tree branches, they can be activated and kept active, they can be operational, have some autonomy in operation, and be activated by solar energy, wind energy, charging of nano-generators, etc.

It is therefore clear that the prevention of forest fires in the protection and rescue services requires radical changes in the organisation of work and the application of modern methods and technologies, following the development of science and technology in the field of monitoring, data collection, alerting, and reporting, all with the aim of preserving human and animal life, protecting nature and reducing potential damage caused by forest fires.

In this context, the paper is structured as follows. In the introductory section, a possible problem and the aim of the paper are described. After the introduction, the second section explains the causes of forest fires, followed by the basic assumptions of previous research.

This is followed by methods for suppression and detection of fires, a description of video surveillance systems for forest fires and finally the conditions for installing video surveillance of forest fire warnings. The last section of the paper briefly documents the basic elements of the video surveillance system for forest fires before concluding the considerations.

CAUSES OF FOREST FIRES

Forests are the protectors of the earth's ecological balance. Unfortunately, a forest fire is usually not discovered until it has already spread over a large area, making it difficult, if not impossible, to control and contain. The result is devastating losses and irreparable damage to the environment and the atmosphere (30% of the carbon dioxide (CO_2) in the atmosphere comes from forest fires) in addition to the irreparable damage to the ecology (huge amounts of smoke and carbon dioxide in the atmosphere). Other dire consequences of forest fires include long-term catastrophic impacts such as changes of local weather patterns, global warming and the extinction of rare animal and plant species.

The problem with forest fires is that forests are usually remote, abandoned/unmanaged areas filled with trees, dry and dried wood, leaves, etc. that serve as a fuel source.

These elements form highly flammable material, provide the perfect environment for the initial ignition of the fire and serve as fuel for the later stages of the fire. Fires can be caused by human activity such as smoking or barbecuing, or by natural causes such as high temperatures on a hot summer's day or broken glass that acts like a converging lens, focusing sunlight on a small spot over a long period of time and starting a fire.

Once ignition begins, the combustible material can easily fuel the central point of the fire, which then spreads further and further. The initial stage of ignition is usually referred to as a 'surface fire', which can then spread to neighbouring trees, causing the flames of the fire to rise higher and higher, becoming a 'crown fire'. At this stage, the fire usually becomes uncontrollable and the damage to the landscape can last a very long time, depending on the weather conditions and terrain.

PREVIOUS RESEARCH

Forest fire detection has been the focus of interest for many researchers over the last decade, as more and more forest fires are being reported worldwide, causing great damage to society and the environment. Many methods have been proposed to detect forest fires, such as camera-based systems, wireless sensor networks (WSNs) (Dampage et al., 2022) and application-based machine learning systems, with positive and negative aspects and detection performances. Due to the higher probability of accurate and early fire detection, as well as the use of multiple sensor sources and the placement of sensor nodes in areas not visible to satellites, WSNs have a more positive outlook and are increasingly used in many fields (Díaz-Ramírez et al., 2012).

Many researchers have focused on environmental parameters such as air temperature, relative humidity, air pressure, sound, light intensity, soil moisture, wind speed and direction, and gases such as CO, CO_2, methane, H_2, and hydrocarbons from smoke to detect a forest fire, taking into account the variations of these parameters during the fire (Sakr et al., 2014; Molina-Pico et al., 2016), while sensors were selected based on

range, sensitivity, and energy consumption (Liu et al., 2018).

METHODS FOR FIRE FIGHTING AND DETECTION

The most common techniques used by the protection and rescue services for detecting and extinguishing fires in general, including forest fires, can be summarised as follows:

1. Controlled burning;
2. Prediction of fire weather and estimation of fuel and moisture content;
3. Optical smoke detection;
4. Observation posts (towers, etc.);
5. Lightning detectors that determine the spatial coordinates of the impact;
6. Infrared identification;
7. Reconnaissance aircraft;
8. Water tanks;
9. WSNs and phone calls, as techniques for early detection and notification of the presence of fire are very common; and
10. Education through fire watch or similar programmes for property and home owners.

Detection and monitoring systems are divided into the following two basic groups:

1. Voluntary reporting systems – through public reporting of fires, public aircraft and ground rescue services;
2. Operational reporting systems: fire towers, air patrols, electronic flash detectors and automatic reporting systems (Alkhatib, 2014).

Today, there are two different types of sensor networks for fire detection: camera monitoring and wireless sensor networks. The development of sensors, digital cameras, image processing and personal computers has led to the development of systems for optical, automatic early detection and warning of forest fires.

Different types of detection sensors can be used in ground systems (Alkhatib, 2014):

- Video camera, which responds to the visible spectrum of smoke that can be detected during the day and fire that can be detected at night;
- Infrared (IR), thermal imaging cameras based on the detection of the heat flux of fire;
- IR spectrometers to detect the spectral characteristics of smoke;
- LIDAR (Light Detection and Ranging) systems that measure laser beams reflected from smoke particles.

The different variants of optical systems, which operate according to different algorithms developed by the manufacturers, all share the same general concept for detecting smoke and embers. Quite simply, the camera generates images from time to time. An image consists of a certain number of pixels, and the processing unit tracks the movement in the images and checks how many pixels contain smoke or embers. Then the processing unit sends the results to another algorithm that decides whether or not to trigger an alarm for the operator. Most optical systems need to be integrated with geographical maps for localisation reasons.

WSNs are autonomous, infrastructure-less wireless networks that help monitor physical or environmental conditions and relay that data over the network to a designated location or sink, where the data can be observed and analysed (Matin & Islam, 2012).

Efficiency and low energy consumption are the main advantages of WSNs. In the proposed detection system, wireless sensor nodes are arranged according to the cellular architecture to cover the whole area with sensors for monitoring temperature, relative humidity, light intensity and carbon monoxide (CO) content with a microcontroller, a transceiver module and a power supply element.

The sensor node is powered by batteries as the primary power supply and by solar cells as the secondary power supply. The sensor nodes have a special spherical shape to avoid damage from environmental influences and animals.

DISADVANTAGES OF EXISTING VIDEO FIRE NOTIFICATION METHODS

The main shortcomings of existing, i.e. traditional, video surveillance systems for reporting and alerting forest fires are:

- inaccurate reporting of the fire location;
- late reporting of the fire;
- inadequacies in reporting fire locations during the day and night.

In the first half of the twentieth century, in Montenegro, but also in other surrounding countries (Bosnia and Herzegovina, Serbia, Croatia and others), there were towers, i.e. lookout points, which were the property of fire brigades and which facilitated the system of alerting, reporting and monitoring the situation on the ground during forest fires. However, as the situation on the ground has changed a lot in the last fifty years due to the construction of high-rise residential buildings, the installation, renovation and construction of new towers to monitor forest fires has lost its purpose. The towers were manned by personnel tasked with visually monitoring and detecting fires in the forest and surrounding areas.

Nevertheless, the idea that links the usefulness of these towers for monitoring forest fires in modern times is very current and can be used in combination with the towers used by today's mobile phone networks and repeaters.

EQUIPMENT FOR VIDEO SURVEILLANCE OF FOREST FIRES

The fear of fire is rightly one of the oldest and greatest fears of mankind, considering that it can destroy

valuable possessions, objects or the greatest value – human life – in just a few minutes. Even if the fire brigade discovers the fire in time and manages with much effort to contain the source of the fire, the consequences of extinguishing the fire remain serious. Everything that is not damaged by the fire is usually already damaged by the extinguishing water. Therefore, fire prevention must always be a priority, whether for residential buildings, industrial plants, or forests. The above illustrates the importance of fire protection systems. The basic task of fire protection systems is the early detection of fires by detecting smoke and heat with the help of fire detectors (fire alarms). The system performs this task with the help of parameters such as measurement of smoke development, measurement of temperature, and detection of flickering flames or heat sources.

Changes are detected by sensors or detectors that forward the information to the control centre. The control centre is the brain of the system, as it processes the information received and makes a decision about the next steps. If the collected data show that the situation is classified as critical, an alarm is triggered. The alarm sounds or triggers a call to the responsible fire station or, in the case of residential buildings, to the owner of the building.

It is important to know that there are specific legal requirements in all countries in the region and beyond regarding installation and maintenance of fire protection systems. Indeed, only professionals who have all the necessary licences can be project promoters. Only a person who holds a licence issued for these tasks by the Ministry of the Interior may be entrusted with the planning, organisation, and implementation of preventive fire protection measures.

Thermal imaging, thermovision, or infrared cameras are devices that respond to the infrared region of the electromagnetic spectrum and reproduce an image based on infrared radiation (thermogram).

Since every object emits heat to a certain degree, thermal imaging cameras can not only detect the heat emitted, but also react when the temperature of the building/room rises, thus fulfilling the conditions for a fire. For example, a thermal imaging camera can detect an electrical appliance that is overheating beyond a certain limit or an unquenched cigarette butt that could cause a fire.

Thermal imaging cameras attached to cell towers in forested areas and neighbourhoods use sensors to detect heat. The temperature is read in a thermogram.

Bodies that radiate a higher temperature are represented by bright colours (usually red and yellow), while cooler objects are represented on the thermogram by dull colours (usually green or blue).

By reading the thermogram, the operator can easily detect sudden increases in temperature and alert the fire brigade in time.

Unlike conventional cameras, thermal imaging cameras do not require special lighting when used at night. Detecting thermal radiation at night is possible without additional lighting because the camera reacts to the radiation emitted by anybody with a temperature above 0° Kelvin.

Thermal imaging cameras are the best means of detecting objects or suspicious activity in complete darkness. There are both tripod-mounted and hand-held thermal imaging cameras. The Faraday ColorWD HD CVI camera, for example, makes it possible to produce a colour image regardless of the operating conditions – day or night and in any weather.

The advanced technology of thermal imaging cameras is able to detect temperature anomalies in the shortest possible time, enabling a timely response. It is also possible to set an alarm at a certain temperature limit. When the limit is exceeded, the alarm is triggered. If the fire has already started, modern thermal imaging cameras offer the possibility to detect the fire at the very beginning – before it has spread.

The camera also provides visual confirmation of where the fire has started, enabling an effective response.

It should be remembered, however, that a thermal imaging camera is not a substitute for a proper fire protection system, especially in large areas such as forests. The fact that the law requires the installation of a proper fire protection system notwithstanding, thermal imaging cameras in combination with sensors can be extremely good allies in the fight against fires.

It should be noted that the use of the most advanced detection and alarming methods possible through thermal imaging cameras cannot extinguish the fire.

Figure 1 shows daytime while Figure 2 shows nighttime fire detection by a thermal imaging camera, which provides very detailed data about the fire scene that are crucial for local emergency services to respond to the fire. Even if the protection and rescue services receive information about the presence of a fire in a particular location through conventional detection systems, the emergency services can use the camera for additional verification of the location and other important elements about the fire.

The use of a camera or sensor depends not only on the specific working conditions, but also on the financial resources available. Alarm-eye, for example, is a forest fire early detection system with integrated infrared, black and white, and colour frequency detection. Its infrared option can distinguish a flame image from a heat vapour.

Optical sensors manufactured for forest fire detection consist of:

- a camera (colour during the day and greyscale at night);
- meteorological stations;
- a sensor for lightning detection;
- a communication unit (0.25 Mbps);
- a power supply system.

Thermal imaging cameras or pan-tilt-zoom cameras may be added to the system. Such a system can also provide automatic smoke detection, which sends

images to the fire brigade as soon as an operator notices smoke, and use control software that uses a GIS map to locate the position of smoke on the ground. A weather station and a lightning detector can also be integrated into the system for greater accuracy.

Figure 1. *Day and night fire detection*

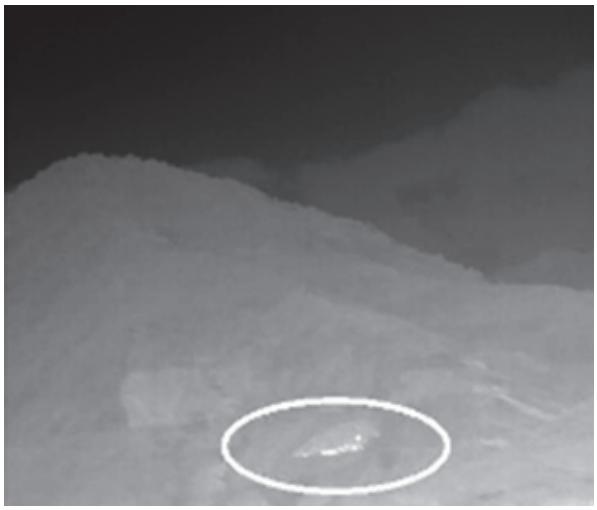


Figure 2. *Night fire detection*

REQUIREMENTS FOR THE INSTALLATION OF FOREST FIRE ALARM VIDEO SURVEILLANCE

Firefighting requires the use of people who have a high level of expertise, knowledge and skills.

The installation of adequate video surveillance in forest areas requires the fulfilment of certain conditions, which are necessary for its smooth operation, namely:

- a good visibility and coverage of the camera or sensor position (Figure 3);
- a high vantage point;
- the ability to rotate and see in a 360-degree radius;
- a continuous supply of low voltage (suitable for the operation of the camera and associated software);
- a high-quality internet connection;
- a location protected from lightning strikes;
- an alternative power supply system (independent generator to produce electricity);
- fire protection;
- coverage of households and facilities in the vicinity of forest complexes.

Since many conditions are very difficult to fulfil, a possible solution could be the installation of video cameras on existing towers, relay-repeaters for mobile telephony and the Internet. As they are installed throughout the national territory, they are of very high quality and have wide coverage throughout the national territory. At the same time, these towers possess all the previously mentioned aspects and also ensure the deployment of 3G, 4G and 5G network technologies. The towers of the 3G, 4G and 5G networks are installed at increasingly smaller distances from each other, which facilitates the collection and transmission of large amounts of data (Big Data) and significantly increases area coverage.

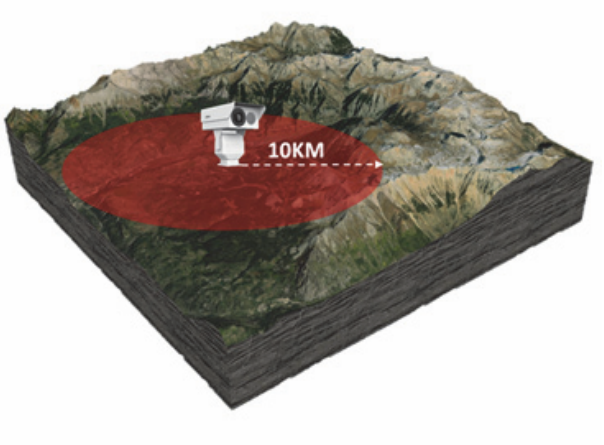


Figure 3. *Camera coverage of the forest area*

FOREST FIRES VIDEO SURVEILLANCE SYSTEM

Modern video surveillance systems for forest fires consist of hardware and software elements. The main hardware elements include a system of sensors and thermal imaging cameras, network recorders capable of recording and storing all video footage 24/7, and information and communication technology capable of storing, processing, managing, transmitting, and archiving information. The software part of the video surveillance system consists of mobile applications stored on the hardware devices that are an integral part of the system (Figure 4).

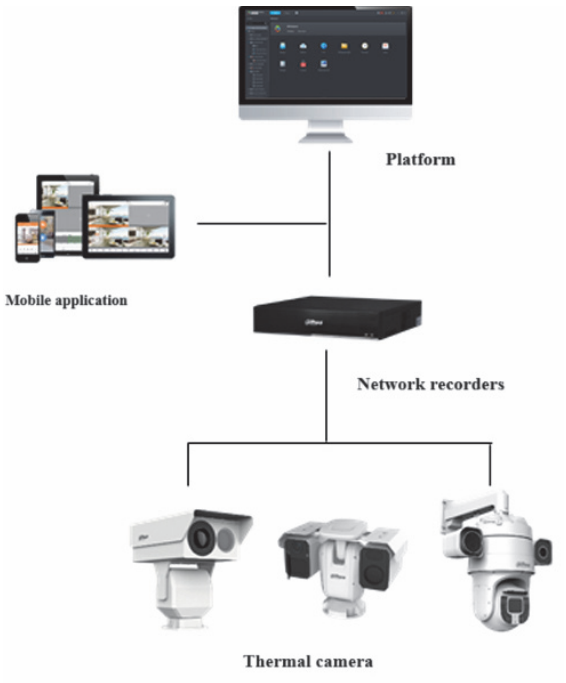


Figure 4. *Forest fires video surveillance system*

CONCLUSION

We conclude that the proposed forest fire detection system using a combination of video surveillance and reporting with wireless sensor networks is an effective method for detecting forest fires, providing much more reliable and accurate, and ultimately much faster, results. To obtain fast, accurate and precise information, the analysis can be carried out within the sensor node and/or in the base station. To adapt the system to any weather, climate or area, it is necessary to introduce a threshold ratio for the analysis in the sensor node. When installing a node, it can be placed anywhere in the forest, even if there is no pre-installed network connection, as the transceiver modules are based on their own built-in network infrastructure. Thanks to the primary power supply from rechargeable batteries and the secondary solar energy, the solution can easily be used as a self-sufficient system over a long period of time. The proposed systems can be integrated into the communication infrastructure and alert the relevant authorities under real-life conditions with less delay than the existing or non-existing systems.

REFERENCES

Alkhatib, A.A. (2014). A Review on Forest Fire Detection Techniques, *International Journal of Distributed Sensor Networks, 2014*(3). Available from https://journals.sagepub.com/doi/epub/10.1155/2014/597368

Aslan, Z. (2010). *A framework for the use of wireless sensor networks in the forest fire detection and monitoring* [M.S. thesis], Department of Computer Engineering, The Institute of Engineering and Science, Bilkent University. Available from https://www.sciencedirect.com/science/article/abs/pii/S0198971512000300

Britannica (2023). Forest fire. Available from https://www.britannica.com/science/forest-fire

Dampage, U., Bandaranayake, l., Wanasinghe, R., Kottahachchi, K., & Jayasanka, B. (2022). *Forest fire detection system using wireless sensor networks and machine learning*, Nature portfolio, Scientific Reports. Available from https://doi.org/10.1038/s41598-021-03882-9

Díaz-Ramírez, A., Tafoya, L.A., Atempa, J.A., & Mejía-Alvarez, P. (2012). Wireless sensor networks and fusion information methods. *Iberoamerican Conference on Electronics Engineering and Computer Science, México*. Available from https://www.sciencedirect.com/science/article/pii/S221201731200237X

Liu, Y., Liu, Y., Xu, H., & Teo, K.L. (2018). Forest fire monitoring, detection and decision making systems by wireless sensor network. *Chinese Control and Decision Conference (CCDC), Shenyang*. Available from https://espace.curtin.edu.au/handle/20.500.11937/73475

Matin, M.A., & Islam, M.M. (2012). Overview of wireless sensor network. *Intech Open*. Available from https://www.researchgate.net/publication/272832872_Overview_of_Wireless_Sensor_Network

Molina-Pico, A., Cuesta-Frau, D., Araujo, A., Alejandre, J. & Rozas, A. (2016). Forest monitoring and wildland early fire detection by a hierarchical wireless sensor network. *J. Sensors 1–8*. Available from https://www.semanticscholar.org/paper/Forest-Monitoring-and-Wildland-Early-Fire-Detection-Molina-Pic%C3%B3-Cuesta-Frau/af42ac8b3644ede583c17a3a9bb0d53ccf9cf278

Nakau, K., Fukuda, M., Kushida, K., Hayasaka, H., Kimura, K., & Tani, H. (2006). *Forest Fire Detection Based on MODIS Satellite Imagery, and Comparison of NOAA Satellite Imagery with Fire Fighters Information*. Available from https://www.researchgate.net/publication/251764783_Forest_fire_detection_based_on_MODIS_satellite_imager_y_and_Comparison_of_NOA_A_satellite_imagery_with_fire_fighters%27_information

NOAA satellite and information service. (2012). Advanced Very High Resolution Radiometer-AVHRR. Available from http://noaasis.noaa.gov/NOAASIS/ml/avhrr.html

Sakr, G.E., Ajour, R., Khaddaj, A., & Saab, B. (2014). Forest fire detection wireless sensor node. *Advances in Forest Fire Research, Imprensa da Universidade de Coimbra*, 1395–1406. Available from https://www.researchgate.net/publication/284237896_Forest_fire_detection_wireless_sensor_node

20th International Conference Man and Working Environment
SEMSIE
Safety Engineering & Management – Science, Industry, Education
www.znrfak.ni.ac.rs/semsie

MIRJANA GALJAK[1]

[1] Kosovo and Metohija Academy of Applied Studies, Leposavić

[1]*mirjana.galjak@akademijakm.edu.rs*

BIOHAZARD RISK PERCEPTION IN THE WORKING ENVIRONMENT

Abstract: *The perception and awareness of the risk of biological hazards in the work environment is extremely important. Some authors even believe that there is a severe lack of information on biological hazards and that analyses of biological hazards in the workplace are urgently needed. In fact, when modern society was faced with the great Covid-19 pandemic, all of its vulnerabilities, as well as the importance of adequate risk perception in working environments, were easily exposed. This paper describes the perception of risk and biological hazards, and also analyses the harmful effects of biological agents on the workers' health. In addition, the paper also provides a brief overview of the Covid-19 pandemic, taking into account the exposure of employees to an infectious disease during a pandemic.*

Keywords: biological agents, risk perception, protective measures, Covid-19

INTRODUCTION

Almost no human activity occurs in sterile conditions without the presence of microorganisms. However, there is a huge number of activities in which the risk of getting sick is increased due to the presence of numerous microorganisms, such as: working with sick people (anthroponoses - in which humans are the only reservoir of the disease) and working with animals (zoonoses - diseases common to both humans and animals) (Čabarkapa, 2008; Delić, 1997). Approximately 18.4% (26.7 million) of workers in the United States work in jobs where exposure to disease or infection occurs at least once a month (Baker et al., 2020).

The International Labour Organization (ILO) (2010) updated its list of occupational diseases, which includes, among other things, various biological agents, infectious or parasitic diseases, as well as post-traumatic stress disorder, as well as diseases brought on by exposure to agents at work (ILO, 2010).

When a worker contracts an infectious disease, the mechanisms of disease spread in the workplace must be investigated, and measures to control exposure to the given disease at work must be implemented (Su et al., 2019). Enterprises are effective platforms where both employers and employees can jointly share information and raise the level of awareness of occupational safety and health, which includes preventive and protective measures to stop the spread of infectious diseases. The lessons learned from previous epidemics demonstrate that in order to stop a potential health and economic disaster, adequate risk perception is required, which results in prompt, targeted, and well-coordinated action at the national level.

Adequate risk perception is a key factor in the management of any crisis and emergency. In practice, employees perceive risk differently, which results in diverse reactions and responses. Moreover, inadequate perception and misunderstanding of any risk in the workplace have a negative impact on employee readiness, and their response to warnings about dangers and personal protection measures, which makes us conclude that the perception of risk affects employee behaviour.

CONCEPTUAL AND THEORETICAL APPROACH

Biological hazards

In the working environment, biological hazards are microorganisms (viruses, bacteria, fungi, protozoa, helminths, arthropods) or their components that can cause occupational diseases or work-related diseases. Microorganisms are abundant in nature and can be found in soil, water, food, various plants, animals and humans. The majority of them are not pathogenic in nature, but pathogens are not rare either. Biological agents can, in relation to the host, be pathogenic (causing mostly asymptomatic infections), opportunistic (causing diseases only when the host's resistance is reduced) and apathogenic. Infections and diseases are caused by pathogenic and opportunistic agents, while apathogenic agents can only result in colonization that is not harmful to the host (Radulović, 1996).

According to the Rulebook on preventive measures for safe and healthy work related to exposure to biological hazards ("Official Gazette of the RS", no. 96/2010 and 115/2020), biological hazards are defined as microorganisms, which include those that are genetically modified, cell cultures and human endoparasites that can cause infection, allergy or toxicity. Thus, biological hazards are infectious agents or dangerous biological materials that adversely affect the health of workers, either directly by infecting workers or indirectly by contaminating the working environment (Kyung-Taek Rim, 2014). Pathogenic microorganisms are most often found in the air of

closed and poorly ventilated workplaces where a large number of people reside. Microorganisms from people get into the air through droplets of secretions from the upper respiratory tract and the mouth when sneezing, coughing, and speaking. Some causative agents of infectious diseases are resistant to the conditions prevailing in the external environment, such as: scarlet fever, tuberculosis and diphtheria.

Considering the level of risk of diseases they can cause in humans, biological agents are classified into four risk groups (Directive 2000/54 EC):

- a biological agent in risk group 1 is an agent that is unlikely to cause disease in humans;
- a biological agent in risk group 2 is an agent that can cause disease in humans and could be dangerous for workers, but it is not likely to spread to the environment; there is usually effective prophylaxis or treatment;
- a biological agent in risk group 3 is an agent that can cause serious illness in humans and poses a serious danger to workers; may pose a risk of spreading to the environment, but there is usually effective prophylaxis or treatment;
- a biological agent in risk group 4 is an agent that causes severe disease in humans and poses a serious danger to workers; it may pose a high risk of spreading into the environment; no effective prophylaxis or treatment is usually available.

Risk perception

Risk perception according to Slović (1992) represents an individual's subjective judgment about the characteristics and severity of the risk itself. It is crucial to examine a risk perception that most people have because risks can be viewed objectively (scientifically assessed risks) and subjectively (an individual determines the degree of risk based on their own experience). There is always a difference between subjective and objective risk assessment (Dwyer et al., 2004). Viewed from the academic discourse, numerous studies have confirmed that inadequate risk perception and misunderstanding negatively affect people's preparedness, response to danger warnings, personal protection measures and recovery (Dillon et al., 2014; Kunreuther et al., 2013). On the other hand, prompt and accurate perception of risk perception has an impact on the delivery of a sufficient response.

Risk perception is related to hazard characteristics and perceived personal consequences (Lindell, 1994). The effectiveness of strategies aimed at reducing risk is significantly determined by human behavior, which is strictly related to risk perception. Risk perception is also influenced by a number of personal variables such as education, gender, etc. (Flynn et al., 1994; Kone, Mullet, 1994; Dosman et al., 2001). By analyzing the literature, we come to the conclusion that when examining risk perception, researchers' attention was most often attracted by the question of whether people are aware of risk, as well as the question of the connection between risk perception and the readiness of employees and in general all people to react (Cvetković, Sandić 2016; Dilley et al., 2005; Pine, 2008). Risk perception is related to the information available to risk assessors, as well as to the way they interpret that information. The degree of risk perception can also be influenced by experience, as found by Elrick-Barr et al. (2015). Many data show that cultural and social circumstances have influenced the way in which people perceive risk (Kammerbauer, Minnery, 2019).

BIOLOGICAL HAZARD RISK PERCEPTION IN THE WORKING ENVIRONMENT

Different perceptions of any risk lead to the conclusion that it is very important to change people's awareness of risks as a key precondition for improving their readiness to respond. The perception of risk and the ability to provide an adequate response, when an undesirable situation occurs, is conditioned by the individual understanding of danger (Anderson-Berry, King, 2005; Miceli et al., 2008; Cvetković, Stanišić, 2015; Cvetković, Stojković, 2015).

Proper and timely perception of the risk of biological hazards in the working environment is very important. Healthcare workers who come into contact with biological material experience the most frequent and severe workplace accidents that can cause a variety of diseases. Health professionals, and nurses, in particular, are exposed to many biological agents in the workplace (direct patient care, administration of drugs, wound dressing, cleaning and sterilization of surgical materials, etc.). Bioaerosols that are found in agriculture are diverse and include bacteria, fungi, endotoxins, mycotoxins and volatile organic compounds. Also, there are different particles of vegetable and animal origin. All these agents can cause allergic and/or immunotoxic occupational diseases of the respiratory organs (inflammation of the airways, rhinitis, asthma, etc.), conjunctivitis and dermatitis in exposed workers (Jacobsen et al., 2010). There are also studies that talk about the dominant types of microorganisms in the waste-handling industries (McSweeney, 2020).

When contemporary civilization was confronted with a severe pandemic like the Covid-19 pandemic, we were able to clearly observe the significance of prompt and precise risk perception. It is the most widespread global pandemic that has produced a global crisis and put humanity to a difficult test (Xue et al., 2020). With the emergence and spread of the Covid-19 pandemic, the Government of the Republic of Serbia adopted the Determination of Measures against the Spread of Covid-19 Coronavirus, which defined the appropriate measures for the prevention and suppression of the infectious disease caused by the SARS-CoV-2 virus, as well as conditions, strategy, agents and means of implementing those measures.

The importance of proper risk perception is confirmed by quantitative research on the citizens' level of preparedness for disasters caused by COVID-19 in Serbia. Based on the findings that there are major differences in the public's perception of risks posed by communicable disease threats such as presented by COVID-19, emergency management agencies should use these differences to develop targeted strategies to enhance community and national preparedness by promoting behavioral change and improve risk management decision-making (Cvetković et al., 2020).

Indeed, during the Covid-19 pandemic, workplaces around the world were the primary locations of Covid-19 outbreaks (Coleman, 2020). Such epidemics emphasize the importance of the physical proximity of employees (density), ventilation, and hygiene at the workplace as a determinant of risk during a pandemic (Directive 2000/54 EC) (Zhang et al., 2011). Workers' readiness to respond and capacity to provide an adequate response increase when they perceive the risk of biological hazards in an appropriate manner.

Biological hazards are specific and can be "elusive", meaning that they can appear and then disappear in a short period of time, so it is important to know how to recognize and prepare for them (Webster et al., 2018). In fact, measures should be taken to prevent the risk of exposure to biological agents or, where this is not feasible, to reduce the risk of exposure to an acceptable level (Jacobsen et al., 2010).

MEASURES FOR THE PROTECTION OF WORKERS AGAINST BIOLOGICAL HAZARDS

The most effective measures to protect workers from biological agents are preventive measures, one of them being risk assessment. According to the Rulebook on preventive measures for safe and healthy work related to exposure to biological hazards ("Official Gazette of the RS", no. 96/2010 and 115/2020), for all workplaces in the working environment, where employees may be exposed to biological agents, the employer is obliged to conduct an assessment of the risk of injury or damage to their health to determine the nature, degree and duration of exposure of employees and methods and measures to eliminate or reduce these risks.

The basic guidelines for assessing the risk of biological hazards as well as measures to prevent and reduce risk are regulated by Directive 2000/54 EC of the European Union on the protection of workers from the risk of exposure to biological agents at work. Also, the use of means and equipment for personal protection, appropriate education and training, as well as vaccination of workers are necessary preventive measures for the protection of workers against biological agents.

It was established that the appropriate qualifications and habits of workers acquired through training are of great importance for the prevention of infections among workers working in laboratories (Kyung-Taek Rim, 2014). Also, the relationship between knowledge, risk perception and behavior related to vaccination among nurses was confirmed (Radulović, 1996).

We can say that the measures of protection against biological agents are the following (Aranđelović, Jovanović, 2009):

- mechanization, automation and hermetization of the process, because this prevents direct contact of workers with biological agents;
- vaccination of livestock and other necessary veterinary measures;
- implementation of appropriate procedures with the corpses of dead animals and people;
- hygienic measures for the protection of all working rooms, surfaces, accessories, instruments and devices, application of disinfectants (acids, bases, alcohol, detergents, formaldehyde, UV-radiation, high temperature, etc.);
- necessary implementation of personal hygiene measures (especially hand hygiene with the use of disinfectants);
- control of the performed disinfection, which is necessary and is carried out by taking air samples, swabs of working surfaces and hands;
- sanitary-hygienic disposal of waste liquid and solid substances;
- mandatory use of means and equipment for personal protection such as: work suits, protective gloves, protective caps, face masks, protective footwear (usually they are for single use), if this is not the case, they are made of material resistant to disinfectants or high temperature;
- infectious diseases are on the list of occupational diseases;
- implementation of professional rehabilitation, because a large number of diseases leave permanent consequences for the health of workers, which requires that after treatment and medical rehabilitation, professional rehabilitation is also implemented.

CONCLUSION

One of the most crucial factors in the decision-making process in order to take effective preventive measures is accurate and timely risk perception. In fact, willingness to respond and the ability to provide an adequate response, depends on the workers' correct perception of the risk of biological hazards.

The paper also emphasizes biological agents and gives some examples of their harmful effects on workers' health. Also, the importance of implementation of preventive measures such as: risk assessment, application of means and equipment for personal protection, training of workers, etc., was emphasized. Moreover, there is a higher risk of infection for many workers, particularly in the healthcare industry. Such infections are caused by a variety of pathogens, some of which are quite different from one another. Risk is typically unexpected or not obvious at first, making

risk assessment particularly challenging. For the prevention of infections among employees who work in high-risk workplaces, risk assessment is of crucial importance. Any assessment of risk potential must take into account: the ability of a pathogen to cause infection and disease (the nature of the pathogen's virulence); the potential of the pathogen to survive in the environment; the risk of disease; the level of exposure necessary to cause disease or infection; transmission method and epidemiological factors.

Also, the Covid-19 pandemic reminds us of the importance of proper and timely risk perception. During the pandemic, workplaces all over the world have been identified as the main centers for the outbreak of Covid-19. We have seen firsthand that the challenge posed by the Covid-19 pandemic can only be overcome with an adequate risk perception, as well as with the introduction of a global and coordinated strategy that requires unprecedented close cooperation between governments, social partners, associations, international organizations and economic and of financial institutions at all levels.

REFERENCES

Anderson-Berry, L., King, D. (2005). Mitigation of the impact of tropical cyclones in Northern Australia through community capacity enhancement. Mitigation and adaptation strategies for global change, 10(3), 367-392

Aranđelović, M., Jovanović, J. (2009). Medicina rada, Medicinski fakultet, Univerzitet u Nišu, Niš.

Baker, M.G., Peckham, T.K., Seixas, N.S. (2020). Estimating the burden of United States workers exposed to infection or disease: a key factor in containing risk of COVID-19 infection. PloS One 2020;15:0232452.

Delić, D. (1997). Profesionalne bolesti izazvane biološkim agensima, U: Vidaković A, urednik. Medicina rada II. Beograd: KCS-Institut za medicinu rada i radiološku zaštitu „Dr Dragomir Karajović" i Udruženje za medicinu rada, Beograd, (str. 857-858)

Dwyer, A., Zoppou, C., Nielsen, O., Day, S. and Roberts, S. (2004). Quantifying Social Vulnerability: A Methodology for Identifying Those at Risk to Natural Hazards. Geoscience Australia Record 2004/14

Dosman, D., Adamowicz, A., Hrudey, S. (2001). Socioeconomic determinants of health-and food safety-related risk perceptions. Risk Anal. 21 (2), 307–317

Dilley, M., Chen, R. S., Deichmann, U., Lerner-Lam, A. L., Arnold, M. (2005). Natural disaster hotspots: a global risk analysis (Vol. 5): World Bank Publications

Dillon, R., Tinsley, C., Burns, W. (2014). Near‐misses and future disaster preparedness, Risk Analysis, 34, 2014(10), 1907-1922

Directive 2000/54 EC, of the European Union on the protection of workers from the risks of exposure to biological agents at work

Elrick-Barr, C.E., T.F. Smith, D.C. Thomsen, and B.L. Preston (2015). Perceptions of risk among households in two Australian coastal communities. Geographical Research. 53(2). pp. 145–159

ILO List of Occupational Diseases (revised 2010) https://www.ilo.org/safework/info/publications/WCMS_125137/lang--en/index.htm

Jacobsen, G., Schaumburg, I., Sigsgaard, T., Schlunssen, V. (2010). Non-malignant respiratory diseases and occupational exposure to wood dust. Part I. Fresh wood and mixed wood industry. Ann Agric Environ Med 2010;17:15-28.

Kyung-Taek Rim, Cheol-Hong Lim. (2014). Biologically Hazardous Agents at Work and Efforts to Protect Workers' Health: A Review of Recent Reports. Safety and Health at Work 5 (2014), pp.43-52.

Kammerbauer, M., Minnery, J. (2019). Risk communication and risk perception: lessons from the 2011 floods in Brisbane, Australia, Disasters, 43(1), pp. 110−134

Kunreuther, H., Meyer, R., Michel-Kerjan, E. (2013). Overcoming decision biases to reduce losses from natural catastrophes, in Shafir, E. (Ed.), Behavioral Foundations of Policy, Princeton University Press, Princeton, NJ, pp. 398-413

Kone, D., Mullet, E. (1994). Societal risk perception and media coverage. Risk Anal. 14 (1), 21–24

Kyung-Taek Rim, Cheol-Hong Lim. (2014). Biologically Hazardous Agents at Work and Efforts to Protect Workers' Health: A Review of Recent Reports. Safety and Health at Work 5 (2014), pp.43-52

Lindell, M. (1994). Perceived characteristics of environmental hazards. International Journal of Mass Emergencies and Disasters, 12(3), 303-326

Miceli, R., Sotgiu, I., & Settani, M. (2008). Disaster preparedness and perception of flood risk: A study in an alpine valley in Italy. Journal of Environmental Psychology, 28(2), 164-173.

McSweeney, E.: COVID-19 Outbreaks at Irish meat plants raise fears over worker safety [Internet]. London (United Kingdom): The Guardian. 2020 May 1 [cited 2020 June 2]. Available from: https://www.theguardian.com/environment/2020/may/01/covid-19-outbreaks-at-irish-meat-plants-raisefears-over-worker-safety.

Pine, C. J. (2008). Natural hazards analysis: reducing the impact of disasters, CRC Press.

Pravilnik o preventivnim merama za bezbedan i zdrav rad pri izlaganju biološkim štetnostima ("Sl. glasnik RS", br. 96/2010 i 115/2020),

Radulović, Š. (1996). Agensi biološke prirode, U: Vidaković A, urednik. Medicina rada I. Beograd: KCS-Institut za medicinu rada i radiološku zaštitu „Dr Dragomir Karajović" i Udruženje za medicinu rada, Beograd, str. 280-282

Su, C.P, Perio, M., Cummings, K., McCague, A.B., Luckhaupt, S., Sweeney, M. (2019). Case Investigations of Infectious Diseases Occurring in Workplaces, United States, 2006-2015. Emerging infectious diseases journal. 25. pp. 397-405.

Slovic, P. (1992). Convergent validation of risk-taking measures. The Journal of Abnormal and Social Psychology, 65(1), 68-71

Flynn, J., Slovic, P., Mertz, C. (1994). Gender, race, and perception of environmental health risks. Risk Anal. 14 (6), 1101–1108

Cvetković, V., Sandić, M. (2016). The fear of natural disaster caused by flood. Ecologica, 23(82), 203-211

Cvetković, V., & Stanišić, J. (2015). Relationship between demographic and environmental factors with knowledge of secondary school students on natural disasters., SASA. Journal of the Geographical Institute Jovan Cvijic, 65(3), 323-340.

Cvetković, V., & Stojković, D. (2015). Knowledge and perceptions of secondary school students in Kraljevo about natural disasters. Ecologica, 22(77), 42-49.

Cvetković, V. M., Nikolić, N., Radovanović Nenadić, U., Öcal, A., Noji, E.K., Zečević, M. (2020). Preparedness and Preventive Behaviors for a Pandemic Disaster Caused by COVID-19 in Serbia, International journal of environmental research and public health 17(11): 4124.

Coleman J. (2020). Meatpacking worker told not to wear face mask on job died of coronavirus: report [Internet]. Washington DC (NW): The Hill. 2020 May 7 [cited 2020 June 2]. Available from: https://thehill.com/policy/finance/496595-meatpacking-worker-told-not-to-wear-face-mask-on-job-died-of coronavirus

Zhang, J., While, A.E., Norman, I.J. (2011). Nurses' knowledge and risk perception towards seasonal influenza and vaccination and their vaccination behaviours: a cross-sectional survey. Int J Nurs Stud 2011;48:1281-9.

Čabarkapa, M. (2008). Čovek i radna okolina-psihofiziološki i ekološki aspekti rada, Čigoja, Beograd

Xue, E., Li, J., Li, T., & Shang, W. (2020). China's Education Response to COVID-19: A Perspective of Policy Analysis. Educational Philosophy and Theory, from https://www.researchgate.net/publication/342939994_How_China's_education_responses_to_COVID-19_A_perspective_of_policy_analysis, accessed: 02.07. 2023.

Webster, R., Liu, R., Karimullina, K., Hall, I., Amlot, R., Rubin, G. A. (2019). Systematic review of infectious illness presenteeism: prevalence, reasons and risk factors. BMC Public Health 2019;19:1-13.

20th International Conference Man and Working Environment
SEMSIE
Safety Engineering & Management – Science, Industry, Education

www.znrfak.ni.ac.rs/semsie

ALEKSANDRA ILIĆ PETKOVIĆ[1]
MILJANA STRATIJEV[2]

[1]University of Niš,
Faculty of Occupational Safety
[2]Attorney at law, Niš

[1]aleksandra.ilic@znrfak.ni.ac.rs
[2]miljana@stratijev.com

OSH STRATEGIC DIRECTIONS IN EUROPEAN AND NATIONAL LEGISLATION

Abstract: *Considering the circumstances, situation and risks in the field of occupational safety and health in the member states of the European Union and in Serbia, the paper analyses the EU and Serbian strategic documents in the field of occupational safety and health. We paid special attention to the European Strategic Framework on Health and Safety at Work 2021-2027 as the basic strategic EU document in this area. We also analysed Serbian strategic documents emphasizing current situations and problems. In light of this, we made proposals for improving the system of safety and health at work in Serbia through certain strategic solutions for the next period. This will contribute to defining goals, measures, activities, deadlines and responsible subjects more clearly.*

Keywords: OSH strategic directions, legislation, European Union, Republic of Serbia

INTRODUCTION

The occupational health and safety system is becoming an increasingly important aspect of organizational strategies in view of the growing demands for preserving the health of employees, their productivity, but also organization's profits and social responsibility (Ilić Petković, 2022). The very idea of strategic planning in the field of safety and health at work has a long tradition that continues to this day. It enables the identification of risks and problems in the occupational safety and health system, definition of goals and priorities, resource planning for the realization of those goals and the establishment of a monitoring and evaluation system. All these matters are regulated by strategic documents.

The European Union, as one of the international organizations with the most developed policies and regulations in the field of occupational safety and health, has the key role in setting strategic goals (Ilić Petković, 2020). The European Union has adopted a large number of documents, primarily directives, in this area. In this sense, a particularly important strategic document is the EU Strategic Framework on Health and Safety at Work 2021-2027, which establishes the basis of the EU policy in this area. Moreover, the EU system contains a special sub-organization with exclusive competence in the field of occupational safety and health - the European Agency for Safety and Health at Work (EU-OSHA), whose activities especially contribute to the realization of strategic goals. Also, EU-OSHA's cooperation with EU institutions is of key importance for the Agency, in particular for its work to support policymaking (EU-OSHA, 2022).

The Republic of Serbia has the same approach to the regulation of the occupational safety and health system. It also has extensive regulations, a special strategy for safety and health at work and a special authority - the Administration for Occupational Safety and Health.

In this paper, we will analyse two basic strategic documents in the field of occupational safety and health in the European Union and the Republic of Serbia. In the European Union, it is the EU Strategic Framework on Health and Safety at Work 2021-2027. In Serbia, the Strategy for Safety and Health at Work (2018-2022) is no longer effective (Strategy on Safety and Health at Work in the Republic of Serbia with an Action Plan for its Implementation (2018-2022), 2018) and the strategy for the upcoming period (2023-2027) is currently being developed. The proposal strategy represents a starting point for the analysis of strategic goals, measures and activities for the next period.

EUROPEAN LEGISLATION

In scientific and professional circles, as well as in the general public, the commitment of the European Union towards occupational safety and health is well known (Walters, 2021). This is supported by the existence of the European Agency for Safety and Health at Work as a special organization within the European Union whose exclusive competence is occupational safety and health. Their key activities are the healthy workplace campaigns, Online Interactive Risk Assessment (OiRA) project, the ESENER survey, OSHwiki — a collaborative online encyclopedia of accurate and reliable information on OSH, foresight projects, OSH overviews, etc. (OSHA, 2023).

Considering the EU legislation in the field of occupational safety and health, the literature usually emphasizes the Framework Directive 89/391/EEC (1989), which establishes the basic principles for improving occupational safety and health in all sectors. In addition, the European Union has adopted a number of directives and other documents that establish standards for safety and health at work.

The European Union established its strategic goals in the field of occupational safety and health in a special document - the EU Strategic Framework on Health and Safety at Work 2021-2027 (2021). Already in its introductory provisions, it is pointed out that the EU occupational safety and health legislation is essential to protect the health and safety of the almost 170 million workers in the EU. Protecting people from occupational health and safety hazards is crucial for achieving sustained decent working conditions for all workers. It has made it possible to reduce health risks at work and to improve OSH standards throughout the EU and across sectors. The 2021-2027 OSH Framework determines the key priorities and actions required for improving workers' health and safety over the coming years in the context of the post-pandemic world, marked with green and digital transitions, economic and demographic challenges and the changing notion of a traditional workplace environment.

The analysis of the current situation in the field of occupational safety and health in the European Union has shown that the last decades have brought significant progress in occupational safety and health. Fatal accidents at work in the EU decreased by about 70% between 1994 and 2018. Despite this progress, there were still over 3,300 fatal accidents and 3.1 million non-fatal accidents in the EU and over 200,000 workers die each year from work-related illnesses. Such statistics were one of the main reasons for innovating strategic goals.

Therefore, the Strategic Framework focuses on three crosscutting key objectives for the coming years:

1. anticipating and managing change in the new world of work brought about by the green, digital and demographic transitions;
2. improving prevention of workplace accidents and illnesses;
3. increasing preparedness for any potential future health crises.

Anticipating and managing change can be achieved primarily through modernizing and simplifying EU OSH rules in the context of green and digital transitions and focusing on psychosocial risks. In order to achieve this goal, the European Union will modernize the occupational safety and health legislative framework related to digitalization by reviewing the Workplaces Directive and the Display Screen Equipment Directive, preparing a non-legislative EU-level initiative related to mental health at work that assesses emerging issues related to workers' mental health and puts forward guidance for action, develop the analytical basis, e-tools and guidance for risk assessments related to green and digital jobs and processes, including in particular psychosocial and ergonomic risks, etc.

Improving the prevention of work-related diseases and accidents can be achieved by analysing the causes of work-related deaths, and hazardous substances, promoting health at work and the concept of a workplace for all. To do this the European Union will update the EU rules on hazardous substances to combat cancer, reproductive, and respiratory diseases, promote a 'Vision Zero' approach to work-related deaths, produce an occupational safety and health overview of the health and care sector, support awareness raising on musculoskeletal disorders, cancer and mental health as well as workplace harassment and gender bias, etc.

Increasing preparedness - responding rapidly to threats - means that the Commission will develop EU OSH emergency procedures and guidance to allow for measures to be rapidly deployed in potential health crises, develop guidance for labour inspectors on assessing the quality of risk assessments and risk-management measures under the Biological Agents Directive, etc (EU Strategic Framework on Health and Safety at Work 2021-2027, 2021). This aim can be achieved by undertaking numerous activities such as launching an in-depth assessment of the effects of the pandemic and the efficiency of the EU and national OSH frameworks to develop emergency procedures and guidance for the rapid deployment, implementing and monitoring measures in potential future health crises, in close cooperation with public-health actors.

The implementation of these three objectives will be underpinned by: social dialogue, strengthening of the evidence base, strengthening of enforcement, awareness raising and funding. The Strategic Framework itself will be underpinned by a strengthened evidence base, strong social dialogue, mobilized funding, improved enforcement and awareness raising.

NATIONAL LEGISLATION

Each member state of the European Union has its own national legislation whereby European standards are implemented, taking into consideration the specific conditions of each state (Schmitz-Felten & Lieck, 2018). This allows the regulations to be adapted to the national culture, industry and work environment. Even though Serbia is not an EU member, it harmonizes its legislation with European regulations, including the Framework. It is important since the preparation and adoption of the Serbian Strategy on Safety and Health at Work for the period 2023-2027 is in progress.

The analysis of the current situation in occupational safety and health shows certain trends that should be considered during strategic planning. For example, Table 1 shows an overview of injuries at work according to their severity, where it can be seen that in the last 5 years, there has been no clear trend in the number of injuries on an annual level (Proposal Strategy on Safety and Health at Work in the Republic of Serbia with an Action Plan for its Implementation (2023-2027), 2023). This applies to all types of injuries. Even though initially such statistical results should not cause any concern, they nevertheless indicate that the number of injuries is not decreasing, which is the first and fundamental strategic goal in occupational safety and health in Serbia.

Table 1. Overview of injury severity (fatal, severe and minor)

Injury Severity	2018*	2019	2020	2021	2022
Fatal injuries at work	7	14	11	12	11
Severe injuries at work	788	1233	1226	1289	1 127
Severe injuries during the journey to or from work	522	597	435	487	596
Minor injuries	9087	11462	8623	9487	10 958
Total:	10404	13306	10295	11275	12692

Source: Administration for Occupational Safety and Health

There is a significant increase in the number of fatal and severe injuries at work in the construction industry (Proposal Strategy on Safety and Health at Work in the Republic of Serbia with an Action Plan for its Implementation (2023-2027), 2023), which provides a clear guideline that the new strategy should treat this issue seriously (Mijailović, Ilić Petković, 2022). This is supported by the analysis of the causes of workplace injuries, where the most prevalent ones are losing control over a machine, means of transport or when handling equipment, hand tools, objects and animals, as well as slips, trips and falls. Construction workers of various profiles - rebar workers, carpenters, masons, car mechanics, electricians, locksmiths, etc. - are particularly at risk.

Considering these and other data, the Proposal strategy for the next period defines the strategic goals in the field of occupational safety and health in the coming period (Proposal Strategy on Safety and Health at Work in the Republic of Serbia with an Action Plan for its Implementation (2023-2027), 2023). The overall goal of the Strategy is to improve occupational safety and health and preserve the health of the working population, that is, to improve working conditions in order to prevent injuries at work, occupational diseases and work-related diseases, minimize them, and eliminate or reduce occupational risks. The Strategy aims to reduce the number of work-related injuries in the Republic of Serbia by 5% in the period of its implementation, compared to the total number of work-related injuries for the previous five-year period of the Strategy's implementation, according to records kept by the Labour Inspectorate.

Specific goals of the Strategy are:

1. to reduce the number of work-related injuries and occupational diseases by minimizing risks related to workplaces and work environment,
2. to promote the culture of prevention in the field of occupational safety and health (raising awareness and informing the public),
3. to improve the administrative capacity of the Labor Inspectorate and the Administration for Occupational Safety and Health,
4. to introduce electronic records on work-related injuries.

There is a series of measures that are to be implemented in order to achieve these specific goals (Proposal Strategy on Safety and Health at Work in the Republic of Serbia with an Action Plan for its Implementation (2023-2027), 2023). For the first goal, which is to reduce the number of work-related injuries and occupational diseases by minimizing risks related to workplaces and the work environment, the measures are: the development of guidelines for the implementation of safety and health measures at work, improvement of checklists, analysis of the entrepreneur and company sector that is engaged in occupational safety and health jobs and improvement of supervision. In order to promote the culture of prevention in the field of safety and health at work and in the field of labour relations, the measures are: raising awareness and informing the public and interested parties, education and training, and social dialogue. For the third goal, the improvement of the administrative capacity of the Labour Inspectorate and the Administration for Occupational Safety and Health, the measures are: improvement of the legal framework for occupational safety and health, improvement of the institute for occupational injury and occupational disease insurance, analysis of the data from the Labour Inspectorate according to the types of subjects for the purpose of supervision based on risk analysis - risk-based assessment, improving the capacity of the Labour Inspectorate. For the realization of the fourth special goal, the improvement of records on work-related injuries, there is one measure - the introduction of a single register of work-related injuries.

All these measures have been elaborated in detail through specific activities stated in the proposal of the action plan. The principal body in charge of the activity, partners, deadline for implementation and financing are provided for each activity. Those activities are, for example, the preparation and adoption of by-laws based on the newly adopted Law on Occupational Safety and Health (2023), the adoption of the law on insurance against occupational injuries and occupational diseases, development of the application for the single register of work-related injuries and training for its implementation, etc.

CONCLUSION

The strategic directions for the development of the occupational health and safety system significantly affect the sustainability of organizations. European and national legislation plays a key role in guiding these directions and their proper implementation brings numerous benefits to organizations (employers), employees and society as a whole (Paula, 2019; Lee et al., 2019).

Based on the analysis we conducted, several conclusions can be drawn. Firstly, both the European Union and the Republic of Serbia have their own policies and institutions in occupational safety and health. It is important to legally regulate safety and health at work on an international level, either regionally (the European Union) or globally (International Labour Organization), because this achieves the harmonization of the rights and obligations of all relevant subjects of occupational safety and health systems in the member states. This is the way to create international labour standards that are adhered to by almost all countries of the world, including Serbia.

Furthermore, as part of international and national occupational health and safety policies, strategic documents should be adopted and continuously innovated, which, based on previous research and analysis, set the course of action for the next period. In the European Union, such a document is the EU Strategic Framework on Health and Safety at Work adopted for the period 2021-2027. This document aims at mobilizing EU institutions, member states, social partners and other relevant stakeholders around common priorities on workers' health and safety protection. It applies to all relevant parties dealing with health and safety at work (national administrations including labour inspectorates, employers, workers, and other relevant OSH actors) and creates a framework for action, cooperation and exchange (EU Strategic Framework on Health and Safety at Work 2021-2027, 2021).

Following the principle of strategic planning, the Republic of Serbia adopted its own occupational safety and health strategies. Currently, the development and adoption of the Strategy for the period 2023-2027 is in progress. Considering its draft, this document is rooted in previous documents and follows their strategic objectives. This is a good way to achieve continuity in the creation and implementation of the national occupational safety and health policy since a significant part of the specific goals (e.g. reducing the number of work-related injuries and occupational diseases by minimizing risks related to workplaces and work environment) can be achieved only through persistent state policy.

All of the above points to one general conclusion - the European Union and the Republic of Serbia determine their strategic directions for the development of the occupational safety and health system, which are mutually harmonized to a significant extent. On the basis of these documents, decisive efforts should be made to turn the defined goals into reality, which requires the support and activity of all subjects in the occupational safety and health system.

ACKNOWLEDGEMENTS

This research was funded by the Ministry of Science, Technological Development and Innovation of the Republic of Serbia, Contract on the realization and financing of scientific research work of the scientific research organization in 2023 number 451-03-47/2023-01/ 200148.

REFERENCES

Council Directive 89/391/EEC on the Introduction of Measures to Encourage Improvements in the Safety and Health of Workers at Work. (1989). https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=celex%3A31989L0391

EU Strategic Framework on Health and Safety at Work 2021-2027. (2021). https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52021DC0323&qid=1626089672913#PP1Contents

EU-OSHA. (2022). OSHwiki: Strategic Planning. European Agency for Safety and Health at Work.

Ilić Petković, A. (2020). Legal Fundamentals of Safety. Faculty of Occupational Safety in Niš.

Ilić Petković, A. (2022). Social and Legal Protection of Employees Against Workplace Injuries and Occupational Diseases in the Legal System of Serbia. Facta Universitatis, Working And Living Environmental Protection, 19(2), 75-84.

Law on Occupational Safety and Health, "Official Gazette of the Republic of Serbia", No. 35/23.

Lee, J. at al. (2019). A Systematic Review of the Safety Climate Intervention Literature: Past Trends and Future Directions. Journal of Occupational Health Psychology, 24(1), 66-91.

Mijailović, I. & Ilić Petković, A. (2022). Protection of Employees in Construction Industry – in Anticipation of the New Law on Occupational Safety and Health. In Nikolić, V., Stojiljković, E. (Eds.), Proceedings of The 19th International Conference "Man and Working Environment" (pp. 111-114). Faculty of Occupational Safety.

OSHA. (2023). What We Do. https://osha.europa.eu/en/about-eu-osha/what-we-do

Paula, N. (2019). A Comparison Study of the Romanian Occupational Safety and Health Strategy with Other European Countries' Strategy. In Proceedings of the 9th International Conference on Manufacturing Science and Education – MSE 2019 "Trends in New Industrial Revolution" (pp. 12021-12029). MATEC Web of Conferences.

Proposal Strategy on Safety and Health at Work in the Republic of Serbia with an Action Plan for its Implementation (2023-2027).

Schmitz-Felten, E. & Lieck, L. (2019). National Strategies in the Field of Occupational Safety and Health in the EU. European Agency for Safety and Health at Work.

Strategy on Safety and Health at Work in the Republic of Serbia with an Action Plan for its Implementation (2018-2022), "Official Gazette of the Republic of Serbia", No. 96/18.

Walters, D. (2021). Securing Compliance: Some Lessons for EU Strategy on Occupational Health and Safety. European Trade Union Institute.

20th International Conference Man and Working Environment
SEMSIE
Safety Engineering & Management – Science, Industry, Education

www.znrfak.ni.ac.rs/semsie

MILIŠA TODOROVIĆ[1]
TAMARA RAĐENOVIĆ[2]
DEJAN VASOVIĆ[3]
ŽARKO VRANJANAC[4]

[1] University of Zenica, Faculty of Metallurgy, Bosnia and Hercegovina

[2,3] University of Niš, Faculty of Occupational Safety, Serbia

[4] Innovation Center, University of Niš

[1]*milisa.todorovic@unze.ba*
[2]*tamara.radjenovic@znrfak.ni.ac.rs*
[3]*dejan.vasovic@znrfak.ni.ac.rs*
[4]*zarevranjanac@gmail.com*

CHALLENGES IN THE IMPLEMENTATION OF THE NEW LAW ON OCCUPATIONAL SAFETY AND HEALTH

Abstract: *We are witnesses to the great expansion of technical and technological development. New technical and technological solutions contribute to creating a safer environment for all workers. As a consequence of such an environment, there arises the need to harmonize legal solutions with new technical and technological solutions. Professional practice has identified certain shortcomings in the legal solutions during the implementation of the previous Law on Occupational Safety and Health, which also served as an incentive for the adoption of new legal solutions. The key question is whether the new legal solutions have resolved all or at least most of the dilemmas that existed in the enforcement of the old Law on Occupational Safety and Health. The question is to what extent the new solutions are clear and applicable in everyday life and work of those responsible for occupational safety and health. Therefore, there is a need for a deeper and more comprehensive analysis of existing legal solutions, problems in implementation, and proposals that could improve or help towards a clearer understanding of the rights, obligations, and responsibilities of all participants – the state authorities, employers, and employees. The starting hypothesis of the study is that the current Law on Occupational Safety and Health, despite all its ambiguities, represents a good basis for improving the position and rights of workers. Descriptive methodology was used in the study, along with the review of available literature, both domestic and foreign.*

Keywords: occupational safety and health, legal solutions, professional practice, responsibilities and obligations of employers

INTRODUCTION

In every social system, from ancient times to the present day, various types of social relations have developed. All these relations make up a unique system of social relations. Observing the development of social relations throughout history, it can be concluded that at a certain stage of development, there arises the need to define specific legal regulations that will govern these relations. The need for the legal regulation of labour relations and occupational safety arises according to the level of development of society itself. Thus, in the territories of former Yugoslavia, regulations such as the Law on Labour Inspection from 1921, the Law on the Protection of Workers from 1922, and the Law on Social Insurance of Workers, among others, were enacted. With the introduction of self-governance, two basic laws emerged – on labour relations and on public servants (Todorović et al., 2014).

Occupational safety and health represent a very significant aspect of social life. It is clear that humans have always strived to carry out their activities in a way that will ensure their safety. Workplace injuries are determined by an imbalance between unfavourable working conditions and insufficient understanding of occupational safety and health by both employers and employees. Unfavourable working conditions encompass a broad spectrum of biological, mechanical, and physical exposures to the working environment, psychological demands related to specific tasks, the work environment, issues related to the handling and use of materials, tools, and machinery, organizational factors, as well as pressure from management to implement the devised plans and achieve the set production goals (Chau et al., 2007).

Occupational safety and health can also be defined as a set of technical, health, legal, psychological, pedagogical, and other activities and measures through which hazards and harmful effects are identified and measures are defined to prevent or reduce the possibility of workplace injuries. The emphasis is placed on creating working conditions in which the occurrence of workplace injuries is prevented or minimized.

The Statistical Office of the European Union (Eurostat) states that nearly 3% of the working population in the EU has experienced a workplace accident that resulted in absence longer than three days, which amounts to 83 million calendar days of sick leave (Eurostat, 2010).

How aware are our employers of the magnitude of the costs of workplace injuries and their impact on the

business competencies of the companies? The implementation of the provisions arising from the Law on Occupational Safety and Health entails the obligation of certain financial investments. Despite the fact that businessmen in practice often characterize expenditures for the field of occupational safety as costs, we believe that these are, in fact, investments. Prevention is the basis for proactive action of every organization. At the foundation of every prevention, the starting point is the fact that in the initial phase, certain financial resources need to be invested to gain positive benefits in the next phase (Todorović & Živković, 2013).

Unfortunately, the number of workplace injuries not decreasing is a clear indicator of the current state. Therein arises a significant dilemma: whether the legal solutions are sufficient and necessary conditions for creating a safer environment. The very realization that there is a problem in terms of the absence of a clear trend in reducing the number and severity of workplace injuries is probably good, because it opens up the possibilities to define activities that should help in finding the appropriate solution. The basis for examining the problem and making decisions is the need for the adoption of certain laws and bylaws, change of the safety culture, promotion of the role of occupational safety in the process of ensuring well-being and designation of benefits for all members of society through responsible politics and implementation of appropriate occupational safety measures. These are some of the questions we plan to address in this paper, with the desire to make a kind of a cross-section at one place, which could serve as a starting point for further activities in the process of creating safe working conditions.

Is the adoption of the Law on Occupational Safety and Health the solution to all problems or should it only be the starting point for further activities? To what extent is the Law itself the solution to all problems if there are no bylaws that should enable the implementation of the Law itself? Who educates engineers in the field of occupational safety and health and fire protection, and do we have enough of them? What is our safety culture like and how do we intend to change it? What is the role of each engineer in the field of occupational safety and health in the process of changing the awareness of each individual about their role and importance in the process of creating a safe environment? These are some of the questions we will try to answer in this paper. The fact is that there are no simple solutions and that every reader of this paper may have their own perspective in relation to the observed questions and dilemmas. Different perspectives and constructive thinking are always welcome in the process of acquiring valid attitudes and conclusions that should change our perception of the role of each of us in the process of creating a better future.

The organization of occupational safety encompasses the entire system of measures taken to prevent and eliminate potential hazards that endanger the lives and health of workers. There are subjective and objective factors that cause hazards and injuries at work. Subjective factors include non-compliance with occupational safety regulations, intentional non-use of protective equipment, insufficient expertise to perform tasks, the psychological state of workers, etc. Objective factors are the means of production, which are being improved to acquire such technical and functional characteristics that reduce the physical threat to the workers (Todorović, 2010).

The issue of safety culture is a very important one, and as long as we do not deal with the problem of occupational safety through the prism of values that determine how a worker behaves during the performance of defined work operations, it is difficult for us to expect better statistics regarding the number and severity of workplace injuries. Individual analyses of numerous cases of major accidents have found that safety culture has a very large impact on creating a safe work environment. It is a well-known fact that culture changes very slowly and with difficulty. Therefore, we must recognize it as a very important factor that increases the business competencies of each organization and actively manage its growth and development. Appropriate safety culture creates the basic prerequisites for long-term productivity and protection of the health of employees, which manifests itself in increasing competencies, both for employers and employees, as well as the state authorities. On the other hand, it creates conditions for a safer working environment for workers (Todorović & Živković, 2017).

LEGAL GROUNDS

Going back many years and centuries, numerous documents and artifacts confirm that the field of occupational safety and health has always been present in social life. Its significance varied from one period to another. Regardless of the period in question, it is clear that the status of workers has gradually improved over time. In the first phase, this was achieved by gradually organizing work in such a way as to reduce human effort and replace it wherever possible. The next phase is characterized by the creation of work tools whose constructive features reduce the likelihood of workplace injuries. The third period involves the gradual inclusion of all stakeholders of an organization in creating safer working conditions.

Today, in the time of intensive development of technology, there arises a dilemma concerning the role and significance of artificial intelligence in creating a safe work environment.

Each of these periods can be viewed from multiple angles and can be divided into several separate units. However, it was only with the development of the working class and the emergence of trade unions that the need arose to involve the state authorities in the relationship between employers and employees. Most countries in the Balkan region have adopted new laws regulating occupational safety and health, largely aligned with the normative acts of the EU, to which all countries in the region aspire. The law defines this field

while numerous bylaws (regulations, ordinances, etc.) specify all economic areas in more detail (Todorović & Živković, 2010). Concerning the legal basis, it is important to mention from the outset that Serbia indeed needs legal and sub-legal acts that will clearly define the rights and obligations of both employers and employees.

The general impression is that all previously enacted Laws on Occupational Safety and Health are in line with the EU directive dealing with this issue. What is a crucial prerequisite for implementing existing legal solutions? Bylaws. What is the situation concerning bylaws? A mere glance at the bylaws regulating individual economic activities unequivocally raises the question of their compatibility with the times we live in. In the Republic of Serbia, the Rulebook on Occupational Safety in Agriculture (Official Gazette of the SFRY, No. 34/68) is still in force. Which plant protection agents were used at the time, and which are used now? We are not sure that the solutions from 60 years ago are appropriate today. In the following sections, we will try to provide a brief overview of several interesting solutions from the new Law on Occupational Safety and Health.

The Law on Occupational Safety and Health was enacted in 2023 and published in the "Official Gazette of the Republic of Serbia", Number 35, from 29 April 2023 (Government of RS, 2023).

CHALLENGES IN THE IMPLEMENTATION OF THE CURRENT LAW ON OCCUPATIONAL SAFETY AND HEALTH IN THE REPUBLIC OF SERBIA

Before we look at the good aspects and solutions that could have been even better, we must acknowledge an important fact. The Law on Occupational Safety and Health that was in effect before the new law had certain shortcomings in its implementation, and it was due to be amended. The original Law on Occupational Safety and Health was passed in 2005 ("Official Gazette of the Republic of Serbia", no. 101/05) with an amendment in 2015 and 2017. The process of enacting a new law took a few years, and through various forms of public debates, different versions of the new Law on Occupational Safety and Health tried to reconcile often conflicting views of the experts and the responsible ministry. In the end, a new law has come into effect, and we are obligated to implement it.

- The first dilemma is the implementation of the law. In Article 11 of the new law, it is clearly defined that employers are obligated to organize their operations in accordance with this law within two years from the date of its enactment. Article 112 of the new law clearly states that from the day this law takes effect, the previous Law on Occupational Safety and Health ceases to apply ("Official Gazette of the Republic of Serbia", no. 101/05, 91/15, and 113/17 – other law). However, there is no clear answer to the question of when employers should adapt their operations to the changes in the law. Employers are left to the discretionary assessment of labour inspectors and their interpretation, which is certainly not a good solution. The Occupational Safety and Health Directorate, the body that prepared the new version of the Law on Occupational Safety and Health, has not yet given any opinions on the questions raised by both employers and labour inspectors themselves. For example, the new law defines the obligation to insure workers against workplace injuries and occupational diseases, and a penalty is prescribed for non-compliance with this obligation. According to Article 111 of the new Law, employers have a two-year deadline. Some inspectors think differently and order employers to immediately comply with this legal standard.
- What is certainly commendable is the clear definition in Article 3 that rights, obligations, and responsibilities related to occupational safety and health, as defined by this law, are further regulated by a collective agreement, safety and health regulations at work, or work regulations (hereinafter: general act), or employment contracts. In practice, this means that responsible persons, through the Regulations on Safety and Health at Work, can define the mechanism for daily monitoring of the implementation of safety measures, which has always been a serious problem. We believe that only by delegating responsibility to immediate managers, in terms of the obligation to control the implementation of safety measures at the relevant location, can conditions for safe work be created. The designated occupational safety and health officer cannot be solely responsible and in charge of organizing and implementing safety measures. These activities must also involve the immediate managers of each worker.
- In Article 4, item 21, we encounter a serious dilemma. There is a need to clearly define what the jobs with increased risk are (although here we could also pose interesting dilemmas, e.g. does every work at height have to be quantified as a job with increased risk? It is important to consider its frequency and make a final assessment). The dilemma relates to the term "driving vehicles"? Should every job where there is vehicle driving be declared as a job with increased risk? Today we are witnessing workers in numerous positions being required to use the company cars. Should all of them then be declared as jobs with increased risk? During the risk assessment, we must recognize the danger of "driving vehicles". We believe that it should have been clearly defined that jobs in which workers use passenger motor vehicles do not automatically have to be jobs with increased risk and that the risk assessor should consider certain factors before the final decision

(e.g. the number of kilometres travelled on a daily or monthly basis).

- A need has been recognized for the legal formalization of the terms "work from home" and "remote work". In practice, it is difficult to create the prerequisites to apply the defined norms. Article 44 of the Law states that when working from home and remotely, the employer is obligated to ensure safety and health at work in cooperation with the employee. The employer is required to establish conditions for safe and healthy work, equipment issued by the employer, define the work process related to the execution of tasks for which the employee is responsible, and prescribe preventive measures for safe and healthy work. How can an employer do all this if the workspace is not under their control and if the worker does not want to 'cooperate' on this issue with the employer? Does this mean that the employer should organize the inspection of working conditions and electrical installations among their employees? How will they fulfil their obligation to ensure safety and health at work if they do not organize these tests? One good definition is that the employer may, but is not required to, issue a Risk Assessment Act for working from home and remotely in written form with the participation of the employee. There are interesting solutions in practice where the employer creates specific checklists, and each worker working from home or remotely fills out the checklist and gives an assessment of whether the measures for safe work have been implemented in their workspace.
- According to Article 15 of the Law, the employer is obligated to inform as soon as possible all employees who are or may be exposed to serious, inevitable, and immediate danger about the present risks and the measures that have been or will be taken for protection. The employer is required to take measures and issue instructions to enable employees to cease work and/or immediately leave the workplace and go to a safe place in case of serious, inevitable, and immediate danger. No expert from practice could explain what the legislator intended with this provision.
- We will especially emphasize the solution from Article 27 of the Law concerning the issuance of work permits. Specifically, the legislator has defined that the employer is obligated to issue a work permit before commencing work at height, in depth, in confined spaces, in potentially explosive atmospheres, in an energy facility, with dangerous chemical materials, and in zones where there is serious, inevitable, or immediate danger or harm that could endanger the health of an employee. Through the Regulation on Occupational Safety and Health, the employer has already defined the obligation to monitor the daily implementation of safety and health measures at work. This obligation is assumed by the immediate supervisor of workers performing activities at that location. One of the solutions is the preparation of specific checklists which the appointed committee goes through and checks whether all the conditions have been met for the work to begin. In some situations, individual employers already have an established system for issuing permits through risk assessments for each risky activity. This is an excellent solution, which refocuses on what is important – supervision of the implementation measures of the immediate supervisor and participation of all responsible persons in risk assessment and definition of appropriate measures for safe work.
- The process of training rather than qualifying workers is thoroughly dealt with in the Law, and one of the innovations concerns the periodic review of worker training, which, according to new solutions, should be organized every 3 and not 4 years.
- For the manner of organizing occupational safety and health, there are no special dilemmas except that new titles are introduced for professional staff, according to their education: advisor (240 ECTS points in academic or applied studies in the field of technical and technological sciences and natural and mathematical sciences in the following fields: biological sciences, environmental sciences, physical sciences, and physicochemical and chemical sciences) or associate (180 ECTS points in the field of technical and technological sciences, natural and mathematical sciences, medical sciences, or social sciences and humanities).
- Another interesting solution is the one that defines the mechanisms of organizing occupational safety and health. Namely, in the activities from Article 48 of the Law, an employer who employs or hires from 251 to 500 employees is required to sign a full-time employment contract with at least two advisors for occupational safety and health, and an employer who employs or hires more than 500 employees is required to sign a full-time employment contract with at least three advisors for occupational safety and health. The situation is the same for the appointment of associates. Thus, a company that has 500 employees should have 3 professional staff members exactly like a company that has 5,000 employees in the same activities. A better solution should have been proposed somewhere, which would take into account not only the number of workers but also the number of locations where they work.
- The impending problem concerns Article 47 of the Law. Namely, the legislator defines that employers can perform occupational safety and health tasks from Article 50 of the Law themselves in retail trade, accommodation and food services, information and communication, financial activities and insurance activities, real

estate business, professional, scientific, innovative, administrative, and auxiliary service activities, mandatory social insurance, education, arts, entertainment, and recreation, and other service activities if they have up to 20 employees. A similar solution was also included in the previous version of the Law. However, the next paragraph defines that the employer is obligated to take a professional exam for occupational safety and health, prescribed by the minister responsible for labour affairs, and is not obligated to have a prescribed license. For example, if an employer engaged in the sale of textile goods has one employee, the said employer is obligated to pass a professional exam or contract a licensed agency. We believe that this solution is not good at all, and there is no logical explanation, at least not available to us, that justifies this position. Regarding this obligation, we could consider that there is a possibility that workers in this category are mandated to attend a seminar where they will be introduced to their rights and obligations, and only then may this solution make sense somewhere.

- There is also a commendable solution that defines the obligation of advisers and associates to educate themselves, attend seminars, and renew the license they receive. It is now clearly defined that the employer is obligated to provide continuous professional development in the field of occupational safety and health to the employee assigned to perform these tasks. Continuous improvement of knowledge for occupational safety and health advisers, associates, coordinators during the project phase, coordinators during the implementation phase, responsible persons for work equipment inspection and verification and for electrical and lightning installation reviews and testing, responsible persons for work conditions inspection, chemical and physical harms (except ionizing radiation), and microclimate and lighting, and responsible persons for work environment biohazard control is a requirement for license renewal. So far, the professional exam has been passed by many professionals who never attend seminars, professional conferences, etc. However, the full effect of this provision largely depends on who will have the right to organize this education and its content. If these activities are designed in such a way that practical experience is not exchanged, that questions are not asked and concrete answers are not given, that there is no labour inspector at each education event of this type who will give a decisive interpretation of a situation, that the causes of serious and fatal injuries at work at the level of a particular activity are not analysed, then significant progress in creating a safe work environment can hardly be expected. Incident investigation is a process carried out to prevent incidents and as such includes collecting and analysing information, drawing conclusions, identifying the causes of the incident, and, when appropriate, making safety recommendations (corrective measures). The investigation is carried out for incidents that have led to work-related injuries as well as for incidents that have not led to work-related injuries. One of the most important steps in the process of determining the causes that have led to work-related injuries is conducting a proper incident investigation (Helvida et al., 2019).
- The issue of employee representatives has not been properly resolved in this version of the Law either. The legislator clearly defines that employees have the right to elect one or more representatives for occupational safety and health. That is, they have the *right* but not the *obligation* to appoint a person who will defend their interests in relation to the employer and the responsible person for occupational safety and health.
- An excellent solution is proposed in the segment of records in the field of occupational safety and health. The employer is obligated to keep records of employees trained for safe and healthy work in accordance with the Law or a copy at the headquarters or other business premises or another location, depending on where the employees work. The records stipulated in paragraph 1 may be kept electronically, except for records dealing with proof of worker training for safe work and any medical examinations.
- The issue of reporting work-related injuries and occupational diseases also raises certain dilemmas. Specifically, the legislator defines that the employer is obligated to immediately, no later than within 24 hours of occurrence, orally, in written form, or electronically report to the competent labour inspection and the competent authority for internal affairs any fatal, collective, or serious injury at work, as well as any dangerous occurrence that could endanger the safety and health of employees. The next paragraph also stipulates that the employer is obligated to immediately, and no later than within five working days from the day of occurrence, orally, in written form, or electronically report to the competent labour inspection a minor injury at work due to which the employee is unable to work for more than three days. How can an occupational safety and health officer assess whether a work-related injury will be categorized as minor or major? If they make a poor assessment, does that mean that they will potentially face consequences? We believe that this is not a good solution. The introduction of an injury registry is stipulated in the Law, and it is necessary to harmonize all the details around this issue as soon as possible and create the preconditions for all activities that will facilitate electronic issuance and processing of injury lists.

- Insurance against work-related injuries was also an obligation of the employer in the old law. The problem was that there were no penal norms that would 'force' employers to insure workers against work-related injuries. The new Law introduces penal measures, and in addition to insurance against work-related injuries, the employer's obligation is to insure workers against occupational diseases. What is not good about this concept is the implementation by insurance companies. Unfortunately, insurance companies offer their product without considering the actual circumstances of that employer regarding occupational safety and health. It would be logical for the offer to be made based on the number of lost days and the number of injuries at work, and not just based on the company's activity. In this way, companies that take care of the safety of their workers and have a small number of injuries pay the same price as companies that do not take care of the safety of their workers. We hope that this segment will also ensure fairer treatment through the implementation of the Law.
- It is important to note that the Law finally defines the obligation of periodic inspections of electrical installations, which has often posed a dilemma in practice. It is now clearly defined that these tests must be organized every three years.

CONCLUSION

In conclusion, the mentioned legislative solutions provide a good foundation for creating safer working conditions. We must start from the fact that these legislative solutions still represent a significant step forward from the previous ones. This does not mean that these solutions are ideal. Occupational safety and health is an ongoing activity, and many developed countries are changing their laws due to changes in technology and work technology. The state authorities should primarily create a clear legal framework for the legal regulation of occupational safety and health. In the next phase, through constant education of labour inspectors and persons responsible for occupational safety and health, preconditions will be created for changing the way of thinking about this field. By applying this approach, we cannot expect quick results, but the basis of any strategy is based on long-term measures and effects that create preconditions for optimizing all technological processes and units in the long run. The Faculty of Occupational Safety, as a higher education institution that organizes and implements study programmes for occupational safety and fire protection, has a major role and responsibility in the process of 'producing' professional staff who will actively participate in the process of improving working conditions in the future.

ACKNOWLEDGEMENTS

This research was supported by the Ministry of Education, Science and Technological Development of the Republic of Serbia (Agreement No. 451-03-47/2023-01/200148).

REFERENCES

Chau N., Gauchard, G., Dehaene, D., Benamghar, L., Touron, C., Perrin, P., & Mur, J. (2007). Contributions of occupational hazards and human factors in occupational injuries and their associations with job, age and type of injuries in railway workers. *International Archives of Occupational and Environmental Health, 80*(6), 517-525.

Eurostat (2010). *Health and safety at work in Europe (1999-2007) – A statistical portrait.* Retrieved on 4 March 2018 from: http://ec.europa.eu/eurostat/documents/3217494/5718905/KS-31-09-290-EN.PDF/88eef9f7-c229-40de-b1cd-43126bc4a946

Helvida, A., Hadžić, S., & Todorović, M. (2019). *Uviđaj incidenata i utvrđivanje korjenitih uzroka*, XVI Međunarodna konferencija za bezbednost i zdravlje na radu, 151-159.

Government of RS. (2023, 29 April). Law on Occupational Safety and Health. "Official Gazette of the Republic of Serbia", Number 35.

Todorović, M. (2010). *Značaj organizacije rada u cilju smanjenja broja i težine povreda na radu*. "50 godina organizovane zaštite na radu u Srbiji", Niš, 313-320.

Todorović, M., & Živković, S. (2010). Organizational culture in the function of occupational health care at work. *International conference – Life cycle engineering and management ICDQM – 2010*, Proceedings, 155-161.

Todorović, M., & Živković, S. (2013). Ekonomske implikacije primene Zakona o bezbednosti i zdravlja na radu. *16. Međunarodna konferencija "Upravljanje kvalitetom i pouzdanošću", ICDQM – 2013*, 357-362.

Todorović, M., & Živković, S. (2017). Analysis of occupational injuries in the Republic of Serbia. *Enhancing micro and macro competitiveness – possibilities and limitations*, University of Niš, Faculty of Economics in Niš, 136-153.

Todorović, M., Živković, S., & Spremo, G. (2014). Uloga države u procesu stvaranja bezbednih uslova za rad. *17. Međunarodna konferencija ICDQM – 2014*, pp. 416-421.

20th International Conference Man and Working Environment
SEMSIE
Safety Engineering & Management – Science, Industry, Education

www.znrfak.ni.ac.rs/semsie

ANĐELA JEVTIĆ[1]
VLADIMIR STANKOVIĆ[2]
DEJAN RISTIĆ[3]
DUŠAN DŽONIĆ[4]

[1,2,3]University of Niš,
Faculty of Occupational Safety
[4]Elixir Prahovo

[1]*andjela.jevtic@znrfak.ni.ac.rs*
[2]*vladimir.stankovic@znrfak.ni.ac.rs*
[3]*dejan.ristic@znrfak.ni.ac.rs*
[4]*Dusan.Dzonic@Elixirprahovo.rs*

SMART FIRE ALARM SYSTEMS

Abstract: *The risk of a fire outbreak and spread is reduced by using a fire alarm system at the earliest stage. Designing a fire alarm system using new technologies is a challenge, given the fact that the system needs to meet many different requirements. It depends on the technological and work process, the structural and architectural characteristics of the protected building, the influence of environmental factors, etc. Fire detection at the earliest stage is directly related to the system's sensitivity to the monitored combustion products, but on the other hand, this increases the risk of false alarms, which affects the reliability of the whole system. This paper presents the latest solutions in the field of fire detection, which can be used to overcome or mitigate the said problem through the use of the so-called smart fire detectors. The paper describes the operating principles, advantages, and disadvantages of different types of smart detectors compared to standard types of fire detectors. Considering that smart fire detectors can make a decision about the alarm state independently, without the need to communicate with the control panel, the paper also reviews the use of distributed intelligence.*

Keywords: fire alarm systems, smart detectors, sensors, distributed intelligence

INTRODUCTION

The disadvantages of current fire detection systems include longer response time, lack of flame-retardant functions, and inapplicability in outdoor environments. Overcoming the mentioned deficiencies is possible through the development and use of fire alarm detectors of the new generation, the so-called smart detectors. These detectors should meet several different requirements. Most importantly, they must have a shorter response time or an early warning signal below the ignition temperature of most combustible materials, maintain structural stability during a fire, and be able to operate in an outdoor environment (Lv et al., 2022).

Most of these requirements can be met by using materials sensitive to temperature changes, such as graphene oxide (GO), MXene, etc. The improvement of the characteristics of these materials is achieved by combining them with other compounds. For example, the stability of a material during a fire can be improved by adding flame retardants. It is also possible to improve the sensitivity of the sensor, adapt it to function in different environments, etc.

Fabrication approaches of smart detectors, as well as the forms in which they exist, are different. Some of the methods used include coating (dip-, drop-, spray-, and brush-coating), casting, layer-by-layer (LBL) assembly, freeze drying, evaporation-induced self-assembly, and other methods (Lv et al., 2022; He et al., 2022).

In this paper, different operating principles of the smart fire alarm system are presented: resistance change-based FASs (Fire Alarm Systems), voltage change-based FASs, shape change- / phase change-based FASs, and color change-based FASs. The paper also describes the communication of these systems, the application of distributed intelligence, and wireless technologies.

RESISTANCE CHANGE-BASED FASs

The warning signal of the smart fire alarm system can be activated by a change in the electrical resistance of the material due to an increase in the external temperature. Materials that are electrically insulated at normal temperatures are used for this type of warning. Due to the increase in temperature, there is a change in the electrical resistance of the material, which changes from an electrically insulating to a conductive state. The decrease in electrical resistance occurs suddenly, which enables the passage of electrical current and the activation of a rapid alarm signal (Lv et al., 2022; He et al., 2022).

A typical representative of materials with these properties is graphene oxide (GO), which has low electrical conductivity. As a result of exposure to high temperature, functional groups containing oxygen (carboxyl, epoxy, and hydroxyl groups) decompose, yielding thermally reduced graphene oxide (rGO), as shown in Figure 1. This leads to the transformation of GO from an electrically insulating to an electrically conductive state (Khan et al., 2022). Due to high electron mobility and good thermal conductivity, GO can be used as a highly effective sensor for fire alarms (Wei et al., 2022). However, it should be noted that GO is thermally unstable, which is why it easily decomposes at high temperatures and burns completely in the event of a fire, resulting in a short alarm time. In addition, GO sensors are conductive only when a sufficient number of oxygen groups are decomposed,

which requires either high temperature or a long period of time at lower temperatures (He et al., 2022).

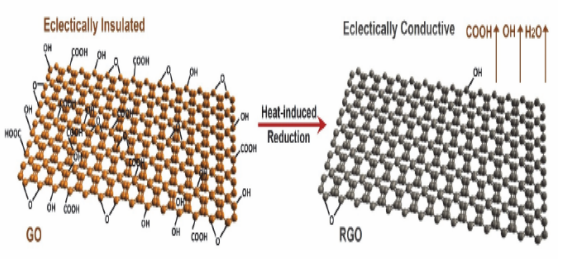


Figure 1. *Thermally induced reduction of GO* (Khan et al., 2022)

The said shortcomings of GO can be overcome by adding different substrates, which improve the characteristics of the sensor. Improving the thermal stability of GO is possible thanks to different types of molecular modification – a covalent bond, a hydrogen bond, π-π interaction, and electrostatic interaction. For this purpose, numerous fire retardants are used, such as hexachlorocyclotriphosphazene (HCCP), L-ascorbic acid (LAA), silicone, silane, or phytic, phosphoric, boric, and tannic acid, etc. In addition to molecular modification, intumescent flame retardant systems and flame retardant additives (organic and inorganic) are also used to improve the thermal stability of GO. The best results are achieved by combining two or more fire retardancy strategies – a synergistic flame retardancy (He et al., 2022). For example, the synergistic interaction between GO molecules, phosphorylated-cellulose nanofibrils (P-CNFs), and tannic acid (TA) resulted in a mother-of-pearl-like structure with good mechanical properties, excellent flame resistance, and exceptional sensitivity, which shortens the alarm time (Cao et al., 2022). In the reaction of silane molecules and GO in an aqueous solution, hydrolysis and condensation produce silane-GO papers, which have excellent flame resistance and better thermal stability compared to pure GO. The silane-GO papers are excellent sensors, considering the response time for flame detection of 1.6 s (Huang et al., 2018).

Early warning of increased environmental temperature, structural stability during a fire, and stable performance are characteristics of the graphene/nitrocellulose alarm sensor. The activation temperature and response time of this sensor can be adjusted by the ratio of graphene to nitrocellulose (NC), so there is a wide range of application possibilities. Figures 2a and 2b show the change in electrical resistance as a function of temperature. The figures also show that the response temperature depends on the proportion of NC in the composite, so that a higher content of NC causes higher response temperatures (Wei et al., 2022).

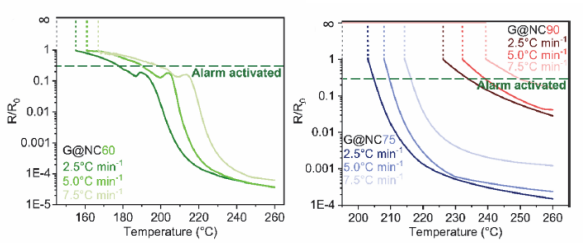


Figure 2. *(a) Electrical resistance change of graphene/NC with 60% of NC (G@NC60) at various heating rates from 30 to 260°C; (b) Electrical resistance change of graphene/NC with 75% of NC (G@NC75) and graphene/NC with 90% of NC (G@NC90) at various heating rates from 30 to 260°C (Wei et al., 2022)*

Graphene/NC sensor with 90% NC reacts at a temperature of 232°C, while the response time is 4.4 s. Sensors with lower NC content (60% and 75%) have lower response temperatures (161°C and 208°C, respectively) and faster response times (1.6 s and 1.9 s, respectively). In addition, the sensor can work in the form of paint, wallpaper, and other composites (Wei et al., 2022).

The detector in the form of wallpaper is made on the basis of ultralong hydroxyapatite nanowires (HNs) and GO. HNs is suitable as a substrate for the detector in the form of a wallpaper due to its good mechanical properties, high thermal stability, and fire resistance. GO is used as a thermosensitive sensor in these wallpapers, and polydopamine is added to improve sensitivity and fire resistance. The characteristics of GO modified with polydopamine (PGO) are low reaction temperature (126.9°C), fast response time (2 s) and stability during a fire (at least 5 minutes). These materials are environmentally friendly and thus suitable for use in interior decoration (Chen et al., 2018).

VOLTAGE CHANGE-BASED FASs

Materials that have thermoelectric properties are used for the design of sensors based on the principle of voltage change. Thermoelectric sensors initiate an alarm signal by converting thermal energy into electricity, which is known as the Seebeck effect. The Seebeck effect is the occurrence of voltage generation between two different conductors or semiconductors, due to the appearance of a temperature difference (Figure 3). Therefore, the magnitude of this voltage, better known as thermal voltage, depends on the temperature gradient (Lv et al., 2022; He et al., 2022; Zhu et al., 2023).

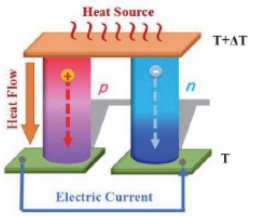


Figure 3. *Seebeck effect (Zhu et al., 2023)*

Good thermoelectric properties, high electrical conductivity, and excellent flame retardancy are the characteristics of MXene – a material that can be used as a smart sensor (He et al., 2022).

MXenes belong to a class of two-dimensional inorganic compounds, consisting of thin layers of carbides, nitrides, or carbonitrides. The general formula of MXene can be written as: $M_{n+1}X_nT_x$, where (Zhu et al., 2023):

M – transition metal;

X – C and/or N;

Tx – functional group (-O; -OH; -F);

n – ranging from 1 to 4.

In addition to the high thermal stability of MXene materials, carbon, which prevents the exchange of heat and mass, and titanium dioxide (TiO_2), whose catalytic effect reduces gaseous products, are also formed during their combustion (He et al., 2022). The advantage of these sensors is that they can be used multiple times and generate electrical signals without an external power source (Lv et al., 2022).

One of the main disadvantages of MXene is its instability in an oxygen-rich atmosphere, which negatively affects the electrical conductivity of these materials. The combination of MXene sheets with renewable lignocellulose nanofibrils (LCNF) molecules to design a sandwich-like fire alarm wallpaper via a vacuum-assisted alternate self-assembly method solves the mentioned problem. In addition to the instability of MXene, the flammability of LCNF is also an issue, which is resolved by using intumescent flame retardants (IFRs). In this case, ammonium polyphosphate (APP) was used as IFR. The characteristics of a sandwich-like fire alarm wallpaper based on MXene, LCNF, and APP include excellent fire resistance, very fast alarm response (0.32 s), and a continuous alarm signal (about 3,000 s); it should also be noted that this structure is environmentally friendly (Ma et al., 2023).

Based on MXene and polyimide, a mechanically robust and composite aerogel (PI@MXene) was made via dip-coating. PI@MXene has exceptional temperature sensitivity, good fire resistance and fire retardancy, and an alarm response that is initiated within 5 s. The operation of this sensor is based on the previously described Seebeck effect, thanks to the linear relationship between the thermoelectric voltage and the temperature difference, which was demonstrated by PI@MXene (Figure 4) (Jiang et al., 2022).

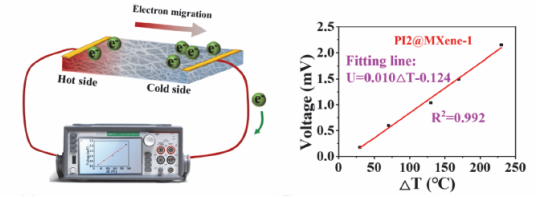


Figure 4. *The working principle of the PI@MXene sensor and the linear relationship between the thermoelectric voltage and the temperature difference (Jiang et al., 2022)*

As shown in Figure 4, with the appearance of a temperature difference between the ends of the PI@MXene composite, there is a movement of electrons from the hot side to the cold side, which generates a potential difference. By increasing the temperature difference from 25°C to 225°C, the thermoelectric voltage gradually increases to about 2 mV. It is clear that the magnitude of this voltage depends on the temperature gradient, so in a practical case of a fire, a large temperature difference could generate a fire warning signal (Jiang et al., 2022).

SHAPE/PHASE CHANGE-BASED FASs

Shape change-based FASs mainly consist of two components – a polymer whose shape changes with temperature changes and a conductor. These sensors keep the circuit open at room temperature because the conductor is not connected to the electrical circuit. Exposure to high temperatures and changes in the shape of the polymer lead to the closing of the circuit, the formation of a conductive path, and the appearance of an alarm signal (Figure 5) (He et al., 2022).

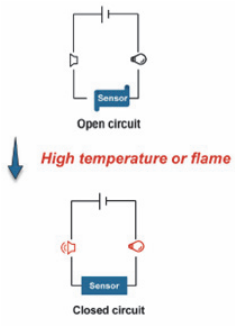


Figure 5. *Shape change-based FAS (He et al., 2022)*

With phase change materials (PCMs), a change in mechanical state occurs when the ambient temperature is above the phase change point. This type of sensor is designed by connecting face-to-face assembled micro-structured gels with an alarm lamp and a power source. As the ambient temperature increases, the gel softens, and the contact surface gradually increases, which activates the alarm signal (Lv et al., 2022). Shape memory polymers (SMPs) function in a similar way to PCMs, with the difference that SMPs can recover their initial shape under the influence of some external stimulation (temperature, light, electric and magnetic fields, chemicals). This ability is called the shape memory effect (SME) (Lv et al., 2022; He et al., 2022; Mishra & Sharma, 2020). Shape-changing polymers used for smart FASs are polyurethane, polycaprolactone, silicon rubber, and poly(ethylene terephthalate) (He et al., 2022). For example, shape-memory thermoplastic polyurethane (SMPU) comprises a physical crosslinking phase and a thermal transition phase, whose glass transition temperature (Tg) can be effortlessly tuned, demonstrating that the response temperature can be easily balanced on a fire alarm sensor. MXene, whose characteristics have been discussed, can serve as a physical barrier for polymers to resist fire. The combination of SMPU and MXene

resulted in a fire-resistant paper, where SMPU plays the role of a thermosensitive sensor, and MXene functions as a conductive and fireproof layer. The SMPU/MXene paper can be effortlessly modified to different shapes with high adaptability and can recoup to its original shape inside 10 s. Furthermore, thanks to the physical barrier effect of MXene, SMPU/MXene paper can achieve self-extinguishment without dripping (Zhang et al., 2021).

COLOR CHANGE-BASED FASs

Materials that change color under the influence of temperature or heat accumulation are called thermochromic materials. With these materials, changes in temperature cause changes in the molecular structure of the materials, which results in a change in their color (He et al., 2022; Li et al., 2022). A good example is the reversible thermochromic film, which, due to its ability to quickly change color with temperature changes, can be used as a fire alarm sensor. The reversible thermochromic POSS (polyhedral oligomeric silsesquioxane)-metal films (PMFs) with a different ratio of POSS (octa-aminopropyl POSS) and metal salt [Cr(NO3)3 • 9H2O] showed excellent thermal stability and repeatability, as well as the ability to change colors with a rise in temperature within a few seconds. Figure 6 shows the change in the color of a PMF from green to yellow-green, orange-green, rose hermosa, and purple when increasing the temperature from 20°C to 80°C, 100°C, 120°C, and 150°C (Xu et al., 2022).

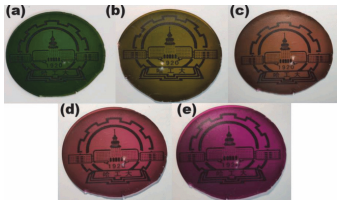


Figure 6. *The color of a PMF with molar ratio 1:1.25 at different temperatures: (a) 20°C, (b) 80°C, (c) 100°C, (d) 120°C, and (e) 150°C (Xu et al., 2022)*

The advantages of color change-based sensors are that they can indicate the danger of fire very quickly and do not rely on the electrical circuit. One of the disadvantages is that these sensors should be combined with additional devices, such as video surveillance. In addition, these materials have not yet been sufficiently researched, and one cannot speak with certainty about their weather resistance (Lv et al., 2022; He et al., 2022).

SMART FIRE ALARM SYSTEM COMMUNICATION

Most smart fire detection systems work using intelligent neural networks, multi-sensing technology, fuzzy logic, etc. These systems are classified under the name distributed intelligence. Each detector in such a system has a processor that monitors its own environment and communicates with other elements of the system. Decision-making processes are carried out in the detector itself, based on fire algorithms obtained as a result of previous fires recorded in the microprocessor inside the detector. Therefore, the detector itself makes a decision about the fire and can enter the alarm state without communicating with the control panel. Fire detection systems with multiple sensors are more efficient than those with a single sensor, and they process the data using fuzzy logic. These systems can use several input parameters (ambient temperature, smoke density, etc.), based on which they make a decision about the alarm state (Deniz & Çunkaş, 2019). Interconnection of detectors and communication are much easier today thanks to the use of wireless technologies. The signal transmission of wireless fire alarm systems is affected by distance and obstacles, so one of the disadvantages is that the transmission speed is slightly lower than with a wired system. Wireless communication-based automatic fire alarm systems can be used both indoors and outdoors, and can serve as supplementary subsystems in large buildings, when existing systems need to be expanded (Dong et al., 2016).

A wireless fire detection system can be used to detect forest fires in the initial stage. One such system, which has proven to be very effective in forest fire warning, consists of wireless sensor nodes deployed to cover an entire area. Sensors monitor temperature, air humidity, light intensity level, and carbon monoxide level, for which alarm thresholds are defined in advance. In order to minimize false sensor readings, long term pattern analysis is carried out by a machine learning algorithm. The primary power supply of the system is provided by rechargeable batteries and solar panels are the secondary power source. In addition, these detectors are designed so that the harmful environmental effects are minimal (Dampage et al., 2022).

Nowadays, the concept of the Internet of Things (IoT) is used in many applications, ranging from smart industry, through smart agriculture, to smart home applications (Alqourabah et al., 2021). It is also important to mention fire alarm systems based on the IoT. IoT systems integrate physical and digital parts to gather data from physical objects and provide operationally useful insights. Physical devices, sensors, data extraction and secured communication, gateways, cloud servers, analytics, and dashboards are some of these components (Jeevanandham & Sivamurgan, 2020). With technological progress comes the development of various possibilities, such as the concept of a smart city. Smart cities, smart houses and buildings, in addition to the IoT, necessitate the application of artificial intelligence (AI), machine learning (ML), cloud computing, and wireless sensor networks (WSN). As a result, users can monitor the building at any time and have remote access to the information they receive from the detector (Shaharuddin et al., 2023).

CONCLUSION

Most fire detectors of the new generation allow faster fire detection and operation in different environments, and they are available in different forms (colors, wallpapers, etc.), so it may be claimed that they largely

overcome the shortcomings of current detectors. In addition, communication using the IoT and wireless connection enable the analysis of a huge amount of data and simpler networking with other systems, but also with system users, which ensures more efficient decision-making and faster response.

In addition to a number of advantages compared to standard detectors, it is important to note that the eventual practical application of the described smart detectors requires further performance improvements. Fabrication of smart detectors is one of the main challenges, given the complexity of most of the methods used.

ACKNOWLEDGEMENTS

This research was supported by the Ministry of Science, Technological Development and Innovation of the Republic of Serbia.

REFERENCES

Alqourabah, H., Muneer, A., Fati, S. M. (2021). *A Smart Fire Detection System using IoT Technology with Automatic Water Sprinkler.* International Journal of Electrical and Computer Engineering, 11(4), 2994-3002. http://doi.org/10.11591/ijece.v11i4.pp2994-3002

Cao, C. F., Yu, B., Guo, B. F., Hu, W. J., Sun, F. N., Zhang, Z. H., Li, S. N., Wu, W., Tang, L. C., Song, P., Wang, H. (2022). *Bio-inspired, sustainable and mechanically robust graphene oxide-based hybrid networks for efficient fire protection and warning.* Chemical Engineering Journal. https://doi.org/10.1016/j.cej.2022.134516

Chen, F. -F., Zhu, Y. -J., Chen, F., Dong, L. -Y., Yang, R. -L., Xiong, Y. -C. (2018). *Fire Alarm Wallpaper Based on Fire-Resistant Hydroxyapatite Nanowire Inorganic Paper and Graphene Oxide Thermosensitive Sensor.* ACS Nano, 12(4), 3159-3171. https://doi.org/10.1021/acsnano.8b00047

Dampage, U., Bandaranayake, L., Wanasinghe, R., Kottahachchi, K., Jayasanka, B. (2022). *Forest fire detection system using wireless sensor networks and machine learning.* Scientific Reports. https://doi.org/10.1038/s41598-021-03882-9

Deniz, V., Çunkaş, M. (2019). *Real time fuzzy logic controlled fire detection system for home applications.* International Journal of Intelligent Engineering Informatics, 7(5), 441-456. https://doi.org/10.1504/IJIEI.2019.103624

Dong, W., Wang, L., Yu, G., Mei, Z. (2016). *Design of Wireless Automatic Fire Alarm System.* Procedia Engineering. https://doi.org/10.1016/j.proeng.2016.01.149

He, X., Feng, Y., Xu, F., Chen, F. F., Yu, Y. (2022). *Smart fire alarm systems for rapid early fire warning: Advances and challenge.* Chemical Engineering Journal, 450(1), art. no. 137927. https://doi.org/10.1016/j.cej.2022.137927

Huang, N. -J., Cao, C. -F., Li, Y., Zhao, L., Zhang, G. -D., Gao, J. -F., Guan, L. -Z., Jiang, J. -X., Tang, L. -C. (2019). *Silane grafted graphene oxide papers for improved flame resistance and fast fire alarm response.* Composites Part B. https://doi.org/10.1016/j.compositesb.2019.03.053

Jeevanandham, A. T., Sivamurgan, P. (2020). *IoT Based Automatic Fire Alarm System.* Bulletin of Scientific Research, 2(1), 29-34. https://doi.org/10.34256/bsr2015

Jiang, C., Chen, J., Lai, X., Li, H., Zeng, X., Zhao, Y., Zeng, Q., Gao, J., Wu, Y., Qui, Y. (2022). *Mechanically robust and multifunctional polyimide/MXene composite aerogel for smart fire protection.* Chemical Engineering Journal. https://doi.org/10.1016/j.cej.2022.134630

Khan, F., Xu, Z., Sun, J., Khan, F. M., Ahmed, A., Zhao, Y. (2022). *Recent Advances in Sensors for Fire Detection.* MDPI Open Access Journals, 22(9), art. no. 3310. https://doi.org/10.3390/s22093310

Li, X., Vázquez□López, A., Sánchez del Río Sáez, J., Wang, D. -Y. (2022). *Recent Advances on Early-Stage Fire-Warning Systems: Mechanism, Performance, and Perspective.* Nano-Micro Letters. https://doi.org/10.1007/s40820-022-00938-x

Lv, L. Y., Cao, C. F., Qu, Y. X., Zhang, G. D., Zhao, L., Cao, K., Song, P., Tang, L. C. (2022). *Smart fire-warning materials and sensors: Design principle, performances, and application.* Materials Science and Engineering: R: Reports, 150, art. no. 100690. https://doi.org/10.1016/j.mser.2022.100690

Ma, T., Li, L., Pan, M., Guo, C., Mei, C. (2023). *Multifunctional MXene-based fire alarm wallpaper with sandwich-like structure for enhanced fire safety and prevention.* Chemical Engineering Journal, 451(1), art. no. 138517. https://doi.org/10.1016/j.cej.2022.138517

Mishra, B., & Sharma, S. (2020). *Shape memory materials with reversible shape change and self-healing abilities: A review.* Materials Today: Proceedings, 44(6), 4563-4568. https://doi.org/10.1016/j.matpr.2020.10.820

Shaharuddin, S., Abdul Maulud, K.N., Rahman, S. A. F. S. A., Che Ani, A.I., Pradhan, B. (2023). *The role of IoT sensor in smart building context for indoor fire hazard scenario: A systematic review of interdisciplinary articles*. Internet of Things, 22, art. no. 100803. https://doi.org/10.1016/j.iot.2023.100803

Wei, W., Yi, Y., Song, J., Chen, X., Li, J., Li, J. (2022). *Tunable Graphene/Nitrocellulose Temperature Alarm Sensor.* American Chemical Society, 14(11), 13790-13800. https://doi.org/10.1021/acsami.2c02340

Xu, Y., Huang, L., Long, J., Zhang, R., Zhong, Z., Yang, L., Liu, L., Huang, Y. (2022). *Reversible thermochromic POSS-Metal Films for early warning.* Composites Science and Technology, 217, art. no. 109083. https://doi.org/10.1016/j.compscitech.2021.109083

Zhang, L., Huang, Y., Dong, H., Xu, R., Jiang, S. (2021). *Flame-retardant shape memory polyurethane/MXene paper and the application for early fire alarm sensor.* Composites Part B, 223, art. no. 109149. https://doi.org/10.1016/j.compositesb.2021.109149

Zhu, M., Lu, C., Liu, L. (2023). *Progress and challenges of emerging MXene based materials for thermoelectric applications.* iScience, 26(5), art. no. 106718. https://doi.org/10.1016/j.isci.2023.106718

Safety Engineering & Management in Education

20th International Conference Man and Working Environment
SEMSIE
Safety Engineering & Management – Science, Industry, Education

20th International Conference Man and Working Environment
SEMSIE
Safety Engineering & Management – Science, Industry, Education
20th International Conference Man and Working Environment
SEMSIE
Safety Engineering & Management – Science, Industry, Education

20th International Conference Man and Working Environment
SEMSIE
Safety Engineering & Management – Science, Industry, Education

www.znrfak.ni.ac.rs/semsie

VESNA NIKOLIĆ[1]

[1]University of Niš,
Faculty of Occupational Safety

[1]*vesna.nikolic@znrfak.ni.ac.rs*

THE FIRST STEP OF THE ANDRAGOGIC CYCLE – ASSESSMENT OF OSH TRAINING NEEDS

Remember, training is not what is ultimately important... performance is.
M. Rosenberg

Abstract: *The assessment of educational needs represents the first step in the andragogical cycle, which is of special significance for the successful implementation of workplace training. Some authors classify it as formative evaluation because it is usually conducted as part of training development or improvement of human performance. The professionalism of occupational safety and health (OSH) training must not be questioned, nor should it leave the impression that it is a formal response to legally established requirements. However, despite the important role of assessing training needs for safety and health at work, there is an evident lack of relevant sources on this topic. The results presented in this paper can serve as guidelines for identifying educational needs and implementing solutions in the practice of occupational safety and health.*

Keywords: andragogical cycle, training needs, occupational safety and health (OSH)

INTRODUCTION

From a global perspective, the issues and challenges related to occupational safety and health are growing, starting with the automation, robotization and digitization of business processes and, in connection with this, changes have been made in the way work is done and organized in developed countries, through the adoption or ratification of ILO and WHO directives in certain countries, alignment of laws and by-law documents in this field, the emergence of new forms of work (from home, remote work, self-employment, etc.), the inclusion of sensitive groups in labor relations (child labor, the elderly, pregnant women, immigrants, refugees, etc.); emergence of new risks and dangers (especially psychosocial risks); neglect of OSH in certain activities (agriculture, "home" activity), the lack of a preventive OSH structure in poor and developing countries, and the problems surrounding the development of qualification standards, i.e., professionalization and the professional identity of occupational safety experts, etc.

In a national context, the contemporary business environment is characterized by constant and rapid changes, increased market competition, the adoption of new technologies, shifts in the labor market, and a growing number of stakeholders with increasing expectations. The turbulent business environment is accompanied by risks of various natures and characteristics. Managing risks related to occupational safety and health of employees becomes a significant area of focus in every organization or company. This is closely related to employee training and the continuous professional development of OSH experts. In most countries, the current legal regulations define and govern the obligation to inform and train employees in the field of occupational safety and health. Additionally, they also address the ongoing professional development of experts in this field. (Nikolić, 2017.)

Training for occupational safety and health represents a fundamental preventive measure in the occupational safety and health (OSH) system. The results of numerous studies confirm the significance of training in creating safe behaviors among employees and fostering positive attitudes towards OSH (Robson, 2012; Laberge, 2014). However, one of the biggest myths in occupational safety is the belief that all issues related to preventing injuries and accidents can be easily resolved through employee training. It is undeniable that workers who are not adequately trained in OSH are exposed to higher risks and occupational illnesses. Nevertheless, there are questions about the effectiveness of training, leading to inquiries regarding the professional approach to training, specifically its organization and efficient didactic and methodological implementation (Cohen & Colligan, 1998.).

The development of andragogy as a science and theory of adult education has certain implications for the advancement of workplace training, including training for occupational safety and health. It has become evident that fundamental andragogical principles and findings can influence the improvement of OSH training performance. The differences between effective and ineffective training can be observed through various performance indicators related to occupational safety, such as the number of injuries, fatalities, occupational diseases, pain, suffering, loss of

profits, and competitiveness (Whiles, 1999). On the other hand, excessive training can sometimes lead to employee frustration and reduce their effectiveness and credibility (Blair & Seo, 2007, p. 42).

In the contemporary economic context, significant resources are allocated to various types of employee training and development. Since training is also considered a service provided to clients, it is worth mentioning that offering "training services" has become a significant business, especially in developed countries. Authors estimate that corporate America provides nearly 2 billion hours of training annually for 60 million employees (Diether & Loos, 2000, p. 28). Apart from data on investments in training, the importance of training is underscored by the presence of numerous strategic and legal documents that define and specify them (e.g., Occupational Health and Safety Act, Official Gazette of RS 35/2023). On the other hand, there is an open question about how much knowledge, skills, and abilities employees truly acquire, remember, or retain after a certain period following the training (Broad & Newstrom, 1992). Estimates suggest that only 10% to 15% of the knowledge acquired during training is retained after 1 year (Ibid).

From the perspective of occupational health and safety, this problem is further complicated by the fact that employers often view training as a legal obligation that needs to be met (training implementation) and documented (training records), with little consideration for the quality and effectiveness of the training provided (Holton, Bates & Naquin, 2000). The effectiveness of training should be closely related to the execution of the andragogical cycle and the involvement of education/training analysts and human resources experts in this process. The andragogical cycle involves the realization of a series of interconnected and interdependent phases, with the initial step in the educational process being the assessment/analysis of training needs, including their identification and determination.

THEORETICAL BACKGROUND

The concept and significance of assessing educational needs

Numerous studies have confirmed the importance of OSH (Occupational Safety and Health) training (Burke et al. 2003; Clemes et al., 2010; Robson, 2012; Laberge; 2014.), but at the same time, they have raised a series of questions regarding the examination of educational needs and the effectiveness of training in this field.

Safety-related training is used to close gaps in knowledge about hazards and associated risks, as well as the necessary controls that are to be consistently used. A safety-related problem may be a precursor to general performance issues impacting productivity or other organizational effectiveness or drivers. For example, an employee may not have an understanding of the required specific sequence of tasks, actions, or the decision rules to follow in taking corrective actions. The job may be one that requires problem-solving skills and not specific rules to follow or skills directly associated with the task (Roughton & Crutchfield, 2008).

When problems arise in an organization related to employee performance and behavior (workplace injuries, near misses, psychosocial risks, etc.) due to a lack of knowledge and skills, there is a need for training and/or education[1]. The need for training or education arises when there is a gap between the standards of work and behavior and the actual practices of employees. This represents a global need - the need for education or training in a specific area, as opposed to specific needs that determine *what knowledge and skills* employees need to acquire. Initiating training and education involves identifying these global needs and taking action accordingly. Initiating training and education involves identifying global needs and initiating activities in that direction.

A needs assessment is the process of identifying the 'gap' between performance required and current performance. When a difference exists, it explores the causes and reasons for the gap and methods for closing or eliminating the gap. A complete needs assessment also considers the consequences of ignoring the gaps (Training and Development, Planning, Evaluating, n.d.).

The experts who plan training as well as efforts to improve human performance are responsible for identifying needs and planning program responses (Davidson, 1995). Some authors draw an analogy between the role of a training needs analyst and that of a doctor: *"A doctor diagnoses a disease using X-rays and laboratory tests before attempting to prescribe a remedy through treatment, surgery, or other techniques. Similarly, training needs analyst diagnoses using organizational analysis, task analysis, and personal analysis to determine whether treatment is necessary and which remedy will achieve the desired results."* (Goldstein, 1974, p. 27).

What are educational needs?

In an organization, there are two main groups of educational needs: the needs of the organization itself and the needs of individual employees. In modern working and business conditions, companies have a continuous need for trained, up-to-date, and educated personnel (organizational needs). On the other hand,

[1] *Education is the acquisition and continuous enhancement of broader knowledge related to the applied scientific disciplines and successful business practices relevant to the company's activities and goals, aimed at improving the content and methods of work, management, and administration. Training is the acquisition of new practical knowledge and skills necessary for work, management, administration, and organizational behavior in accordance with adopted rules, regulations, and standards. Training involves practicing acquired practical knowledge and skills.*

individuals who face new job requirements, new technologies, and new hazards feel the need for new professional knowledge and skills (in addition to their personal aspirations and expectations). Rational organizational behavior involves aligning these two types of needs for mutual benefit.

The point in space and time where these two types of needs align is when the organization realizes there is a gap between the current state of affairs and the planned, desirable, and expected state. At that moment, the need for professional education or training can be outlined (although only in a global sense), which is relevant both for the organization and for the individual. *The need for education is, therefore, the difference between existing and required knowledge, skills, and various abilities needed to carry out current and planned assignments and organizational roles.* When the need arises, it is necessary to initiate action.

The initiators of training in a company can be (within their responsibilities): the management, the company's director, other managers, immediate supervisors, the human resources management, the employee education and development officer, individual employees, and especially the occupational health and safety officer (advisor or collaborator).

The initiative is directed towards the relevant human resources management function. All initiatives, individual employee requests for education, and offers of educational programs should flow into this function. In this way, this function manages education, training, and the overall development of employees. It collaborates with relevant managers and specialist services to select organizers, programmers, and programs and directs the right participants to attend the offered programs.

METHODOLOGY

The research was conducted with the aim of understanding the issues and specifics of identifying OSH (Occupational Safety and Health) training needs. It was desktop research based on the following databases: Google Scholar, KoBSON, and Science Direct. The search of sources was conducted using the following keywords: training needs, occupational safety, and assessment. The sources included in the search covered various topics, and through selection, references listed in the literature were identified. The analysis of these sources directed the research in two directions, from which two research tasks were defined: (1) identify the need and significance of training needs assessment within the modern business context, (2) present the specifics of OSH training needs assessment models (at the organizational analysis, task analysis, and individual analysis levels).

Assessment of Educational/Training Needs

The assessment of educational needs is often defined as "*the process of gathering data in order to identify educational needs and define the training that will help an organization achieve its goals"* (Brown, 2002, p. 569). In simple terms, it is "the process of collecting information about an explicit or implicit organizational need that can be met through training" (Barbazette, 2006, p. 5).

In essence, information is gathered and analyzed to create a training plan. The assessment determines the need for training, identifies the type of training required, and examines the kind and extent of resources to support the training program (Sorenson, 2002). An organization conducts a training needs assessment to obtain information about: 1) optimal performance or knowledge; 2) actual or current performance or knowledge; 3) employee attitudes; 4) causes of problems; and 5) solutions to problems (Rossett, 1987, p. 15).

Why conduct a training needs assessment?

Training needs assessment provides data for targeted training implementation. Through the assessment of training needs, a company verifies that the training is suitable for addressing specific issues (performance gaps, workplace injuries, occupational diseases, etc.). However, training cannot solve problems caused by poor work design, inadequate resources, or insufficient staffing (Sorenson, 2002).

Training needs assessment allows for *identifying the "gap," deficiency, or difference between the existing and required knowledge of employees,* and between the existing and required competencies for performing specific tasks. For example, suppose that in a company, the number of slips, trips, and falls has increased by 25% on the production line. This could signal a development issue. By conducting a needs assessment, the company can gather information about workers' abilities or task specifics, leading to the identification of the root causes of the problem. Competencies of "assessors" and "analysts," along with an understanding of the problem and the skill to find appropriate solutions, are crucial in this process (Rossett, 1987). It is also necessary to make conceptual distinctions between global and specific educational needs, as discussed in the previous part of the paper. Global educational needs indicate the need for training, while specific needs refer to specifying the content of the program.

They answer the question of what needs to be learned and practiced. Specific educational needs are determined by:

1. Job analysis and standards of work and behavior in terms of knowledge and skills and comparing them with the current situation.
2. Consultation (through surveys or oral communication) with:
   - Immediate supervisors and other relevant managers.
   - The participants themselves.
   - Clients, customers, service users.
   - Competent experts from within or outside the organization.

A proper analysis and assessment of training needs is a wise investment for the organization. It saves time,

money, and effort by addressing the right issues (McArdle, 1998). Failure to assess educational needs can lead to "costly mistakes," focusing the company on training instead of seeking other solutions.

OSH TRAINING NEEDS ASSESSMENT MODELS

The relevant literature contains various models for assessing educational needs (Rossett, 1999; Witkin & Altschuld, 1995). However, there is still limited research dedicated to assessing educational needs for workplace training (Salas & Cannon-Bowers, 2000; Clarke, 2003; Mosli & Hian, 1994), and research on educational needs in the field of occupational health and safety is almost entirely lacking (Sleezer, 2000).

A significant number of researchers use the Performance Analysis for Training model (PAT) (Knorr, 1997; Kunneman & Sleezer, 1996) to find optimal solutions in training program design and models for improving employee performance and overall organizational performance (Lincoln & Denzin, 2003). According to this model, the assessment of training needs is influenced by the characteristics of the organization, decision-makers, and analysts (Figure 1), and it is through their interaction (shaded area) that training opportunities and needs are perceived, negotiated, and prioritized.

According to this model, the training needs assessment is carried out in three phases during which data are collected and synthesized. In the first phase, organization analysis, strategic needs are examined; in the second phase, the behaviors required for a specific job are examined (e.g., job analysis, or task analysis, or competence analysis); in the third phase, individual abilities are examined (e.g., knowledge and skills analysis). The PAT model also includes many worksheets containing information from the literature on each step and space for recording assessment data (Knorr, 1997; Kunneman and Sleezer, 2000).

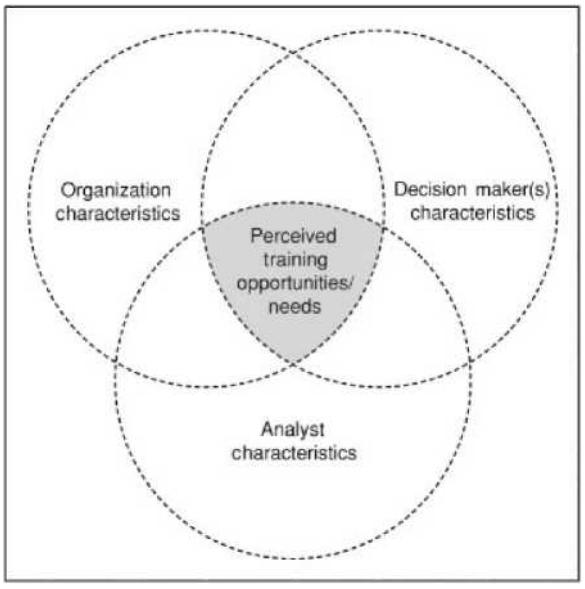


Figure 1. *Elements that influence decisions about training needs (Sleezer, 1991).*

The authors agree that organizational characteristics (such as size, resources, organizational climate, etc.) can influence the methodology of training assessment. The traditional approach involves employees ranking desired training, which, in fact, allows employees to participate in the assessment of educational needs (which certainly affects morale but may limit on-the-job impact).

The fundamental framework for conducting training assessment is provided by the approach of McGehee and Thayer (1961), which identifies three levels of assessment/analysis: organizational analysis, job/operations/task analysis, and individual analysis (Holton, et al., 2000.) from which we started discussing training needs for occupational safety and health in the workplace.

Organizational analysis involves examining organizational factors that impact training needs for occupational safety and health (such as the introduction of new equipment, new technologies, the implementation of standards, etc.) and identifying content that can enhance the safety performance of employees and the organization as a whole. It also involves identifying determinants of human resource development (knowledge and skills) in line with the organization's development, current changes, and expected future changes (Brown, 2002.).

Understanding organizational changes can reveal the skills needed for the future. What personal protective equipment will employees use? How will new equipment be installed? How should the new process be implemented? Will standards and regulations change? Is technology evolving in ways that require communication and interpersonal skills? Will cultural shifts play a role in production?

Different types of changes imply changes in the organization and the need for OSH training. Changes in the demographic structure of employees (e.g., an aging workforce) – the increased participation of older workers, women, workers from socially sensitive and vulnerable groups – changes in legal documents and other regulations, competition, economic changes, operating costs, and so on, also lead to changes in the organization's business and the need for specific OSH training content. New legal requirements often specify that organizations must provide training in specific areas. For example, workers handling hazardous materials may be required to undergo annual retraining, changes in policies related to bullying and workplace violence may require informing employees, and so on.

Task/operation analysis examines the required knowledge and skills needed for each specific job and compares those requirements with the actual knowledge and skills of employees. Any gaps or deficiencies in knowledge indicate the need for training. Sources for collecting data include job descriptions, standard procedures for operations, job safety analysis, risk assessment, hazard analysis, performance standards, analysis of best practices, on-site observations, and more. Effective task analysis

identifies the tasks that must be performed, the conditions for their execution, the quantity and quality of required performance, the necessary knowledge, skills, and capabilities to acquire them, etc. (Brown, 2002.)

Individual analysis looks at employees as individuals and their performance in the job (number of workplace injuries, near misses, etc.). Employees can be interviewed, surveyed, and tested to determine their individual levels of knowledge and skills. Performance reports are also a valuable source of data. Additional performance issues can be uncovered by analyzing various factors such as productivity, absenteeism, delays, injuries, customer complaints, and more (Miller & Osinski, 1996, p. 4). When deficiencies are identified, training can be organized to meet the individual needs of workers.

All three levels of needs analysis are interconnected and interdependent. Based on the collected information, needs are identified, learning objectives are determined, and a training plan and program are created.

Starting from Barbazette's model (2006) in occupational safety and health education, the training needs assessment should answer the following questions (Holton, et al., 2000, p. 251):

WHY? This question helps to relate workplace problems (work-related injuries, performance deficiencies) to educational needs and assess whether the benefits of training outweigh the costs of the current issue or work deficiency

WHO? This question helps to determine who is responsible for the problems that have occurred in the workplace (e.g., work-related injuries, performance deficiencies) and identifies the "target audience" for training

HOW? This question should answer how the workplace problem (injury, hazards, performance deficiency) can be resolved (i.e., whether a lack of knowledge and skills led to the problem)

WHAT? This question should address what is the best course of action to achieve the desired outcome. Standard procedures can emphasize how to perform tasks or what legal regulations to consider when carrying out a task. Additionally, it should verify which occupations are at risk of injuries, performance issues, and other workplace problems. This way, critical points that can jeopardize employee health, safety, or property damage can be identified. This process involves analyzing records of injuries and incidents, interviewing employees, etc.

WHEN? This question should provide an answer to when it is best to conduct training (considering its potential negative impact on daily job duties). Additionally, the proper execution of training is essential.

Brown (2002) believes that the answers to the following questions are essential for a proper training needs analysis:

What is the nature of the problem?

What were the past training requirements and what were the results?

What is the budget for the training needs analysis?

How is the analysis of employees' needs perceived in the organization?

Who is available to assist in conducting the analysis?

What is the timeframe for completing the training needs assessment?

What will be the measure of a successful training needs assessment report?

The time frame for the training needs analysis will certainly vary depending on organizational needs, resources, management commitment, and other factors. However, the fundamental steps in this process are:

Determine the purpose of the training needs analysis (e.g., for identifying individual skills and knowledge, financial planning, organizational development needs, etc.).

Collect data (using various instruments - through observation, questionnaires, interviews, performance analysis, tests, document review, etc.) or a combination of these methods.

Analyze the data - identifying any deviations and gaps between the skills and knowledge possessed by employees and those required for a specific job.

Determine what can be achieved through training - recognizing workplace issues that can be rectified by increasing employees' skills and knowledge.

Proposal for solutions. If the solution to workplace problems (injuries, near misses) involves training, then the following key steps should be taken into account:

a. Conduct a cost-benefit analysis of the training.
b. Establish clear and measurable objectives in line with the organization's policies and mission.
c. Create a training program and determine the method of delivery (in-house, open-house, video, web-based, computer-based training, etc.).
d. Consider who will deliver the training – internal or external sources. The benefits of in-house training include lower costs, flexible scheduling, and greater practical knowledge, while external consultants (open-house) are associated with greater credibility on specific topics.
e. Ensure that training materials/literature align with the objectives.
f. Understanding the learners is crucial (instructors' understanding of andragogical principles of adult learning will pave the way for training effectiveness).
g. Transfer theoretical knowledge into practice on the job.
h. Identify and overcome training barriers (coaching, behavior observation, the credibility of managers, supervisors, and employees are ways to improve training).

i. Evaluate the effectiveness of the training, including both initial training and later, with more complex and aggressive evaluation methods such as leadership assessment and other indicators to measure performance progress.

j. Implement recommendations from the evaluation. Improvements can vary, ranging from changing training materials, adjusting the time for content absorption, altering the training location, enhancing instructor performance, content, and evaluation tools.

If this process is interrupted, the benefits of continuous improvement will be missed.

When identifying OSH training needs, it is most favorable to achieve a reasonable synthesis of deductive and inductive methodological approaches. As emphasized in their conceptual thinking, we find organizational (company needs) and individual educational needs, but it is also possible to identify a range of variations and subgroups, such as the needs of individual job positions to the needs of specific categories of employees/workers, as well as all others who could potentially be participants in the educational process (members of vulnerable groups, youth, pregnant women, elderly workers, etc.).

CONCLUSION

The development of technology worldwide, structural changes in the economy (transition from an industrial to a post-industrial era), competition, and the need for constant quality improvement have necessitated a change in the traditional approach to education. Organizations today have ongoing needs for restructuring and bridging the so-called "skill gap" - the gap between the competencies employees possess and the new job requirements. On the other hand, structural changes in the economy and changing market demands require a flexible, adaptable organization, qualitatively different management and leadership, and flexible employee behavior, which in turn changes the approach to education. To survive, modern organizations are forced to develop their employees, enabling them not only for specific skills but also for critical thinking, problem-solving, collaboration, and taking responsibility.

The modern concept of training[2] and education is closely linked to individual development, organizational growth, and even the progress of entire societies. Apart from its role in personal and professional development, training is attributed to two seemingly contrasting yet complementary processes: adapting to change and driving change. In fact, training continually evolves in response to modern expectations, demands, and needs.

Training needs assessment represents the first phase of the andragogical cycle and the initial step in creating an effective training program. It serves as the foundation for determining learning objectives, designing the training program, and evaluating the training's effectiveness. Additionally, it provides an opportunity for managers, instructors/trainers (in the context of occupational safety and health, for example), to engage with employees, gather information, foster innovation, creativity, and create a positive learning environment for training implementation.

A well-organized training needs assessment provides numerous advantages to an organization:

1. Increased Management Commitment and the engagement of potential participants in ongoing training and development.
2. Enhanced Visibility of the Training Function
3. Clarification of Key Organizational Issues
4. Optimal Resource Utilization
5. Generation of Program and Design Ideas

Development of Training Implementation Strategies
Other benefits relate to creating opportunities for employee development, acquiring knowledge, skills, and attitudes for safe and healthy work, developing a safety culture, improving employee morale, enhancing communication quality, etc.

Training is often seen as a hindrance and cost rather than an investment in development, safety, and decent work for all employees. The negative perception of training is often a result of failing to short-term costs and benefits of training. Certainly, considering the difference between good and bad practice examples can help identify cost savings as a clear indicator (and necessary support) for organizing and implementing occupational health and safety training, as well as in other areas of protection and safety.

ACKNOWLEDGMENT

This research was published with the support of the Ministry of Science, Republic of Serbia, following the Agreement on Realization and Financing of Scientific Research of the Scientific Research Organization in 2023, Agreement Registration Number 451-03-47/2023-01 /200148.

REFERENCES

Barbazette, J. (2006). Training needs assessment: Methods, tolls and techniques. San Francisco: Pfeiffer.

Blair,E&Seo,D.(2007).Safety training: Making the connection to high performance. Professional Safety, 52 (10) 42-48.

Broad, M. L. & Newstrom, J. W. (1992). Transfer of training. Reading, MA: Perseus Books.

Brown, J. (2002.). Training needs assessment: A must for developing an effective training program. Public Personnel Management, 31 (4), 569-578.

[2] Due to the growing interest in studying training, we should not succumb to the impression that training is a phenomenon of the modern era. Historically, we can see that training has been a constant companion of human society (in primitive communities, teaching the young to make weapons, tools, hunting, fishing; later on, apprenticeships, journeyman training, etc.).

Burke, M.J. et al. (2006.). Relative effectiveness of worker safety and health training methods. Am. J. Public Health 96 (2), 315–324.

Clemes, S.a., Haslam, C.O., Haslam, R. (2010.). What constitutes effective manual handling training? A systematic review. Occup. Med. (Oxford, England) 60 (2), 101–107.

Cohen, A. & Colligan, J. (1998). Assessing occupational safety and health training: NIOSH Publication, Washington.

Diether, J. & Loos, G. (2000). Advancing safety and health training. Occupational Health and Safety, 69, 28-34.

Goldstein, I. L. (1974). Training in organizations: Needs assessment, development, and evaluation (2nd ed.). Monterey, CA: Brooks/Cole

Holton, E., Bates, R. & Naquin, S. (2000.). Largescale performance-driven training needs assessment: A case study. Public Personnel Management, 29 (2), 249-267.

Kunneman, D. E., & Sleezer, C. M. (2000). Using performance analysis for training in an organization *implementing ISO-9000 manufacturing practices: A case study*. Performance Improvement Quarterly*,* 73(4), 47-66

Laberge, M., MacEachen, E., Calvet, B., 2014. Why are occupational health and safety training approaches not effective? Understanding young worker learning processes using an ergonomic lens. Saf. Sci. 68, 250–257.

Machles, D. (2002.). Training transfer strategies for the safety professional, Professional Safety, 47 (2), 32-34.

McArdle, G. (1998). Conducting a needs analysis. Menlo Park, CA: CrispLearning. McClelland, S. (1993). Training needs assessment: An "opensystems" application. Journal of European Industrial Training, 17 (1), 12-17.

McConnell, J. (2003). How to identify your organization's training needs. NewYork: American Management Association.

McGehee, W. & Thayer, P. (1961). Training in business and industry. NewYork: Wiley.

Miller, J. & Osinski, D. (1996.). Training needs assessment. Retrieved Jan. 26, 2010, from http://www. ispi. org/pdf/ suggestedReading/Miller_Osinski. pdf.

Nikolić, V. (2017). Osnovi koncepcije kontinuiranog usavršavanja za zaštitu na radu, Međunarodni naučni skup, FTN Novi Sad, SIZRS,Novi Sad..

Robson, L.S.. et al. (2012.). A systematic review of the effectiveness of occupational health and safety training. Scand. J. Work Environ. Health 38 (3), 193–208.

Robotham, G. (2001.). Safety training that works. Professional Safety, 46 (5), 33-37.

Rogers, M. (1991). Health and safety training. Accident Prevention, 38, (20)

Rossett, A. (1987). Training needs assessment. Englewood Cliffs, NJ: Educational Technology Publications.

Sorenson, S. (2002.). Training for the long run. Engineered Systems, 32.

Rossett, A. (1999*)*. First things fast. San Francisco: Jossey-Bass.

Roughton, J. E., & Crutchfield, N. (2008). Job hazard analysis: A guide for voluntary compliance and beyond. Chemical, petrochemical & process. Elsevier/Butterworth-Heinemann.

Sleezer, C. M. (1991). Developing and validating the performance analysis for training model. Human Resource Development Quarterly, *2(4), 355-372.*

Witkin, B. R., & Altschuld, J. W. (1995). Planning and conducting needs assessments: A practical guide. Thousand Oaks, CA: Sage.

Whiles, A. (1999.). Workplace training: The learning curve. Occupational Health and Training, 10.

Zakon o bezbednosti i zdravlju na radu, ''Sl.glasnik RS'' 35/2023.

20th International Conference Man and Working Environment
SEMSIE
Safety Engineering & Management – Science, Industry, Education

www.znrfak.ni.ac.rs/semsie

TOMISLAV KATIĆ[1]

[1]ORSUS Group LLC

[1]*tomislav@orsusgrupa.hr*

A NEW CONCEPT OF SAFETY LEADERSHIP

Abstract: *Leading people is the most complex function of safety management, and its purpose is to influence people so that they contribute as much as possible to a common goal. In general, it can be said that leadership is the ability to influence, inspire, and direct individuals or groups towards achieving desired goals. Given that changes in the way of working, working relationships and working conditions are becoming more frequent and intense, in order to effectively manage people, safety managers must adapt their leadership style accordingly. Previous concepts of leadership were based on control, while the new concept is based on caring for people. In order to apply this approach, safety managers must acquire new skills. This paper presents the most important components of safety leadership and a new concept of safety leadership based on the conducted research.*

Keywords: human resources, leadership, new concept, safety management

INTRODUCTION

Through the thoughtful application of safety leadership, dangers are eliminated and the risks of basic dangers that occur in the business process are reduced, whether it is the risk of work injuries, fire, explosions, criminal acts, accidents and environmental pollution, or natural disasters.

The process functions of safety management comprise planning, organizing, staffing, leading, and controlling. Management and leadership are often considered one and the same thing. Although it is almost a rule that the most effective managers are also successful leaders, management is more than a function of leadership. Leadership is actually a basic management function.

To lead is to influence people to contribute to the organization and collective goals. This field is predominantly concerned with the interpersonal aspects of management. Practice confirms that the most important problems for managers come from people, their desires and attitudes, and their behaviour as individuals and in groups. All this leads to the conclusion that an effective safety manager must be an effective safety leader.

Safety leadership helps people see that they can meet their own needs and use their potential to simultaneously contribute to the goals of the safety system. Previous concepts of leadership were based on control, while the new concept is based on caring for people. In order to apply this approach, safety managers must acquire new skills.

METHODOLOGY

Aim and tasks of the research

The problem that has been recognized in this area is the lack of current knowledge about new concepts of safety management. The aforementioned problem is manifested in the lack of published current research in this area. Considering the recognized problem, the goal of the research is to investigate and establish new concepts about leadership in security.

According to the set goal, the research tasks are

- to collect data on safety management concepts;
- to analyse the content of the concept of leadership in safety; and
- to present the elements of the new concept of leadership in safety.

Research methodology

In the analysis, a number of scientific methods are applied, which, by their combination and sequence, form an established research methodology. A combination of deductive and inductive analysis is applied in order to classify and summarize the basics of the research subject. Using the method of studying the content of scientific and professional literature, the content pertaining to management in safety is analysed. The method of description describes the essential features and elements of the research subject and synthesizes the conclusions.

Hypothesis

On the basis of the recognized problem and the set goal of the research, a hypothesis was set up, which will be confirmed or rejected based on the results of the conducted research: there are new safety leadership concepts.

RESULT AND DISCUSSION

Occupational health and safety management system

The Occupational Health and Safety Management System (OHSMS) represents a structured framework and approach that enables organizations to effectively manage risks associated with the health and safety of

employees in the workplace. This system assists organizations in identifying, assessing, and controlling potential hazards to ensure a healthy and safe working environment for all employees. The goal of OHSMS is to identify, analyse, and mitigate risks associated with safety in order to protect lives, health, and property, both of employees and of other stakeholders. The occupational health and safety management system is part of the overall system that is responsible for the management of health risks inherent in the organization's business activities. The system includes the organizational structure, planning, responsibility, practice, procedures, processes, and resources for the development, application, implementation, review, and maintenance of the health and safety protection policy of the organization (Palačić & Mudri, 2014).

The OHSMS is typically based on specific norms and standards, such as ISO 45001, or specific laws and regulations, depending on the country in which it is implemented. This system consists of several key components:

1. Occupational Health and Safety Policy: The organization establishes formal policies that express its commitment to the health and safety of employees. These policies usually include goals and guidelines that the organization aims to achieve in terms of workplace safety.
2. Hazard Identification and Risk Assessment: The organization analyses its work environment to identify potential hazards that could jeopardize the health or safety of employees. The risk that these hazards pose in terms of causing injuries or damage is then assessed.
3. Planning and Implementation of Prevention Measures: Based on the identified hazards and assessed risks, the organization develops and implements appropriate prevention measures. This may involve implementing technical solutions, providing personal protective equipment, conducting employee training, and other activities aimed at preventing injuries.
4. Training and Informing Workers: Employees are trained and informed about workplace hazards, safety rules, and procedures in case of emergencies. Training and informing employees are crucial for creating a culture of workplace safety.
5. Monitoring and Supervision: The organization continuously monitors the implementation of measures and risk monitoring. Monitoring helps identify changes and new hazards and ensures that prevention measures remain effective.
6. Continuous Improvement: The OHSMS is dynamic. The organization regularly analyses its procedures, evaluates results, and identifies opportunities for improvement to ensure continuous progress in workplace safety.

The OHSMS assists organizations in creating an environment where employees are protected from potential hazards and where a safe and healthy way of working is promoted on a daily basis.

Leadership

Leading people is the most complex function of safety management, and its purpose is to influence people so that they contribute as much as possible to a common goal. If we talk about leadership, we are actually talking about the ability and skill of a manager to successfully and responsibly use power, to have the ability to understand that people at different times and in different situations have different motives, to have the ability to inspire subordinates, and to have the ability to act in a way that will develop a suitable climate for encouraging motivation (Palačić, 2004).

Despite all of the above, it is not possible to simply define the concept of leadership. According to T. Costley, "leadership is easy to recognize, but difficult to define" (Žugaj & Brčić, 2003).

For different authors, leadership has a different meaning. Some of the authors define leadership in the following ways:

- leadership is "the influence or art and process of influencing people in such a way that they readily and energetically strive towards the realization of collective goals" (Weihrich & Koontz, 1998);
- leadership is "the ability to influence, inspire and direct individuals or groups towards achieving desired goals" (Bass, 1981);
- leadership is "the ability to influence behaviour in a certain direction regardless of means" (Hodgetts, 1985);
- leadership is "the manager's ability to influence subordinates to perform specific tasks in order to achieve goals" (Bedein & Glueck, 1983);
- leadership is "motivating people" (Žugaj & Brčić, 2003);
- leadership is "a dynamic process in a group by which one person influences another to voluntarily participate in the performance of a group task in a given situation" (Cole, 1990).

The way a leader resolves personal issues has a great influence on a person's behaviour (Armstrong, 2001). Considering the established importance of leadership, numerous studies that have been conducted have resulted in a multitude of models that are usually classified into four basic groups: trait models (personality theories), behavioural models (style theories), contingency models (situational theories), and modern approaches to leadership (Carnegia, 1995).

Safety leadership

Safety leadership is a vital component of any safety, health & environment process. Safety leadership is defined as "[t]he process of defining the desired state, setting up the team to succeed, and engaging in the discretionary efforts that drive the safety value," which broadly boils down to "engaging in and maintaining behaviours that help others achieve our safety goals" (B-Safe Management Solutions, 2023).

The known documented benefits of effective safety leadership are the following:

- It improves employees' safety behaviour by as much as 86%;
- It independently reduces lost time and minor

injury frequency rates by around 35%;
- It creates better business continuity, thereby increasing productivity by avoiding incidents, accidents, breakdowns, and process failures;
- It helps reduce insurance premiums by around 30%;
- It improves standing and reputation among suppliers, clients, and partners;
- It leads to better all-round economic performance (b-safe management solutions, 2023).

Common safety leadership strategies include the following:

1. Value Alignment: Encouraging people to take personal responsibility for safety by setting expectations for each level of management (senior, middle, and lower-line management, and employees) linked to clear goals. It is important to ensure that the adopted strategies and interventions are aligned with the strategic goals and that they are not limited to the formal definition of the security policy.

2. Systems & Monitoring: Establishing a risk or safety management system that includes (but is not limited to) preventive maintenance, operational procedures, inspections, permit-to-work systems, safety interviews, safety committees, risk assessments, near miss reporting, training, management changes, risk management plans, etc. In terms of effectiveness, the focus of monitoring is primarily on incident rates, security surveys, and gap analysis through internal audit functions (leading indicators).

3. Education & Awareness: The provision of safety management training is implemented to make safety management a corporate value. Evaluation of the effectiveness of the training strategy is based on employees perceiving leadership's commitment to a safe workplace, leaders in the organization having more knowledge about safety, and line management accepting their responsibilities for safety.

4. Exhibiting Visible Leadership: Encouraging the management team (from the top down) to demonstrate leadership's visible commitment to a safe workplace. This visible demonstration takes the form of chairing safety meetings, taking responsibility for the SMS (i.e. conducting risk assessments, investigating accidents), participating in reviews and training, conducting two-way safety dialogues with workers, and making safety tours of the workplace.

From all of the above, it can be concluded that safety culture is the basis for effective safety leadership. There is no effective safety leadership without a good safety culture. Safety leadership in turn plays a crucial role in creating a strong safety culture.

In every business system, with the emergence of an organizational culture, its subcultures also develop, including cultures of individual functional departments, administrative culture, work culture of direct executors, safety culture, etc. (Pavković, 2006).

Safety culture is usually described as a corporate atmosphere or culture in which safe production is taken for granted and is accepted as a priority. Therefore, for effective safety leadership, it is mandatory to build a good safety culture. Previously conducted research did not show significant differences in raising the level of safety culture in organizations. Nevertheless, it is considered that the development of a culture of safety at work affects the reduction of the number of accidents and injuries at work, and thus also the reduction of costs and losses in a business (Palačić, 2010).

On the basis of conducted research, Petersen describes the essential elements of security programs based on the behaviour of employees. Among others, the author believes that leadership affects the construction of a safe working environment through motivation, encouraging a culture of safety, increasing worker participation and encouragement (Petersen, 2001). Petersen also believes that the influence of leadership and management of people on the improvement of protection performance is significant (Petersen, 2005). A systematic approach to safety management implies the application of safety leadership, which is of particular importance when taking a proactive approach (Petersen, 2023). On the basis of research, Petersen developed a method of analysing the effectiveness of the safety system, which, among other things, includes the analysis of aspects of managing people in the management system (Petersen, 1996).

After the analyses and methods of theoretical assumptions and the obtained results on leadership models and approaches, the realization emerges that today's leadership is positively oriented in the field of interpersonal communication in safety management systems (Katić, Ban, & Palačić, 2013).

Safety leadership is focused on transforming the culture from within to value safety, including psychological safety. A psychologically safe work environment invites employees to share their thoughts and feelings without retaliation, which can help them feel more comfortable alerting management to risks and concerns.

New concepts in safety leadership

It is a common belief that safety leadership is made up exclusively of senior management or executives. This is partly true. Safety leaders are individuals with the greatest understanding of the importance of safety and with the ability to inspire and communicate with fellow employees. A safety leadership team will be the most effective when it is multidisciplinary, involving multiple departments and roles. Hiring from across departments gives management members a clearer picture of how safety directly touches every aspect of the organization and allows them to provide a more informed rationale for safety direction and improvement.

The skills expected of safety leaders go far beyond the safety domain. The era of 'safety first' is considered to be over. Companies are aware that security is just one of many other challenges they must deal with. Therefore, safety processes are integrated into regular operations and work performance, and responsibilities are assigned according to the functions in the processes.

Nothing affects the behaviour of employees more than the behaviour of their managers. What managers talk about most with their workers is the area they are most

interested in. If they keep asking about production and performance, they show that these factors take precedence over worker safety. If they are concerned about safety, monitoring and measuring safety will send a clear signal of its importance. The position of managers in the organization ensures that they have a strong influence on different dimensions of human and organizational factors: workplace situations, groups, organizational processes, etc., and consequently, that they promote safer behaviour.

Safety leadership is a critical aspect of any organization's health and safety program. It plays a vital role in developing a strong safety culture, which can ultimately lead to a safer workplace, increased productivity, and better employee morale.

As today's workforce continues to evolve, so do the challenges of leading a multigenerational team. Therefore, it is necessary to apply effective strategies to effectively lead and manage different teams. Safety requirements are an integral part of that (Arnold, 2023).

Rapid social changes in workplace culture are evident in recent years, and therefore the importance of mental health in the workplace is increasing. There are obvious cultural differences and differences in expertise, abilities, interest, and motivation of workers. It has become imperative for business leaders to focus on how their company culture affects their employees and whether their employees feel safe, seen, and supported. The concepts and practices that leaders have used over the centuries to create commitment, accountability, and excellence are changing. Managers must have a deeper understanding of how these issues affect every aspect of organizational performance. The COVID-19 pandemic was a global event that broke through the barrier of significant systemic change. Moreover, we are still experiencing changes from psychological 'swelling' to 'lying down' and the great phenomenon of resignation. However, the change is accelerating and it is necessary to better navigate through volatile social and psychological situations. Systems thinking, integration of people and technical systems, and trust-based leadership are the key ingredients for a new arrangement of people in time and space. Well-being is the goal, and intentionally designing our social networks is a means of becoming 'future-ready' (Carillo, 2023).

It is necessary to recognize that a good culture is simply not enough to achieve top performance. It takes more to achieve better safety results. People look for teams with a purpose, a compelling vision, and a sense of belonging where they can reach their full potential (Havens, 2023).

The change in safety leadership represents a new safety paradigm that is clear and practical. The goal is to improve safety and overall organizational performance with a feasible, different, and focused approach using multiple small steps. It is essential to integrate the natural variability of human performance – and our ability to compensate for unpredictability elsewhere – into organizational systems, thus ensuring successful outcomes. This approach covers important topics, including complexity, effective workplace innovation, micro experiments, maintaining alignment between rules and reality, maximizing learning, and restoring relationships (De Boer, 2021).

Safety is traditionally defined as a state in which the number of adverse outcomes is as low as possible. From this perspective, the purpose of safety management is to ensure that the number of accidents and incidents is as low as possible or as low as reasonably practicable. This means that safety management must start from the manifestations of non-existence of safety and that, paradoxically, safety is measured by counting the number of cases in which it fails, not the number of cases in which it succeeds. This inevitably leads to a reactive approach based on reacting to what goes wrong or what is identified as a risk – something that *could* go wrong.

Focusing on what goes right rather than what goes wrong changes the definition of security from 'preventing something from going wrong' to 'ensuring that everything goes right'. More precisely, safety is the ability to succeed in different conditions, so that the number of planned and acceptable outcomes is as high as possible. From that perspective, the purpose of safety management is to ensure that as much as possible goes right, in the sense that day-to-day operations achieve their goals. This means that safety is managed by what is achieved (successes, things that go right), and is also measured by counting cases where things go right. In order to achieve this, security management cannot only be reactive, it must also be proactive. But it must be proactive about how actions succeed, to day-to-day acceptable performance, rather than how they can fail, as traditional risk analysis does (Hollnagel, 2014).

For leaders to fulfil their process safety responsibilities, they must demonstrate the same leadership attributes required for success in every other business area.

Much has been written about the differences between management and leadership. Managers manage things and lead people. Traditional safety approaches have sought to manage people through the imposition of rules, policies, procedures, rewards, and punishments, which inevitably requires a bureaucratic, hierarchical, top-down management style aimed at enforcing compliance. This very approach has prevented the development of something that organizations need most to manage risk and foster a culture of care, which is trust.

The new generation of safety leaders must continue to focus on risks and their mitigation. It must still meet regulatory standards and be involved in designing secure systems and practices. The difference is that the new generation of safety leaders does this with their teams, while until now they mostly worked alone.

A new generation of safety leaders recognizes every meeting, every tool talk, and every conversation as an opportunity to build trust and show care. In order to achieve this, they will possess the necessary knowledge and skills. They will 'talk' less and ask more, knowing their teams have most of the answers they are looking for. These actions will help leaders engage their teams, resulting in ownership, pride, intrinsic motivation, and trust. Such psychologically safe teams begin a shift towards working on safety differently and have the

confidence to share their ideas, concerns, and even their mistakes.

The new concept of safety leadership implies that leaders should be authentic people based on values, brave and humble enough to be vulnerable, discard their masks, and honestly associate with their people. Safety leadership requires a generational change towards a humanistic approach.

A survey by Acre Frameworks Advisory (composed of 96 senior health and safety professionals from over 20 different sectors) found that 89% of panel members rated non-technical skills as most important and 100% said that technical skills were the least important when hiring and developing health and safety managers (Acre, 2020). Therefore, it is necessary to effectively define a more advanced set of non-technical skills.

Based on the research, the following key attributes of the new generation of safety leaders were identified:

It is necessary to

- constantly ask questions, not to know;
- become masters of emotional and relational intelligence, not of technical expertise;
- inspire others to find meaning in the work they do and create intrinsic motivation, rather than offer only extrinsic rewards;
- discover unprecedented opportunities and challenges by embracing uncertainty and vulnerability, not by trying to remove humanity from work processes;
- be a servant leader, not an authority figure in a hierarchical relationship;
- listen and teach, not command and control (Acre, 2020).

According to the new concept, effective safety managers must possess a range of skills and attributes that enable them to successfully promote and maintain a strong safety culture. Some of the key attributes include the following:

Commitment to safety – Leaders need to demonstrate their commitment through their behaviours and decision making authentically.

Communication Skills – Effective safety leaders must be skilled communicators who can articulate the importance of safety in a way that resonates with employees. They must be able to actively listen to employee concerns and provide clear and concise feedback to help resolve safety issues.

Questioning – Knowing what questions to ask and when can help a leader determine competence assurance and make sure the relevant controls are in place to stop something bad from happening.

Listening – Effective listening can be perceived as caring by the workforce, as it can lead to people feeling that their leaders want to hear what they have to say.

Integrity – Having integrity means being self-aware, showing your personal values (what you care about), and managing your emotions.

Emotional Intelligence (Humanity) – Having emotional intelligence means you are self-aware and you understand how you come across to others.

Empathy – Safety leaders must be able to empathise with employees and understand their concerns and challenges related to workplace safety. The empathy helps build trust and relationships with employees, which is critical to fostering employee engagement in safety initiatives.

Adaptability – As the work environment and safety regulations evolve, effective safety leaders must be able to adapt their strategies and approaches to meet these changing demands. They should be open to learning from past experiences and implementing new ideas and best practices.

Decision-making skills – Safety leaders must be able to make informed decisions based on a thorough understanding of the organization's security needs and priorities. They need to be able to weigh the potential risks and benefits of different options and choose the most appropriate course of action.

Situational Leadership – The ability to adapt the style of leadership used to the situation at hand is something leaders do not always get right. Leaders specifically need to know when a command-and-control style is appropriate and when it is not.

Accountability – Accountability is the personal choice to rise above your own circumstances and demonstrate the responsibility necessary to achieve desired results.

Visibility – Being present and visible among workers reassures people that you care about them and that you can see for yourself that everything that can be done for safety has actually been done.

Standard setting – Implementing a just and fair culture means standards for acceptable behaviour within the organizations are set. Leaders must define and communicate clearly the line between acceptable and unacceptable behaviours.

All of these are key traits of an effective safety leader.

The fundamental approach of the new concept is to approach people as a solution, recognizing their skills, knowledge, and experience. Therefore, employees are involved in the processes. This approach replaces control with curiosity, prescription with participation, and instruction with involvement. Applying this approach is a step towards the decentralization of power and decision-making about safety by involving workers who do specific work.

Joint efforts in building relationships between adults and psychological safety help the organization to develop organically according to this approach. Conversely, if trust and psychological safety are low, it will be difficult to introduce a new approach, since no new initiative (regardless of merit) is likely to gain traction among a fearful or distrustful workforce.

Safety leaders who want to embark on a journey towards a different way of doing safety should consider whether or not they have created a climate where this approach is likely to be accepted. The new concept of safety leadership relies on trust.

CONCLUSION

Some believe that safety leadership is nothing more than another component of leadership in general. Companies, in the context of their managerial

transformations, establish requirements that prescribe what they expect from their managers-leaders. Among other things, they put safety in it. However, safety leadership requires adequate professional knowledge and skills in the field of safety, which managers do not possess. According to the new concept, effective safety leaders must possess a range of skills and attributes that enable them to successfully promote and maintain a strong safety culture.

It can be concluded that the goals and objectives of this research have been achieved. A survey of recent literature was conducted, in which the defined research methodology was compared.

The proposed hypothesis has been confirmed: there are new safety leadership concepts.

In order to continue with this line of research, empirical research should be conducted on the application of the new concept of safety leadership.

REFERENCES

Acre (2020). *Co-creating the future of H&S leadership development*. Retrieved 8 October 2023, from https://www.acre.com/thought-leadership/co-creating-the-future-of-h-and-s-leadership-development

Armstrong, M. (2001). *Complete managerial skills - Managing people and yourself*, M.E.P. Consult.

Arnold, J. (2023). *Leading Across Generations: A Guide to Managing and Motivating a Multi-Generational Workforce*. Kindle Unlimited.

Bass, B.M. (1981). *Stogdill's Handbook of Leadership.* Free Press.

Bedein, A.G., & Glueck, W.H. (1983). *Management*. Dryen Press, Hinsdel III.

B-Safe Management Solutions. (2023, October 8). *Safety Leadership*. Retrieved 8 October 2023, from https://www.behavioural-safety.com/behavior-based-safety-solution-center/safety-coaching-and-training/safety-leadership

Carillo, R.A. (2023). *Health and Safety Leadership Strategy*. Routledge.

Carnegie, D. (1995). *The leader in us*. Prosvjeta.

Cole, A.G. (1990). Management: Theory and Practice. DP Publications Ltd.

Cooper, D. (2018). *Assessing safety culture: Old wine in a new bottle*. B-Safe Management Solutions. Retrieved 8 October 2023, from http://www.behavioral-safety.com/articles/she_expo_%202018.pdf

De Boer, R.J. (2021). Safety Leadership - A Different, Doable and Directed Approach to Operational Improvements. CRC Press.

Havens, J. (2023). Leading with Significance: How to Create a Magnetic, People-First Culture. Greenleaf Book Group Press.

Hodgetts, R.M. (1985). *Management*. Academic Press.

Hollnagel. E. (2014). *Safety-I and Safety-II The Past and Future of Safety Management*. CRC Press.

Katić, T., Ban, K., & Palačić, D. (2013). The influence of the leadership model on the application of interpersonal communication in the safety management system, *Management and Safety, 8*, 327-339.

Loyd., C. (2021). *Next Generation Safety Leadership*. CRC Pres, London.

Palačić, D. (2004). *Leadership as a process function of occupational safety management*. V. Zbornik stručno-znanstvenih radova "Čovjek i radna okolina". IPROZ.

Palačić, D. (2010). Research on the development and impact of safety culture on the safety management system. *Sigurnost, 52*(2), 105-112.

Palačić, D., & Mudri, M. (2014). Defining Policy for Management of Occupational Health, Safety at work and Environmental Protection in order to Manage the Crisis in a Business Organization, *Collegium Antropologicum, 38* (Suppl. 1), 13-24

Pavković, D. (2006). Occupational safety as a function of organizational culture. *Sigurnost, 48*(3), 285-294.

Petersen, D. (1996). *Analyzing Safety System Effectiveness*. John Wiley and Sons.

Petersen, D. (2003). *Techniques of Safety Management: A Systems Approach*. American Society of Safety Engineers.

Petersen, D. (2005). *Measurement of Safety Performance*. American Society of Safety Engineers.

Petersen, D. (2021). *Safety management: A human approach*. American Society of Safety Engineers.

Weihrich, H., & Koontz, H. (1998). *Management*. Mate.

Žugaj, M., & Brčić, R. (2003). *Management*. Varteks & FOI Varaždin.

20th International Conference Man and Working Environment
SEMSIE
Safety Engineering & Management – Science, Industry, Education

www.znrfak.ni.ac.rs/semsie

MAJA MEŠKO[1]
SNEŽANA ŽIVKOVIĆ[2]
TAMARA RADJENOVIĆ[3]
MIRKO MARKIČ[4]

[1]University of Maribor, Faculty of Organizational Sciences, Kranj
[2,3]University of Niš, Faculty of Occupational Safety, Niš
[4]University of Primorska, Faculty of Management, Koper

[1]*maja.mesko@um.si*
[2]*snezana.zivkovic@znrfak.ni.ac.rs*
[3]*tamara.radjenovic@znrfak.ni.ac.rs*
[4]*mirko.markic@fm-kp.si*

OCCUPATIONAL HEALTH AND SAFETY PRACTICES IN SLOVENIA AND SERBIA: COMPARATIVE ANALYSIS

Abstract: *Ensuring occupational health and safety (OHS) and preventing injuries at work and occupational diseases is one of the main priorities of every employer. Therefore, the employer must enable the employee to work in a safe and healthy working environment, and the employee has to comply with the regulations and safety precautions and perform the work carefully. Nevertheless, every worker is exposed to accidents in the workplace, even when some workplaces are less risky. This study focuses on reviewing legislation, national and international standards, and certifications for OHS in both countries. Additionally, it explores examples of good practices in the field of OHS in Slovenia and Serbia. The findings of this study contribute to a better understanding of the measures and initiatives taken to ensure OHS in these countries. By identifying successful practices, this research aims to serve as a useful resource for improving OHS policies and practices in Slovenia and Serbia.*

Keywords: working environment, occupational health and safety, comparison between Slovenia and Serbia

INTRODUCTION

Occupational health and safety (OHS) refers to the practices and procedures put in place to prevent harm and protect workers' physical, mental, and social well-being in the workplace. It is concerned with identifying and controlling risks, hazards, and dangers associated with work activities to ensure employees a safe and healthy working environment (Alli, 2008). OHS goals include preventing workplace injuries, illnesses, and fatalities, promoting employee well-being, reducing absenteeism and accidents, improving productivity, and complying with legal and regulatory requirements (Zanko & Dawson, 2012). Key components of OHS include risk assessment and management, workplace hazard identification and control, training and education for employees, ensuring proper use of personal protective equipment, regular safety inspections, accident and incident reporting and investigation, emergency preparedness and response plans, and ongoing monitoring and evaluation to improve safety performance continuously (Darabont et al., 2017). OHS are essential aspects of responsible and ethical business practices, as they demonstrate a commitment to the health and well-being of employees, reduce potential liability and costs associated with workplace incidents, and contribute to overall organizational success (Vasconcelos et al., 2016). This study analyzes the legislative framework, national and international standards, and certifications for OHS in Slovenia and Serbia. It also examines examples of good practices in the field of OHS in these countries.

A GENERAL OVERVIEW OF THE LEGISLATION ON OHS IN SLOVENIA AND SERBIA

OHS in Slovenia is regulated under the Health and Safety at Work Act (ZVZD-1), adopted by the National Assembly of the Republic of Slovenia at its session on May 24, 2011. This Act lays down the rights and duties of employers and workers with respect to healthy and safe work and measures to ensure OHS (Health and Safety at Work Act (ZVZD-1), 2011). The Ministry of Labour, Family, Social Affairs and Equal Opportunities oversees the country's OHS practices. The Labor Inspectorate of the Republic of Slovenia conducts inspections and enforces compliance with the regulations (The Ministry of Labour, Family, Social Affairs and Equal Opportunities, 2023).

The OHS system in Slovenia is based on preventing accidents, injuries, and occupational diseases and promoting overall health in the workplace. Employers are required to perform risk assessments and implement measures to prevent or minimize workplace hazards. This includes providing appropriate employee training, maintaining safety equipment, and establishing emergency response procedures (The Ministry of Labour, Family, Social Affairs and Equal Opportunities, 2023).

Slovenia has also established several measures to prevent occupational hazards and promote employee well-being. These include regular medical check-ups for employees, ergonomic workplace design, and promoting mental health in the workplace. There is an emphasis on raising awareness and providing education on OHS practices for employers and workers (The Ministry of Labor, Family, Social Affairs and Equal

Opportunities, 2023).

The Law on Safety and Health at Work regulates OHS practices in Serbia. The Ministry of Labor and Social Policy oversees and implements these regulations. The National Occupational Safety and Health Institute plays a key role in providing training and support for occupational safety measures (European Agency for Safety and Health at Work, 2023).

The law in Serbia establishes general obligations for employers and employees to create safe and healthy working conditions. Employers are required to assess workplace risks and implement appropriate preventive measures. Workers have the right to be adequately informed and trained regarding OHS procedures. The law also covers aspects such as record-keeping, reporting of accidents or illnesses, health surveillance, and providing personal protective equipment.

Both countries have legislation to ensure OHS in various industries. However, the effectiveness and enforcement of these measures may vary, and organizations must stay up-to-date with the relevant regulations to ensure compliance and protect OHS (European Agency for Safety and Health at Work, 2023).

COMPARISON OF LEGAL FRAMEWORKS OF OHS BETWEEN SLOVENIA AND SERBIA

Different legal frameworks govern the health and safety regulations at workplaces in Slovenia and Serbia and may vary in certain aspects. Here is a comparison between the OHS in Slovenia and Serbia (The Ministry of Labor, Family, Social Affairs and Equal Opportunities, 2023; Serbia: New Law on Safety and Health at Work, 2023):

1. Legal Framework:

- Slovenia: In Slovenia, the Health and Safety at Work Act (ZVZD-1) is the main legislation governing workplace health and safety.

- Serbia: In Serbia, the Law on Safety and Health at Work was published on April 29, 2023, in the Official Gazette of RS no. 35/23, providing the legal framework for health and safety regulations in the workplace.

2. Responsibilities and Duties:

- Slovenia: Employers in Slovenia have a duty to implement measures that ensure the OHS. They must appoint a competent person to oversee workplace safety and establish a health and safety committee if there are more than 20 employees.

- Serbia: Similarly, employers in Serbia are responsible for implementing necessary measures to protect employees' health and safety. They must appoint a Safety Officer and adopt OHS regulations.

3. Risk Assessment and Management:

- Slovenia: Slovenian employers must conduct risk assessments to identify potential hazards and take appropriate preventive measures. Hazardous substances, equipment, and work processes need to be properly managed.

- Serbia: Similarly, employers in Serbia are mandated to conduct risk assessments and implement preventive measures. They must document their findings and take steps to minimize risks.

4. Worker Participation and Training:

- Slovenia: Workers in Slovenia have the right to participate in matters related to OHS, including the right to refuse unsafe work. Employers are also responsible for providing necessary training and instructions to employees.

- Serbia: In Serbia, workers have the right to participate in decision-making processes related to OHS matters. Employers are required to provide appropriate training and information to employees.

5. Inspections and Penalties:

- Slovenia: Slovenia has a systematic system of regular inspections by the labor inspectorate. Non-compliance with OHS regulations can result in fines and penalties.

- Serbia: Serbia also has a system of inspections carried out by the Labour Inspectorate. Violations of health and safety regulations can lead to penalties and legal consequences.

OHS IN SLOVENIA AND SERBIA: A COMPARATIVE ANALYSIS

Implementing OHS is a long-standing tradition in Slovenia. The state has established strict regulations and organizations that take care of the implementation of these regulations. Industries such as construction, manufacturing and the chemical industry are exposed to various risks that need to be controlled and managed. Slovenia is one of the countries with the lowest number of occupational accidents and occupational diseases per worker. This results from improved awareness of the importance of OHS and the implementation of preventive measures. Organizations actively cooperate with trade unions and institutions to improve working conditions and reduce workplace hazards (Pavlič et al., 2011).

On the other hand, Serbia is on its way to enforcing OHS standards. Despite the recent adoption of laws and regulations governing OHS, they still face challenges in this area. Work-related accidents are still a major problem in some industries. A lack of professionals, a lack of worker awareness, and an outdated infrastructure contribute to increasing occupational hazards. There is a need for more control and implementation of preventive measures in the industry and strengthening cooperation between organizations, unions, and institutions.

Similarities between Slovenia and Serbia lie in the fact that both countries take care of the use of protective equipment, provision of first aid, and workplace lighting. Both countries have established institutions that monitor and control OHS regulations implementation. It is also important to mention that it is important to educate workers, raise awareness of the importance of OHS, and promote a workplace safety culture in both countries.

In the future, it is necessary to improve OHS in Slovenia and Serbia. The fundamental steps include education, control, and implementation of preventive measures, and coordination between institutions and organizations. Cooperation between the two countries in exchanging experience and good practices to achieve the highest safety and health standards at work is also important.

NATIONAL AND INTERNATIONAL STANDARDS AND CERTIFICATIONS FOR OHS IN SLOVENIA AND SERBIA

National and international standards and certifications for OHS in Slovenia and Serbia are mostly based on European standards and guidelines.

In Slovenia, the key OHS standard is ISO 45001:2018, which replaced the previous standard, OHSAS 18001. This standard sets the requirements for systematic OHS management in organizations and provides a framework for preventing accidents and occupational diseases. Organizations seeking certification must adhere to the guidelines of the standard and fulfill all its requirements (Črv, 2023).

In Serbia, the standard for OHS is SRPS OHSAS 18001:2008, which is adapted to local legislative requirements. This standard follows the guidelines of the OHS management systems and sets forth preventive measures to reduce risks and improve working conditions. This standard was valid in the Republic of Serbia until April 5, 2018, and after that date, the regulation of OHS issues at the organizational level is harmonized exclusively according to SRPS ISO 45001:2018 (OHSAS 18001, 2023).

In addition to standards, some certification organizations conduct OHS certification in Slovenia and Serbia. In Slovenia, one of the most recognized certification organizations is the Association for Testing and Certification (ZAPS), which carries out certifications in accordance with the requirements of ISO 45001:2018. In Serbia, a similar role is undertaken by the Ministry of Labor, Employment, Veterans, and Social Affairs, which conducts certification in accordance with the RS 18001 standard (The Ministry of Labor, Family, Social Affairs and Equal Opportunities, 2023; Serbia: New Law on Safety and Health at Work, 2023).

Obtaining a certification for OHS proves that an organization meets the standard's requirements and demonstrates a proper dedication to OHS. It can bring several benefits, such as improving reputation, preventing accidents and occupational diseases, and enhancing employee working conditions.

EXAMPLES OF GOOD PRACTICES IN THE FIELD OF OHS IN SLOVENIA AND SERBIA

Examples of good practices in Slovenia (Kovačič, 2023):

1. Rewarding safe work: Some companies in Slovenia reward their employees for practicing safe work and adhering to safety procedures. This encourages a positive safety culture and reduces the number of work accidents.

2. Education and training: Slovenian companies actively engage in educating their employees about OHS. They provide the necessary knowledge and skills for accident prevention and proper response in case of danger.

3. Employee involvement: OHS in Slovenia is considered the responsibility of all employees in a company. Companies encourage employee participation in identifying hazards and improving safety procedures and overall safety systems.

4. Regular workplace evaluations: Companies conduct regular risk assessments and perform inspections to ensure safety and health measures are appropriate. Equipment and machinery are regularly maintained and tested to ensure employee safety.

Examples of good practices in Serbia (Macuzic et al., 2016; Rakic et al., 2018):

1. Building safety awareness: Companies in Serbia strive to educate and raise employee awareness about the importance of OHS. They organize training sessions, workshops, and campaigns to promote a positive safety culture.

2. National programs and campaigns: Various national programs and campaigns are implemented in Serbia to improve OHS. These programs provide information on legislation, guidelines, training, and awareness regarding OHS.

3. Collaboration between employers and unions: Employers and unions in Serbia collaborate to shape and implement OHS policies and programs. Together, they strive to provide all employees with a safe and healthy working environment.

4. Measures to prevent workplace accidents: Serbian companies implement various measures to reduce the risk of work accidents, such as the use of personal protective equipment, regular equipment maintenance, promotion of ergonomic workstations, and conducting regular safety inspections and accident analyses.

These examples of good practices in Slovenia and Serbia represent a few of the approaches used to improve OHS in these countries. Implementing these practices is crucial for ensuring a safe and healthy working environment.

CONCLUSION

Based on the examples of good practices in OHS in Slovenia and Serbia, the following conclusions and recommendations can be made for enhancing mutual exchange of experiences and improving OHS:

1. Increase communication and collaboration: Slovenia and Serbia should establish strong connections and collaboration between relevant institutions, organizations, and experts in OHS. Regular exchange of information, experiences, and best practices will contribute to improving standards and approaches in both countries.

2. Organise joint conferences, seminars, and workshops: arranging joint events focused on OHS, such as conferences, seminars, and workshops, will

facilitate the exchange of knowledge, experiences, and ideas among professionals from Slovenia and Serbia. This will stimulate innovative approaches, foster collaboration, and develop common guidelines for enhancing OHS.

3. Establish bilateral working groups: Slovenia and Serbia should establish bilateral working groups that regularly collaborate on developing and implementing safety standards, guidelines, and legislation in both countries. Communities of experts from both countries can exchange knowledge and experiences and participate in joint research and projects aimed at improving OHS.

4. Support European and international initiatives: Slovenia and Serbia should actively participate in European and international initiatives and projects in the field of OHS. This will enable them to access the latest information, trends, and guidelines that can be utilized to enhance practices in both countries.

5. Exchange educational programs: Slovenia and Serbia can exchange educational programs and training in the field of OHS. This will contribute to greater awareness and knowledge among employees in both countries and strengthen a shared understanding of concepts and approaches to OHS.

Ensuring OHS is crucial in any society. Through the exchange of experiences and close collaboration between Slovenia and Serbia, both countries can advance in improving standards and providing a safe and healthy working environment for all employees.

ACKNOWLEDGEMENTS

This paper is part of the Bilateral Project Slovenia-Serbia (No. 337-00-110/2023-05/52).

REFERENCES

Alli, B. O. (2008). *Fundamental Principles of Occupational Health and Safety*. Geneva: ILO.

See Legal Matters. (2023). *Serbia: New Law on Safety and Health at Work*. Retrieved October 12 2023, from https://ceelegalmatters.com/serbia/23363-serbia-new-law-on-safety-and-health-at-work

Črv, S. (2023). Occupational Accidents and Occupational Health and Safety Management Systems ISO 45001: 2018 in EU. *RUO. Revija za Univerzalno Odlicnost*, *12*(1), 18-42.

Darabont, D. C., Antonov, A. E., & Bejinariu, C. (2017). Key elements of implementing an occupational health and safety management system using ISO 45001 standard. In *MATEC web of conferences* (Vol. 121, p. 11007). EDP Sciences.

European Agency for Safety and Health at Work. (2023, October 11). *Serbia*. Retrieved October 11 2023, from https://osha.europa.eu/en/about-eu-osha/national-focal-points/serbia

Health and safety at work act (ZVZD-1). (2011). Retrieved October 13 2023, from https://www.ilo.org/dyn/natlex/docs/ELECTRONIC/89470/102799/F2013305698/Slovenia%20Health%20and%20Safety%20at%20Work.pdf

Kovačič, H. (2023). Occupational health in Slovenia. *Teorija in Praksa*, *60*(1), 136-180.

Macuzic, I., Giagloglou, E., Djapan, M., Todorovic, P., & Jeremic, B. (2016). Occupational safety and health education under the lifelong learning framework in Serbia. *International Journal of Occupational Safety and Ergonomics*, *22*(4), 514-522. https://doi.org/10.1080/10803548.2016.1153222

The Ministry of Labor, Family, Social Affairs and Equal Opportunities. (2023, October 6). *Varnost in zdravje pri delu*. Retrieved 6 October 2023, from https://www.gov.si/podrocja/zaposlovanje-delo-in-upokojitev/varnost-in-zdravje-pri-delu/

OHSAS 18001. (2023). Health and safety management OHSAS 18001. Retrieved 14 October 2023, from https://www.nqa.com/nl-nl/certification/standards/ohsas-18001

Pavlič, M., Likar, B., Pavlič, A., & Markič, M. (2011). Managing occupational injuries records in Slovenia from 1948 to 2008. *Safety science*, *49*(6), 834-842. https://doi.org/10.1016/j.ssci.2011.01.013

Rakic, S., Novakovic, B., Stevic, S., & Niskanovic, J. (2018). Introduction of safety and quality standards for private health care providers: a case-study from the Republic of Srpska, Bosnia and Herzegovina. *International Journal for Equity in Health*, *17*, 1-21. https://doi.org/10.1186/s12939-018-0806-0

Vasconcelos, D., Melo, M. B., Souto, M. S. M., Caldas, A., & Muniz, D. (2016). Good management practices of the waste and of the health and the safety conditions in the constructive process: Sustainability, social responsibility and ethical business activity. *Occupational Safety and Hygiene IV; CRC Press: New York, NY, USA*, 133.

Zanko, M., & Dawson, P. (2012). Occupational health and safety management in organizations: A review. *International Journal of Management Reviews*, *14*(3), 328–344. https://doi.org/10.1111/j.1468-2370.2011.00319.x

20th International Conference Man and Working Environment
SEMSIE
Safety Engineering & Management – Science, Industry, Education

www.znrfak.ni.ac.rs/semsie

FILIP KOVAČIĆ[1]
DARKO PALAČIĆ[2]

[1,2] University of Applied Sciences in Security and Safety, Zagreb

[1]*filipkovacic13@gmail.com*
[2]*darko@vss.hr*

COMPARATIVE ANALYSIS OF THE FUNDAMENTAL ELEMENTS OF OHS LEGAL REQUIREMENTS IN CROATIA AND SERBIA

Abstract: *Effective management of safety at work is the goal of every responsible legislator, i.e. the state, whereas the solid and comprehensive legal framework is the basis for the effective implementation of occupational safety. Safety at work is therefore an integral part of the legislation of the Republic of Croatia and the Republic of Serbia, but also a part of the fundamental values and civilizational achievements of modern times. The aim of this paper is to analyse and present the current legislation in the management of the process of occupational safety in the Republic of Croatia and the Republic of Serbia and, in accordance with the conducted analysis, to present a personal review of authors through the discussion of the obtained research results and previously set hypotheses, after which conclusions are made and hypotheses are confirmed or refuted.*

Keywords: comparative analysis, occupational health and safety, legal regulations, Republic of Croatia, Republic of Serbia

INTRODUCTION

According to official data recorded by the World Health Organization (WHO) and the International Labour Organization (ILO), it is estimated that 1.9 million people die from occupational diseases and injuries at work worldwide annually. However, a closer look at the statistics of this estimate leads to interesting data that "only" 19% of these deaths result from occupational injuries, while the other 81% are associated with occupational diseases, caused or exacerbated by harmful exposures in the workplace. This is proof that the consequences of adverse effects on the health of workers do not have to be immediately obvious, but they entail inevitable and often fatal consequences. This fact reflects the importance and necessity of systematic, high-quality and consistent implementation of the occupational health and safety management model.

The occupational health and safety management system is part of the overall system that realizes the management of health risks inherent in the business activities of the organization. The system includes organizational structure, planning, responsibility, practice, procedures, processes, and resources for the development, application, realization, review and maintenance of the organization's health and safety policy (Palačić, Mudri, 2014).

In the circumstances of specific socio-economic, technological and economic circumstances of today, occupational safety should be a constructive and indispensable part of any work organization, regardless of its type, size, or activity that a business entity is engaged in. The key factors of quality implementation of Occupational health and safety (hereinafter referred to as OHS) are a quality, exhaustive and unambiguous legislative framework, as well as the level of awareness of one's own environment and the level of knowledge of the matter, work tasks and workplace. The higher the level of occupational safety professionals, the greater the level of awareness of possible hazards and risks.

Speaking about the specifics of today's working conditions, it is inevitable to mention the increasingly widespread tendency to work from home, especially after the outbreak of the global Covid-19 pandemic. This is supported by the Eurostat survey – the Statistical Office of the European Communities for 2020 and 2021, respectively. The research showed that in the years before the Covid-19 epidemic, only 5.5% of the working population of the EU practiced working from home, while in times of full swing of the epidemic in 2020 and 2021, this percentage increased to 12.3% and 13.5%, respectively. A simple statistical calculation easily leads to the conclusion that in this regard, the number of workers working from home has increased by as much as 123.7% and 140%, respectively. Such a rapid and abrupt change has welcomed much more socially and legally developed EU member states than Croatia, especially in terms of preserving health and safety at work, which has brought many legislators, as well as OHS, to a new challenge.

Occupational health and safety can also be determined as a system of technical, health, legal, psychological, pedagogical and other activities, which detect and eliminate dangers and harms that can endanger the life and health of persons at work (Palačić, 2006).

Occupational health and safety is an integral part of the legislation of the Republic of Croatia and the Republic of Serbia, but also a part of the fundamental values and civilizational achievements of modern times and an extremely important aspect of corporate social responsibility of the 21st century. Therefore, OHS should be seen as the benefit of all subjects of a business organization, and not as unnecessary fatigue

or unnecessary expense, as many ignorant of this profession often superficially articulate.

METHODOLOGY

Aim, tasks and research methodology

Occupational health and safety in each country is prescribed by national regulations. Given that Serbia this year published a new Law on Safety and Health at Work, the aim of this research is to compare the basic elements of the implementation of occupational safety in Croatia and Serbia.

According to the objective set, the tasks of the research are:

- collect data on the basic elements of implemented OHS in Croatia and Serbia
- analyse the content of the implemented OHS in Croatia and Serbia
- compare analysed data on the implementation of OHS in Croatia and Serbia.

In the implementation of comparative analysis, a number of scientific methods are applied, which, by their combination and order, constitute an established research methodology that should meet the requirements of the planned research. A combination of deductive and inductive analysis is applied in order to classify and summarize the basics of the subject of research. The documentation study method analyses national regulations for the implementation of occupational safety. The method of description describes the essential features, and after comparative analysis and comparison, common properties, i.e. identification, are synthesized, and conclusions are drawn.

Hypotheses

Based on the recognised problem and the set goal of the research, 3 hypotheses have been set, which will be confirmed or rejected based on the results of the conducted research:

H1: The responsibilities and duties of the employer in the implementation of OHS are identical in both states.

H2: Contracting for OHS is identical in both countries.

H3: The conditions for performing working tasks of OHS specialists are identical in both countries.

RESULT AND DISCUSSION

Occupational health vs occupational safety vs safety at work

From the very beginning of work and production processes, man was exposed to dangers that he began to notice and that brought certain consequences. OHS, or whatever you call this area, began to develop back in the day. (Učur and all, 2023).

In practice, different terms such as Occupational health, occupational safety and safety at work are used in different countries, on different continents in the subject area of this research. In Croatia, the Occupational Health and Safety Law is in force, while in Serbia the Law on Safety and Health at Work is in force, and at the national level these terms are used. Although at first it may be thought that all these terms mean the same, this is not really the case.

Occupational health deals with a variety of illnesses and conditions. One of the primary concerns for office workers is a sedentary lifestyle. A sedentary lifestyle can cause a series of negative health problems like obesity and diabetes. Occupational health seeks to reduce employees' health risks by improving their lifestyles. The goal of occupational health is to promote physical and mental wellness. Occupational health focuses on the employee as a whole. It takes into account lifestyle choices, genetic predispositions, and mental health on top of workplace hazards (Work Health Solutions).

Occupational safety protecting employees. Occupational safety deals with all aspects of physical, mental and social health and safety in a workplace. It is the umbrella for the company's efforts to prevent injuries and hazards in all work environments. Every industry presents various kinds of safety hazards to its employees (PropleHum, 2023).

Safety at work is a synonym for occupational or workplace safety, and refers to the measures, guidelines, and procedures to protect employees from hazards they may encounter while performing their jobs. Workplace safety aims to create a healthy and safe environment where workers can perform their tasks without risk to their well-being (HSEblog, 2023).

One simple way to understand the difference between occupational health and safety and workplace health and safety is to think of occupational health and safety as the laws, agencies and guidelines created to ensure worker health and safety. This includes agencies such as OSHA in the U.S., The Center for Occupational Health and Safety in Canada, EU-OSHA in the UK, the Administration for Labor and Safety at Work in Croatia Administration for Safety and Health at Work in Serbia, and the rules and guidelines they enforce. Workplace health and safety, on the other hand, at the very least must ensure that employers follow all rules and guidelines created by the above-mentioned agencies (McWhorter, 2019).

Fundamental elements of the implementation of occupational health and safety in Croatia

In the Republic of Croatia, OHS is carried out pursuant to the Occupational Health and Safety Law (Official Gazette no. 71/14, 118/14, 94/18, 96/18). The fundamental elements of the application of OHS covered by this analysis are those that directly confirm or reject the hypotheses. In addition to the above, there are other elements that are not addressed in this analysis.

In accordance with the aforementioned Act, the duties of the employer in organizing and implementing OHS are:

- organising and enforcing OHS
- implementing prevention in all work processes and adaptation to changing circumstances
- improving the level of safety at work and adjusting work procedures to reflect developments and changes
- making modifications in OHS procedures in accordance with technical progress
- reducing workers' exposure to dangers, harms and efforts
- assessing the risks to the life and health of workers, in particular in relation to means of work, working environment, technology, harm, effort, standard work, night work, mental and workload and other risks
- having a risk assessment made in writing or electronic form
- applying OHS rules based on the assessment
- carrying out preventive measures and other activities to prevent and reduce workers' exposure to identified risks
- involving workers or their representatives in the risk assessment process and have documented information thereon
- by a general Act or Ordinance to determine the organisation of the OHS implementation as well as the rights, obligations and responsibilities
- conducting worker training in a safe manner
- prohibiting work for untrained workers
- training of employers and delegates
- informing and consulting workers
- availability of documentation to OHS specialist, authorized, trustee and inspection
- forming an OHS Board if there are more than fifty employees.

In accordance with the OHS Act (Official Gazette no. 71/14, 118/14, 94/18, 96/18), the following procedure is used to contract for OHS performance:

- there is an obligation to identify OHS activities in accordance with the risk assessment
- an employer who employs up to 49 workers, can perform OHS tasks alone (if he meets the requirements for an OHS specialist who has completed first-degree studies) or with an employment contract with an OHS specialist of the 1st
- for objective and justifiable reasons, the employer may enter into a contract with an authorized individual to perform occupational safety.
- an employer employing from 50 to 249 workers is obliged to employ at least one OHS specialist of the 2nd degree, usually by employment contract (if at least 80 percent of workers perform only small-risk tasks, OHS tasks can be performed by at least one OHS specialist of the 1st degree)
- for an employer who employs from 250 to 499 workers, OHS tasks are performed by at least one OHS specialist of the 2nd degree and one OHS specialist of the 1st degree, and up to every subsequent 500 workers at least one more OHS specialist of the 2nd degree (if at least 80 percent of the workers perform exclusively small-risk tasks, at least one OHS specialist of the 2nd degree may perform OHS duties, and for every subsequent 2000 workers at least one OHS specialist of the 2nd degree is required)
- if several employers are operating in the same location, they can coordinate the joint performance of OHS duties based on the previously mentioned criteria.

The working conditions for OHS specialists are as follows:

- the Ordinance on performing OHS (Official Gazette no. 126/19, 154/22) prescribes the types, degrees of professional qualifications and the number of OHS experts, the manner and conditions for performing OHS tasks with the employer, depending on the risks, activity and number of workers
- OHS specialist is a person who has passed the professional exam and obtained a certificate for an OHS professional
- OHS specialist of the 1st degree is a person who has at least a high-school or secondary education degree
- OHS specialist of the 2nd degree is a person who has completed at least an undergraduate study with the acquired title bachelor (baccalaureus).

The most fundamental components of the rules pertaining to OHS implementation in Croatia are outlined here, and all of these components are related to the hypothesis. In addition to the fact that all the elements presented are defined by the Law, there are also a number of bylaws that regulate the individual elements presented in more detail.

Fundamental elements of the implementation of occupational health and safety in Serbia

In the Republic of Serbia, OHS is carried out on the basis of the Law on Safety and Health at Work (Official Gazette no. 35/23). This analysis focuses on the fundamental elements of OHS application that directly confirm or reject the hypotheses. In addition to the above, there are other elements that are not addressed in this analysis.

In accordance with the aforementioned Act, the duties of the employer in organizing and implementing safety at work are as follows:

- to ensure and implement preventive measures of safety and health at work
- if an employee sustains an injury at work as a result of a natural disaster that was unavoidable, the employer is not liable under this Act.
- to adapt the workflow to the capabilities of employees

- to ensure the appropriate working environment conditions
- to provide adequate resources for work and personal protective equipment
- to consult with the employees and/or their representatives and to provide them with appropriate instructions
- to provide preventive measures
- to apply the 9 Principles of Prevention
- all rights, obligations, and responsibilities are defined by general act and employment contract
- to develop a risk assessment act
- to appoint an advisor, i.e. associate for workplace safety and health, by act in writing
- assign the employee to perform tasks at the workplace and in the working environment where occupational safety and health measures have been implemented
- to inform employees and representatives of employees about the dangers and hazards that may lead to injuries at work and health damage
- to organise training of employees for safe and healthy work
- to conduct training of employee representatives
- to ensure the use of personal protective equipment in accordance with the Risk Assessment Act
- to ensure the maintenance of working equipment and personal protective equipment in good condition
- to hire a licensed legal entity to perform routine and preventive equipment inspections and checks, as well as inspection and testing of electrical and lightning installations, as well as preventive and periodic testing of working conditions, i.e. chemical, and physical hazards (except ionizing radiation), microclimate and lighting and biological hazards
- to provide proper medical examinations of employees
- to ensure the provision of first aid, as well as to train an appropriate number of first aid workers
- to prevent any form of work which is a serious, unavoidable and imminent danger to the life or health of employees
- to determine the procedure and manner of issuing work permits and ensure the issuance of a work permits for specific dangerous jobs.

In accordance with the Law on Safety and Health at Work (Official Gazette of RS, no. 35/23) contracting for the performance of occupational safety tasks is carried out as follows:

- the employer is obliged to organise OHS at workplace
- when in comes to OHS activities referred to in Article 50 of this Law, the employer is in charge of OHS alone in the activities of retail trade, accommodation and food services, information and communication, financial and insurance activities, real estate business, professional, scientific, innovation, administrative and auxiliary service activities, compulsory social insurance, education, art, entertainment and recreation, other service activities, if there are up to 20 employees
- the employer is obliged by the general act referred to in Article 14 of this Law, to make an employment contract or other contract in accordance with the regulation governing work,and to regulate obligations and responsibilities related to the daily monitoring and control of the application of occupational safety and health preventive measures
- in terms of OHS at workplace, the employer must appoint one or more individuals with whom he has concluded an employment agreement and who satisfy particular requirements as specified by this Law (advisor, i.e., associate for occupational health and safety).
- occupational safety and health activities may be performed by a person who has passed a professional exam for performing occupational safety and health tasks and has a license to perform the duties of an advisor, i.e. an associate occupational health and safety in accordance with this Law
- if there are no employees who meet the requirements from Article 48, i.e. Article 49 of this Law, the employer may, exceptionally, hire a legal entity or entrepreneur who has a license to perform occupational health and safety
- in the activities referred to in Article 48 of this Act, an employer who employs between251 and 500 employees is obliged to conclude a full-time employment contract with at least OHS advisors, and an employer who employs or hires more than 500 employees is obliged to conclude a full-time employment contract with at least three OHS advisors
- in all other activities, an employer who employs or hires more than 500 employees is obliged to conclude a full-time employment contract with at least two associates for occupational health and safety
- if the employer hires a legal entity or entrepreneur who has a license to perform occupational health and safety, that legal entity, i.e. entrepreneur, determines the number of advisors for safety and health at work.

An OHS specialist must meet the following requirements:

- an employer who performs occupational safety and health tasks is obliged to take a professional exam in OHS as required by the competent Ministry, and is not obliged to have a license.

- according to this law, an individual who has passed a professional exam and obtained a license to act as an advisor—that is, an associate for safety and health at work—may carry out OHS tasks.
- in the activities referred to in Article 48, the employer is obliged to designate a person who can act as an advisor for safety and health at work for OHS tasks, i.e. the person who has acquired at least 240 ECTS credits
- in activities not specified in Article 48, paragraph 1 of this Law, if the employer does not perform OHS tasks referred to in Article 47, paragraph 1 of this Law, they are obliged to designate an officer for occupational safety and health, i.e. a person who has acquired least 180 ECTS credits
- the Minister in charge of labor affairs is accountable for carrying out relevant OHS duties and issues or renews licenses through a decision.

Given that the deputies are not able to apply the Law from 7 May 2023 in the coming period, new bylaws are anticipated in Serbia, which will additionally prescribe and elaborate on these elements.

CONCLUSION

Based on the obtained results are compared in terms of hypotheses, where the hypotheses are either accepted or rejected.

- Hypothesis H1: The responsibilities and duties of the employer in the implementation of OHS are identical in both countries.

The hypothesis is accepted. The results of the conducted research show that the responsibilities and duties of the employer in the implementation of safety at work are identical in both countries, with the exception that in the Republic of Serbia, they are described in more detail.

- Hypothesis H2: Contracting for OHS tasks is identical in both countries.

The hypothesis is rejected. The results of the conducted research show that there are significant differences when it comes to contracting for OHS tasks. In Croatia, an employer can perform OHS tasks on their own in the case of companies with up to 49 employees; however, in Serbia, the employer can perform OHS tasks on his own if there are less than 20 workers, and in certain activities. In order to perform OHS tasks in Serbia, the person must pass a professional exam and have a license, while in Croatia it is only necessary to pass a professional exam. In Serbia, the necessary advisors and associates are designated depending on the number of employees, and in Croatia, the number of specialists depends on the risks at work. In Serbia, it is advised that those persons conclude a full-time employment contract, while in Croatia it is possible to conclude part-time contracts.

- Hypothesis H3: The requirements for performing tasks of OHS specialists are identical in both countries.

The hypothesis is rejected. In Croatia, the tasks of OHS specialists of the 1st degree can be performed by a person who has at least a high school or secondary education. There is no such possibility in Serbia. Also, in addition to passing the professional exam, the OHS specialists in \ in Serbia must have a license that is issued for 5 years, which is not the case in Croatia. Based on a comparative analysis, it is evident that the Republic of Serbia has implemented more detailed regulations in some areas of Occupational Health and Safety (OHS) compared to the Republic of Croatia. In general, it can be concluded that OHS in the Republic of Serbia is prescribed in a more modern and efficient way, which is probably the result of the Law being passed this year, 2023. Given that Croatia has announced that the new Law will be adopted in 2024, it will undoubtedly be necessary to analyze the new provisions at the time of their adoption. New legal solutions in Serbia, in relation to solutions in Croatia, additionally regulate: the conclusion of an agreement on the joint implementation of OHS measures when two employers share a workspace, a single electronic register of occupational injuries is introduced according to the European Methodology of Occupational Injuries (ESAW), as well as the obligation to issue permit to work for dangerous jobs. It is important to highlight that employers have two years from the new law's implementation to align their operations with its requirements. As the Law entered into force on 7 May 2023 there will be time until 7 May 2025 to harmonize. Bearing this in mind, it should be stated that the competent ministry must adopt several bylaws in order for employers to fully implement all of the.

Based on the collected data, a more detailed comparative analysis and determination of the interconnectedness of individual requirements of regulations is proposed. In addition, for the continuation of the research, a more detailed comparative analysis of other provisions of regulations regulating the implementation of occupational safety in Serbia and Croatia is suggested. The established methodology proved to be suitable for the conducted research on the legal requirements of the application of OHS in Serbia and Croatia.

The main reason for the implementation and regulation of OHS is primarily humane. Following the conducted research, the authors emphasize the fact that OHS has once again proven to be a very vivid and interdisciplinary science. Due to accelerated technological progress and inevitable socio-cultural challenges arising from demographic migration at the global level and constant ecological, climate and other changes, OHS is continuously facing new challenges and new complex questions that require a response from the profession, often in cooperation with other scientific fields and experts. Therefore, the task of current and future generations of safety engineers is to devote time and resources to education and continuous improvement of their own knowledge, skills and competencies. They should also advise lawmakers on how to update and modify existing laws to reflect the

state of the industry today. Monitoring and adaptation of legislative regulations and the education system are key factor in maintaining a high-quality system of OHS.

REFERENCES

Albaneze, Ž. (2023) *Komentar potpunog teksta Zakona o bezbednosti i zdravlju na radu („Sl. Gl. RS" br.35/2023)*. Poslovni biro.

Eurostat - European Statistical Office. https://ec.europa.eu/eurostat/en/web/products-eurostat-news/-/edn-20210517-2), Retrieved 30.08.2023.

Eurostat - European Statistical Office. https://ec.europa.eu/eurostat/web/products-eurostat-news/-/ddn-20221108-1, Retrieved 30.08.2023.

HSEblog. Safety At Work | Definition, Benefits, And How To Stay Safe? https://www.hseblog.com/safety-at-work-workplace-safety-tips-you-should-know/, Retrieved 04.09.2023.

McWhorter B. (2019). What is the difference between occupational health and safety and workplace health and safety SafeOpedia. https://www.safeopedia.com/7/1180/health--safety-programs/what-is-the-difference-between-occupational-health-and-safety-and-workplace-health-and-safety, Retrieved 04.09.2023.

Palačić, D. (2006). Security Management. *Zaštita*, 2 (1), 23-25.

Palačić, D., Mudri, M. (2014). Defining Policy for Management of Occupational Health, Safety at work and Environmental Protection in order to Manage the Crisis in a Business Organization. *Collegium Antroplologicum*, 38 (Suppl. 1), 13-24.

PropleHum. Occupational safety, https://www.peoplehum.com/glossary/occupational-safety, Retrieved 04.09.2023.

Učur., M., Kovač, C., Šijaković, A., Krišto, I. (2023) *Osnove prava i zakonodavstvo zaštite zdravlja i sigurnosti na radu*. Zavod za istraživanje i razvoj sigurnosti

WHO/ILO joint estimates of the work-related burden of disease and injury, 2000-2016: global monitoring report. wcms_819788.pdf (ilo.org), Retrieved 30.08.2023.

Work Health Solutions. What's the Difference Between Occupational Health and Occupational Safety, https://workhealthsolutions.com/docs/whats-the-difference-between-occupational-health-and-occupational-safety/, Retrieved 04.09.2023.

Zakon o bezbednosti i zdravlju na radu (Sl. glasnik RS, br. 35/23)

Zakon o zaštiti na radu (N.N.br. 71/14, 118/14, 94/18, 96/18)

20th International Conference Man and Working Environment
SEMSIE
Safety Engineering & Management – Science, Industry, Education

www.znrfak.ni.ac.rs/semsie

MILE VAJKIĆ[1]
BILJANA VRANJEŠ[2]
MILAN ERIĆ[3]

[1]School of Mechanical Engineering, Prijedor
[2]Faculty of Mechanical Engineering, University of Banja Luka
[3]Faculty of Engineering, University of Kragujevac
[1]m.wajkic@gmail.com
[2]biljana.vranjes@mf.unibl.org
[3]ericm@kg.ac.rs

USING VIRTUAL REALITY AND AUGMENTED REALITY FOR TRAINING FOR HEALTHY AND SAFE WORK

Abstract: *Training for healthy and safe work, in addition to being a legal obligation for employers, is the foundation of preventive action in the field of occupational safety and health. In modern industrial systems, there is a need to expedite the process of training for healthy and safe work while maintaining the quality of training. To improve the quality of training for healthy and safe work, it is necessary to introduce advanced technologies into the training process. Currently, virtual reality (VR) and augmented reality (AR) technologies are the most developed, making them the most suitable for integration into the training process for healthy and safe work. This paper explores the possibilities of using VR and AR technology for the purpose of training employees for healthy and safe work. The paper provides an overview of scientific and practical advancements in these technologies for training in healthy and safe work. Examples and case studies are presented, showcasing different software and hardware solutions, demonstrating various applications of VR and AR technologies in training for healthy and safe work. The aim of the paper is to demonstrate how advanced technologies can enhance employee training for healthy and safe work, ultimately improving job skills. The advantages and limitations of implementing these technologies in training for healthy and safe work are discussed, and a model for integrating VR and AR technology into existing training methodologies is proposed.*

Keywords: Virtual Reality (VR), Augmented Reality (AR), training for healthy and safe work

INTRODUCTION

Training for safe and healthy work is the foundation of occupational safety and prevention. The aim of this process is to equip employees with the necessary skills and knowledge to perform their tasks in a safe manner. During training, workers become familiar with potential hazards and harmful aspects in the workplace, the risks they pose, and safety regulations for managing identified risks. Training for safe and healthy work also includes education on ergonomics, which involves proper arrangement of workstations, correct handling of equipment and tools, and appropriate movement and lifting techniques, all aimed at reducing risks in the workplace. This type of training should be regular and tailored to the specific needs of each workplace. In many countries, such training is a legal requirement for employers, who are obligated to provide training for every worker in their respective positions. Training for safe and healthy work for employees in Bosnia and Herzegovina (Republic of Srpska) is conducted according to the current legal regulations when establishing an employment relationship and in case of circumstances in the workplace that affect the level of risk and necessitate changes in measures for safe and healthy work (such as job transfers, introduction of new technologies or tools, or changes in work processes). This training is one of the fundamental duties carried out by the employer. The training methods are defined by the regulations set forth by the relevant ministry (Pravilnik, 2011). Employers provide training for safe and healthy work based on a program that takes into account the employer's industry, the specific job for which the training is conducted, and the type of tasks the worker will perform. Additionally, the program should be in line with the risk assessment document. Training for safe and healthy work consists of two parts: the theoretical part (introduction to general occupational safety rules, organization of occupational safety, obligations in the field of safety, workplace hazards and harm, risk assessment, working environment conditions, organization of first aid, fire safety, and emergency evacuation plan) and the practical part (practical presentation of workplace hazards and harm during work and measures for prevention, elimination, or reduction of emerging risks). Training sessions take place within the company premises, specifically at the workplace. The practical part of the training involves the immediate supervisor. After completing the training and passing the assessment for competence (both in the theoretical and practical aspects), employees receive certificates confirming their qualifications for safe and healthy work. It is important to note that only licensed instructors are allowed to conduct training for safe and healthy work. Periodic assessments of qualifications for safe and healthy work are carried out by the employer

in accordance with the current risk assessment regulations. The development and implementation of new information technologies, along with significant changes in the field of work, have led to alterations and adaptations in training models across various sectors, including occupational safety and health. These trends are changing the approach to knowledge management in the field of workplace safety and health, giving rise to various forms and models of e-learning and training. One of such innovative models for enhancing and improving the quality of training processes in the field of occupational safety and health is the application of Augmented Reality (AR) and Virtual Reality (VR) technologies, which are becoming increasingly accessible to potential users. The aim of paper is to showcase the possibilities for enhancing occupational safety training using Virtual Reality (VR) and Augmented Reality (AR) technologies.

AR (AUGMENTED REALITY) AND VR (VIRTUAL REALITY) TECHNOLOGIES

In the age of modern information technologies, hardware development (phones, tablets, computers) allows for the application of various interactive user-device interactions in diverse fields. The most common forms of such bidirectional interactive connections between users and devices involve the application of Augmented Reality (AR) and Virtual Reality (VR) technologies. AR is the exchange of digital information with the user within a given environment in real-time. In essence, AR is placed in an existing environment with new digital information. With AR technology, users can identify objects in their real-world surroundings using hardware and specialized software, which provides a real-time view of the environment augmented with virtual information on the device screen (Figure 1). Today, AR technologies find wide applications in various spheres. The most common applications of AR are in the fields of medicine, tourism, education, and industry. The use of AR technology in the industry is gaining increasing significance, leading to a growing possibility and necessity for its utilization in training for safe and healthy work.

Figure 1. *AR Display (IKEA Place Application) (Source: https://www.shutterstock.com /search/augmented-reality)*

Unlike AR, which allows us to expand the real world around us with virtual elements, VR immerses users in a completely virtual world. The widespread use, availability, and ease of use of mobile and other smart devices have greatly influenced the development of VR. The VR industry is experiencing tremendous growth, with estimates suggesting that the global VR market will reach $100 billion by 2026 (Okuka, 2022). VR is an artificial, computer-generated simulation or replication of a real environment or situation. It is an artificial environment created and presented to the user in a way that the user accepts it as real. In VR, users 'enter' a virtual environment (Figure 2) generated as a unique combination of auditory, visual, and sometimes tactile and other sensory experiences. This is done to create the illusion that items stored in the computer's memory can be heard, seen, or felt. VR changes the way users interact with the world, offering the ability to use anything, anytime, and anywhere. The simplest form of VR is a 3D representation. The VR360^0 technology is also used, where users are immersed in a virtual world through images or videos recorded in 360-degree format.

Figure 2. *Real-Virtual Environment (Source: https://whataftercollege .com/)*

THE APPLICATION OF AR AND VR IN TRAINING FOR SAFE AND HEALTHY WORK

The technology of AR in the field of training for safety and health is insufficiently explored and still has limited application. The most common pedagogical methods in occupational safety training are primarily theoretical without practical field experience. A group of authors (Rios et al., 2011) conducted a comparative analysis of three training methods: traditional methods (using printed instructions), multimedia instructions (utilizing audio-visual elements), and AR. The application of AR has proven to be the most effective training method compared to the other two. It has been demonstrated that only a well-implemented combination of AR technology and HWD (Head Worn Device) systems can contribute both to improving workplace safety and to successfully executing work tasks (Kim et al., 2016). In the worker training program for safe and healthy work, it is essential to familiarize employees with safety instructions for handling and maintaining work equipment, as well as other guidelines for the safe execution of tasks. Instructions based on AR applications have proven to be more efficient solutions in training (Yim et al., 2010). AR technology can be implemented by displaying security alerts through AR technology. Displayed warning elements should be as simple as possible and easily

visible (Dzwiarek et al., 2008). AR technology has found application in training for safe work in high-risk industries (such as construction, mining, etc.) and in emergencies. Its use in construction, especially during installation modifications, is significant due to the complexity of underground installations and the potential hazards that can arise during work (Talmaki et al., 2010). AR is applied in evacuation training, where its usage enables faster and easier preparation of people for rapid evacuation. With the help of this mobile system, shelters are efficiently located, and the evacuation of people is conducted (Kim et al., 2016). AR technologies introduce indoor orientation and integration with a 3D model, aiding in evacuation. Additionally, two mechanisms are integrated: alarm and SMS service (Tsai et al., 2012).

The application of VR in training for safe and healthy work is less prevalent than the use of AR technology in this field of training. Despite the rapid development of hardware components in the VR technology sector, the software aspect for training purposes in this technology is still not as well developed. The fundamental advantage of VR in safety training lies in the ability to immerse workers in a realistic, simulated, yet controlled environment. This enables them to gain experience and practice dealing with potential hazards and emergencies without risking their safety and health. In this way, workers can engage in a more involved and effective training experience, retaining information for a longer period, building confidence in responding to dangerous situations in accordance with safety procedures, and ultimately improving their performance in real-life situations. Hendrix and Johannsen, (2008) emphasize the advantages of VR in conveying tacit knowledge and providing valuable platforms for real experiences and the transmission of tacit knowledge. The ability to tailor such training to the specific needs of a company and its employees is another benefit. By using VR simulations that match the layout and equipment of real workplaces, as well as simulating specific scenarios and situations employees might encounter on the job, the training experience becomes more relevant and useful for the participants. The most common models of applying VR technology in training for a healthy and safe work environment are desktop training, game-based training, and BIM (Building Information Modelling) software regard to utilizing VR technology for learning and enhancing educators' skills, Pham et al. (2019) have developed a prototype based on desktop application of VR technology. Pedro et al., (2020) utilized the desktop application of VR technology to develop a system for visualizing the construction environment. In addition to these models, game-based applications of VR in training can minimize the complexity of intricate tasks and enhance user interactions with one another (Wang et al., 2018). As prime examples of using VR technology in game-based training, there are safety training systems (Li et al., 2012) designed for multiple users to dismantle tower cranes on construction sites, and safety game models for students (Dickinson et al., 2011) to enhance their knowledge of safety in construction earthworks (excavations). Currently, the most widely used model of VR technology in training is the Building Information Modelling (BIM) software, which finds extensive application in the construction industry. BIM software deals with the development and utilization of three-dimensional objects (Wang et al., 2018). Unlike other VR models used in training, BIM-based VR relies on the model to repeat construction processes and operations. An example of BIM software for VR training in construction safety purposes was demonstrated in the research conducted by authors (Ahn et al., 2020). Additionally, within their study, Park et al., (2013) developed a prototype system based on BIM to enhance workplace safety. In addition to advantages such as flexibility, mobility (training at different locations and at different times), repeatability, and relatively low training costs, this form of training also has certain disadvantages. The primary disadvantage of this training system is the time required for preparation, that is, the time for creating educational content. Another disadvantage is the high purchase price of hardware and software. The obstacle to greater use of these technologies might be that creating high-quality educational content tailored to specific types of training requires competent experts.

PROPOSED MODEL OF AR AND VR APPLICATION IN OCCUPATIONAL HEALTH AND SAFETY TRAINING SYSTEM

Within the prescribed methodology for occupational health and safety training regulated by laws and regulations, the improvement of the training process is possible by implementing augmented and VR technologies into existing training methodologies. The best current solutions for enhancing occupational health and safety training processes using AR and VR technology are found in initial, periodic, and targeted training (e.g. training for the use of specific work equipment where there is a high safety risk, firefighting, mining operations). In initial training for occupational health and safety, VR and AR technologies can be applied within the theoretical part of the training (Figure 3).

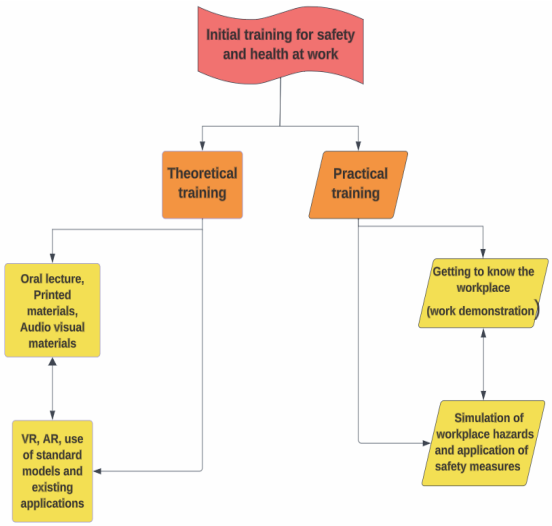
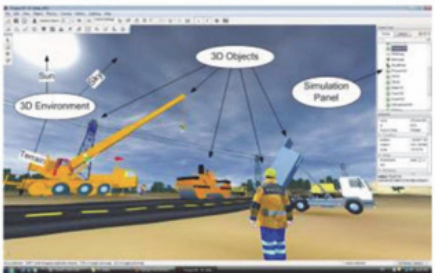


Figure 3. *Application of VR and AR technology in initial training (Source: Authors)*

In the initial training, VR and AR technologies would be a support for oral presentation or an addition to some audiovisual material in such a way as to use already existing software intended for training in specific workplaces: software for simulating the handling of cranes (Figure 4a) (Zhao et al., 2014), installation display software (Figure 4b), BIM software, i.e. 3D workplace model display (Figure 4c) (Ahn et al., 2020). Using these software applications for VR and AR technologies within the theoretical part of the training would contribute to a better understanding of the workplace, work processes, and hazards at the workplace.



(a) Crane handling simulation software

(b) Software for displaying pipe installations

(c) Software BIM

Figure 4. *Examples of the use of VR and AR technology in periodic training*

The second model of applying VR and AR technology in occupational health and safety training is within the periodic training of workers during the actual work process. The use of VR and AR technology in this type of training aims to continuously improve workplace safety through ongoing practical education on workplace hazards and risks. In periodic training, alongside the theoretical component, VR or AR technology (Figure 5) should be introduced within practical training, further preparing the worker for all workplace hazards before the actual work process begins.

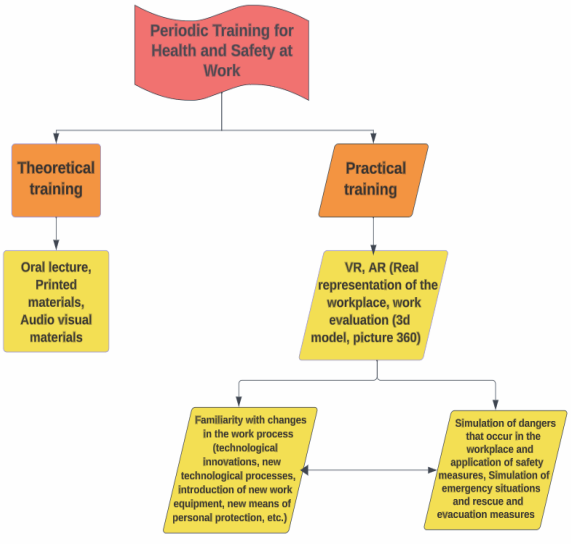
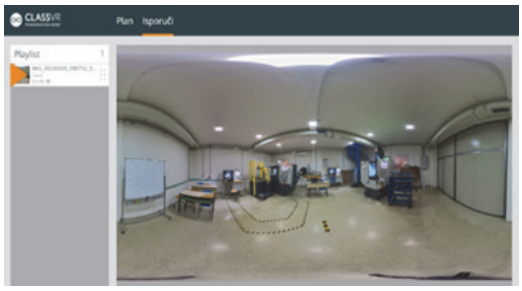
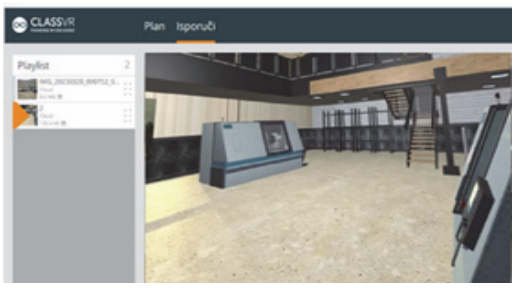


Figure 5. *Application of VR and AR technology in periodic training (Source: Authors*)

In this model, VR and AR technologies utilize software that allows the creation of educational content to simulate a real workplace environment in augmented or virtual reality. For example (Figure 6), for the CNC operator's workplace, three simplest ways of representing the workplace in VR and AR technologies have been created. This way, workers gain practical insights into the workplace across all work segments, focusing on specific work elements such as hazards, personal protective equipment, transportation routes, etc. By utilizing this model, it is possible to monitor all changes in the work process even before their implementation, create VR and AR content, and educate workers about potential new hazards in the workplace.



(a) 360-degree display of the workplace



(b) 3D workplace model

(c) AR info table

Figure 6. *Forms of representation of a specific workplace where the worker performs tasks in VR and AR technology (Source: Authors)*

A good example of using this training model is the initial fire extinguishing training (Figure 7). This method of periodic (and/or targeted) training provides a safe environment for workers (no real fire and smoke, no environmental pollution), eliminating the risk of injury and health hazards. The use of VR and AR technology in this training provides flexibility (training anytime, anywhere), simplicity (various types of fires), and cost optimization (providing specific fuel materials, various types of fire extinguishers, refilling them after training, engaging instructors, etc.).

Figure 7. *Virtual training in fire safety training (Source: https://www.vobling.com/news/top-5-benefits-of-virtual-reality-in-fire-safety-training/)*

CONCLUSION

Using VR and AR technology in occupational health and safety training has many advantages, as it provides a real and interactive experience without real risks or consequences. VR and AR technologies allow users to 'immerse' themselves in a simulated environment that can depict real situations, work processes, or events they might encounter in the workplace. By integrating these technologies into the existing training methodology, there is no doubt that the training process itself would be enhanced, consequently reducing the risks in the workplace. In addition to the two presented models of using VR and AR technology, it is possible to combine these technologies in countless ways with existing training methods. The VR and AR technology itself, in terms of training for safe and healthy work, should find its most significant application in practical training for safe and healthy work in specific professions where it is difficult to conduct training at the workplace, especially in workplaces with increased risk. In addition to all the known advantages of using these technologies (availability, flexibility, mobility, repeatability), the main drawbacks are the cost of hardware and software, and the required level of expertise for creating VR and AR content. Considering all the advantages and disadvantages of using VR and AR technologies in occupational health and safety training, it can be concluded that these technologies will be integral part of all training processes, including occupational health and safety training, in the future.

REFERENCES

Ahn, S., Kim, T., Park, Y. J., & Kim, J. M. (2020). Improving Effectiveness of Safety Training at Construction Worksite Using 3D BIM Simulation. *Advances in Civil Engineering,* 2020, 1-12. https://doi.org/10.1155/2020/2473138

Dickinson, J. K., Woodard. P., Canas, R., Ahamed, S., & Lockston, D. (2011). Game-based trench safety education: development and lessons learned. *Journal of Information Technology in Construction (ITcon), 16*, 118-132. https://www.itcon.org/2011/8

Dzwiarek, M., & Luczak, A. (2008). Application prospects of the augmented reality technology for improving safety of machine operators, In Kikuo Asai (Ed.): *Human-Computer Interaction* (pp. 217-230). InTech. DOI: 10.5772/5877

Hendrix, D., & Johannsen, G. (2008). A knowledge sharing and collaboration platform, *Knowledge Magazine*, *11*.

Kim, S., Nussbaum, M.A., & Gabbard, J.L. (2016). Augmented Reality "Smart Glasses" in the Workplace: Industry Perspectives and Challenges for Worker Safety and Health, *IIE transactions on occupational ergonomics and human factors*, *4*(4), 253-258. https://doi.org/10.1080/21577323.2016.1214635

Kim,W., Kerle, N., & Gerke, M. (2016). Mobile augmented reality in support of building damage and safety assessment, *Natural Hazards and Earth System Sciences*, *16*(1), 287-298. https://doi.org/10.5194/nhess-16-287-2016

Li, H., Chan, G., & Skitmore, M. (2012). Multiuser Virtual Safety Training System for Tower Crane Dismantlement. *Journal of Computing in Civile Engineering*, *26*(5), 638–647. https://doi.org/10.1061/(ASCE)CP.1943-5487.0000170

Okuka, M. (2022). Primjena tehnologije virtuelne realnosti u različitim sferama nauke, društva i industrije, in Proc. *21st International Symposium INFOTEH-JAHORINA*, 16-18 March 2022, B&H, pp. 298-301.

Park, C. S., & Kim, H.J.A. (2013). A framework for construction safety management and visualization system. *Automation in Construction*, *33*, 95–103. https://doi.org/10.1016/j.autcon.2012.09.012

Pedro, A., Pham, H. C., Kim, J. U., & Park, C. (2020). Development and evaluation of context-based assessment system for visualization-enhanced construction safety education. *International Journal of Occupational Safety and Ergonomics*, *26*(4), 811–823. https://doi.org/10.1080/10803548.2018.1553377

Pham, H. C., Dao, N. N., Cho, S., Nguyen, P. T., & Pham-Hang, A. T. (2019). Construction Hazard Investigation Leveraging Object Anatomization on an Augmented Photoreality Platform. *Applied Sciences*, *9*(21), 4477. https://doi.org/10.3390/app9214477

Pravilnik. (2011). *Pravilnik o načinu i postupku osposobljavanja radnika za bezbjedan i zdrav rad* [Regulation on the Manner and Procedure of Training Workers for Safe and Healthy Work], Službeni glasnik Republike Srpske broj 42/11.

Rios, H., Hincapié, M., Caponio, A., Mercado, E. & Mendívil, E.G., (2011). Augmented reality: An advantageous option for complex training and maintenance operations in aeronautic related processes. In R. Shumaker (Ed.), *International Conference on Virtual and Mixed Reality* (pp. 87-96). Springer. DOI:10.1007/978-3-642-22021-0_11

Talmaki, S.A., Dong, S., & Kamat, V.R. (2010). Geospatial databases and augmented reality visualization for improving safety in urban excavation operations. In: *Construction Research Congress 2010: Innovation for Reshaping Construction Practice* (pp. 91-101). https://doi.org/10.1061/41109(373)10

Tsai, M.K., Lee, Y.C., Lu, C.H., Chen, M.H., Chou, T.Y., & Yau, N.J. (2012). Integrating geographical information and augmented reality techniques for mobile escape guidelines on nuclear accident sites, *Journal of Environmental Radioactivity*, *109*, 36-44. https://doi.org/10.1016/j.jenvrad.2011.12.025

Wang, P., Wu, P., Wang, J., Chi, H. L., & Wang, X. (2018). A Critical Review of the Use of Virtual Reality in Construction Engineering Education and Training. *International Journal of Environmental Research and Public Health, 15*(6), 1204. https://doi.org/10.3390/ijerph15061204

Yim, H.B., & Seong, P.H. (2010). Heuristic guidelines and experimental evaluation of effective augmented-reality based instructions for maintenance in nuclear power plants. *Nuclear Engineering and Design*, *240*(12), 4096-4102. https://doi.org/10.1016/j.nucengdes.2010.08.023

Zhao, D., & Lucas, J. (2014). Virtual reality simulation for construction safety promotion. *International Journal of Injury Control and Safety Promotion, 22*(1), 57–67. https://doi.org/10.1080/17457300.2013.861853

20th International Conference Man and Working Environment
SEMSIE
Safety Engineering & Management – Science, Industry, Education

www.znrfak.ni.ac.rs/semsie

PREDRAG NIKETIĆ[1]

[1]University of Niš,
Faculty of Occupational Safety

[1] predrag.niketic@znrfak.ni.ac.rs

USAGE INCONSISTENCIES OF SERBIAN TRANSLATIONS OF THE ENGLISH TERM 'SAFETY'

Abstract: *This paper discusses Serbian language translation equivalents for the English term 'safety' and the way these are used in several safety-related professional discourses, specifically those pertaining to occupational safety (and health). The first issue discussed is the interchangeable usage of two Serbian terms – 'zaštita' and 'bezbednost' – to denote 'safety' within the said contexts. The two words are near-synonyms and both are frequently used in the aforementioned professional discourses, especially in the field of occupational safety. However, their interchangeability in the professional context might lead to potential confusion, both among the professionals in the field and among translators, who are faced with an almost haphazard use of the two terms when doing a simple Google search of the relevant noun phrases containing them. The problem is further exacerbated when one considers the broader semantic field, which includes the English words 'protection' and 'security' and their Serbian equivalents: 'zaštita' for the former and 'bezbednost; sigurnost' for the latter. The Serbian Committee for the Standardisation of the Serbian Language tackled this issue 15 years ago, but reached a decision that is, in this author's opinion, inconclusive. As a result, legislative acts, scientific writings, professional reports, and even names of university degrees often use different terms to denote the same concept. In such highly formalized discourses, any inconsistency of this type is far from ideal. The two most obvious solutions would be to either opt for one word over the other or to somehow formalise their interchangeability. Although a permanent solution is nowhere in sight for the time being, the issue deserves to be raised, as any solution will have to involve experts from the professional, scientific, and linguistic community.*

Keywords: safety, translation, English to Serbian, inconsistencies

INTRODUCTION

During his 15 years of working as the English teacher at the Faculty of Occupational Safety in Niš, the author of this paper has frequently been tasked with translating various documents and scientific papers pertaining to occupational safety, fire safety, and environmental protection – the main three engineering degrees the faculty offers. In the process, an interesting linguistic phenomenon was observed. Successful completion of the said translation tasks necessarily involved learning new professional terminology, both in Serbian and in English. Naturally, one of the first terms to be acquired was the one included in the faculty name itself – *occupational safety*. The Serbian phrase used in the faculty's name is *zaštita na radu*.[1] Even though the literal English translation of this phrase is *protection at work*, the phrase is standardly used within this context, the Faculty of Occupational Safety having been established in 1968. In addition, the former Yugoslav Law on Occupational Safety (Zakon o zaštiti na radu, 1998) also utilised *zaštita na radu*, as did professionals in this field. Therefore, it would be fair to assume that *zaštita na radu* is the official Serbian phrase denoting occupational safety. The matter is, however, complicated by the existence and equally common usage of the phrase *bezbednost na radu*, which also denotes *occupational safety*. Serbian term *bezbednost* is usually translated as either *safety* or *security*, depending on the context. It is impossible to pinpoint when the phrase *bezbednost na radu* was first used officially or unofficially, but a simple Internet search strongly suggests that the phrase gained prominence with the enactment of the Serbian Law on Occupational Safety and Health (Zakon o bezbednosti i zdravlju na radu, 2005), which succeeded the Law on Occupational Safety from 1998, and used the term *bezbednost* instead of *zaštita*. As a result, both *zaštita na radu* and *bezbednost na radu* are used nowadays to refer to the exact same concept. Another potential point of confusion is that Serbian *zaštita* is also used to refer to

[1] For the non-Serbian-speaking readers, this, as well as other Serbian words and phrases used in the paper, may be spelled differently in different references listed. This is due to the grammatical case system in the Serbian language. For ease of comparison, the isolated Serbian words in the paper are given in their nominative case.

English phrases *fire safety* and *fire protection* (*zaštita od požara*), as well as *environmental protection* (*zaštita životne sredine*). This inconsistency will be analysed in more detail in the following sections, with a primary focus on Serbian translations of *safety* and relevant notes on the translations of *protection* and *security*, as they pertain to occupational safety, as well as English translations of Serbian words *zaštita* and *bezbednost*. The discussion will also include the expert opinion and by the Serbian Committee for the Standardisation of the Serbian Language, albeit tangentially related to the presented issue.

DICTIONARY ENTRIES

Before the main discussion, this section will provide the meaning equivalents for both the Serbian and the English words considered, as given in six selected reputable dictionaries, namely the Oxford English-Serbian Student's Dictionary (Oxford University Press, 2017), Morton Benson's English-Serbian and Serbian-English dictionaries (Benson, 2003), the Contemporary English-Serbian and Serbian-English dictionaries (Šipka 2013a; Šipka 2013b), and the Dictionary of the Serbian Language [in Serbian] (Vujanić et al., 2011), published by *Matica srpska*, the oldest Serbian cultural and scientific institution and one of the foremost authorities on the Serbian language. The purpose of the dictionary examples is to illustrate the inconsistencies of using the Serbian words *zaštita* and *bezbednost* to translate the English word *safety*, as well as *protection* and *security*, and to provide a wider context of what the two words denote in Serbian.

The Oxford English-Serbian Student's Dictionary (Oxford University Press, 2017) is a combination of a monolingual and bilingual dictionary, as it provides an English description for each lexical entry, followed by a Serbian translational equivalent or equivalents. The entry for the noun *safety* provides a single Serbian translational equivalent – *bezbednost* (Oxford University Press, 2017, p. 715). In a similar vein, the entry for *protection* again provides a single equivalent – *zaštita* (Oxford University Press, 2017, p. 651). The noun *security* has three translational equivalents, two of which are relevant to the present discussion: *sigurnost* (e.g. financial security) and *obezbeđenje* (e.g. bank or airport security) (Oxford University Press, 2017, p. 731).

Morton Benson's English-Serbian and Serbian-English dictionaries (Benson, 2003) are primarily targeted towards foreign learners of Serbian. The English-Serbian dictionary provides the following equivalents of the three English nouns:

- safety: four equivalents, two of which are relevant, *bezbednost* and *sigurnost*;
- protection: also four equivalents and two relevant ones, *zaštita* and *odbrana* (defence);
- security: of the seven equivalents, three are relevant – *bezbednost, sigurnost,* and *obezbeđenje*.

The Serbian-English dictionary offers the following equivalents:

- zaštita: four equivalents – *protection, defence, care* (medical)*,* and *conservation*;
- bezbednost: two equivalents – *security* and *safety*, with one relevant example phrase: *zaštita rada*[2] – *industrial safety*.

The following translational equivalents are provided in the Contemporary English-Serbian Dictionary (Šipka, 2013a):

- safety: of the seven equivalents offered, the only relevant one is *bezbednost*; however, one of the example phrases for this equivalent is *work safety* – *zaštita na radu* (Šipka, 2013a, p. 850);
- protection: a single equivalent, *zaštita* (Šipka, 2013a, p. 786);
- security: of the six equivalents offered, three are relevant – *bezbednost, sigurnost,* and *obezbeđenje* (Šipka, 2013a, p. 868).

Its counterpart, the Contemporary Serbian-English Dictionary (Šipka, 2013b) provides the following equivalents:

- zaštita: five equivalents – *protection, care* (medical)*, conservation, defence,* and *shelter*, with the repeated example from the ENG-SER version, *zaštita na radu – work safety* (Šipka, 2013b, p. 214); an example phrase "protivpožarna zaštita" (lit. *fire protection*) is translated as *firefighting*, for which there are better equivalents in the Serbian language;
- bezbednost: only as related to the Serbian adjective *bezbedan* – safe, secure, with nouns *security* and *safety* given in several example phrases (Šipka, 2013b, p. 63).

Finally, the Dictionary of the Serbian Language (Vujanić et al., 2011) provides explanations of lexical entries either through synonyms or descriptively. The used synonyms are listed and translated:

- zaštita: *odbrana* (defence)*, obezbeđenje* (security)*, pomoć* (help, aid)*, podrška* (support)*, pokroviteljstvo* (patronage)*, bezbednost* ([in the sense of] security) (Vujanić et al., 2011, p. 408);

- bezbednost: *stanje onoga koji je bezbedan/što je bezbedno* ([the state of being] safe), *sigurnost* (security) (Vujanić et al., 2011, p. 67).

Judging by the above examples alone, it would appear that the only truly consistent translation from English to Serbian is that of environmental protection – *zaštita životne sredine*. The word *zaštita* would thus be the odd one out when used to translate occupational safety – *zaštita na radu*, as safety is prevalently translated as *bezbednost*, with only one dictionary mentioning *zaštita* in the occupational context. With regard to the field of fire, the situation may be described as reverse compared to that of occupational safety, as the phrases

[2] This phrase is actually incorrect. Literally, it means *protection of work* and is never used to denote *occupational safety*.

fire safety and *fire protection* are commonly used interchangeably, but are consistently translated into Serbian as *zaštita od požara*. Thus, two words are commonly used to translate *safety* in occupational safety – *zaštita* and *bezbednost*, whereas a single word, *zaštita*, is used to translate the two English words – *protection* and *safety*. The following sections will attempt to illustrate how these inconsistencies are manifested in practice.

PROFESSIONAL USAGE

During the better part of the 20th century, English phrase *occupational safety* and its variants *workplace safety, work safety,* and *safety at work* were translated into Serbian as *zaštita na radu*, which is reflected in the former Yugoslav Law on Occupational Safety (Zakon o zaštiti na radu, 1998), the establishment of the Faculty of Occupational Safety (for a long time, the only higher education institution (HEI) of this kind in the entire country), and the establishment of various institutes dedicated to occupational safety, all of which utilised *zaštita na radu* in their titles/names. However, in the early 21st century, whether politically or professionally motivated, the said Law was replaced by a new one, the Law on Occupational Safety and Health (Zakon o bezbednosti i zdravlju na radu, 2005), whose Serbian title is *Zakon o bezbednosti i zdravlju na radu*, with its most recent iteration from this year (Zakon o bezbednosti i zdravlju na radu, 2023).

Yet, even now, in 2023, the new official term *bezbednost na radu* is not used uniformly across the board. As expected, government entities are required to use the new terms as evident in the name of the Administration for Occupational Safety and Health (Serb. *Uprava za bezbednost i zdravlje na radu*) with the Ministry of Labour, Employment, and Veteran and Social Affairs (2019). The word *bezbednost* has also been adopted by public (Putevi Srbije, n.d.; Sindikat poljoprivrede, n.d.[3]) as well as private entities (Secut, 2021; Tehpro, 2023), but not all of them. Some institutes have retained the word *zaštita*, for instance, the Institute for Occupational Safety (Serb. *Institut za zaštitu na radu*) (2013) and the Institute for Prevention, Occupational Safety, Fire Safety, and Development (Serb. *Institut za preventivu, zaštitu na radu, protivpožarnu zaštitu i razvoj*) (n.d.). Even some private companies still use the word *zaštita*, such as the KESZ International construction company (KESZ International, n.d.), even though the English language version of their website uses *labor protection* [sic] instead of *occupational safety* and has generally been poorly translated.

Unfortunately, there are also cases of inconsistent usage, which may result in terminological confusion. The website of A1, a mobile network operator operating in Serbia, contains a page dedicated to environmental protection and occupational safety policies, entitled *Zaštita životne sredine, bezbednosti i zdravlja na radu*, officially translated into English as *Protection of the environment, safety and health at work* on their website (A1, 2023). The translation is correct, albeit somewhat confusing, as it implies 'protection of safety at work', but this is exactly what the original Serbian phrase means. The Serbian phrase contains poor grammar, which was overlooked in the translations, but common sense dictates that the original idea was to use 'environmental protection and occupational safety and health'. This is one example where *zaštita* and *bezbednost* were used in the same phrase, although *zaštita* primarily refers to the environment. Another example is found on the website of a construction company called Letač, LLC. One page is entitled *Bezbednost i zaštita na radu* (literal English translation: *Safety and protection at work*) (Letač, 2022). Thus far, all examples included the use of either *bezbednost* or *zaštita*, but this example utilises both. It would be very difficult to determine with certainty if the error was made unintentionally, i.e. if the word *zdravlje* (health) was intended instead of *zaštita*, which would make sense, or if the error was due to inability to opt for a single word, which in turn was caused by the change of official terminology. As it is, the phrase only indicates unnecessary repetition and a potential source of confusion that the two words are not in fact synonymous.

There is also an example of both words (*bezbednost* and *zaštita*) being used, only this time to avoid confusion rather than add to it. The website of Atlas, a private agency for occupational safety and health, fire safety, and environmental protection, contains a page entitled *Bezbednost i zdravlje na radu (zaštita na radu)* (Atlas, 2007). By now, it is clear that this would translate into English as *Occupational safety and health (occupational safety)*, but what is interesting is that the authors used the phrasing from both the newer Serbian law (Zakon o bezbednosti i zdravlju na radu, 2005) and the old Yugoslav law (Zakon o zaštiti na radu, 1998), as they essentially cover the same fields, the only formal difference being the addition of the word *health*, even though the health aspect was covered in the old law, as well. This is a commendable attempt to eliminate any ambiguity and confusion resulting from the official transition from *zaštita* to *bezbednost*.

The aforementioned case of simultaneous use of *bezbednost* and *zaštita* (Letač, 2022) was by no means isolated. A newspaper article published by the BBC in Serbia is potentially even more detrimental to any chance of terminological consensus. The article in question is entitled *Srbija i zaštita na radu: Šta donosi novi Zakon o bezbednosti i zaštiti na radu* (Eng. *Serbia and occupational safety: What changes are introduced by the new Law on Occupational Safety and Protection*) (Georgievski, 2023). The simultaneous use of *bezbednost* and *zaštita* in the article title is an obvious error, as is easily determined from the body of the article, which clearly refers to the Law on Occupational Safety and Health (Zakon o bezbednosti i zdravlju na radu, 2023). The word *zdravlje* from the

[3] It should be noted that the web link for the page dedicated to occupational health and safety contains the phrase *zaštita na radu*: https://sindikatpoljoprivrede.rs/zastita-na-radu/.

actual law was erroneously replaced with *zaštita*; unlike with the case of Letač (2022) above, the context is explicit here. If a layperson should read the entire article, there should not be any confusion whatsoever, but if they skim through the title, the phrase may be retained unconsciously. The real issue with this example is what the underlying cause of both the journalist and the editor overlooking the error is. Two hypotheses emerge as the frontrunners: negligence or an accident resulting from terminological confusion, but to confirm or reject either would require personal communication with the journalist/editor, which is beyond the scope of this paper. Considering that the BBC News in Serbian's articles are shared and disseminated by other news portals in Serbia, oversights of this kind are cause for concern in terms of terminological consistency.

ACADEMIC USAGE

For many years, the Faculty of Occupational Safety in Niš was the sole HEI in Serbia (and Yugoslavia) dedicated to educating occupational safety, environmental protection, and fire safety engineers (Cvetković et al., 2018). Over the years, especially since the beginning of the 21st century, other HEIs followed suit. It would be logical to assume that the new HEIs or the new study programmes within existing HEIs would exhibit a high degree of terminological overlap with the pioneering HEI; yet again, this is not the case.

Probably the biggest terminological issue related to HEIs lies in the discrepancy between the law that regulates the field, the Law on Occupational Safety and Health (Zakon o bezbednosti i zdravlju na radu, 2023) and the Regulation on the List of Professional, Academic, and Scientific Titles (Pravilnik o listi stručnih, akademskih i naučnih naziva, 2023), which provides a list of titles as they pertain to the relevant educational-scientific and educational-artistic fields. Unlike the law, which translates *safety* as *bezbednost*, the regulation lists the educational-scientific field discussed in this paper as *Inženjerstvo zaštite životne sredine i zaštite na radu* (Eng. *Environmental [protection] and Occupational Safety Engineering*). This means that each academic title, regardless of the degree (bachelor's, master's, or PhD) has to include *zaštita* to denote *safety*. The consequences of this discrepancy are obvious – students receive an engineering degree in a field that has a different name in the national law.

In practice, unsurprisingly, there are numerous inconsistencies. Terminology-wise, the regulation mandates HEIs to issue occupational safety engineering degrees that contain the phrase *zaštita na radu* (Pravilnik o listi stručnih, akademskih i naučnih naziva, 2023). The law, on the other hand, contains no such mandate (Zakon o bezbednosti i zdravlju na radu, 2023). In addition to the Faculty of Occupational Safety, which has always been called *Fakultet zaštite na radu*, other HEIs have also remained true to the 'old' terminology and use the phrase *zaštita na radu* in the study programmes they offer. For instance, the Faculty of Technical Sciences, University of Novi Sad, offers a bachelor's, a master's, and a PhD degree in occupational safety engineering, in all three cases *inženjerstvo zaštite na radu* (Faculty of Technical Sciences, 2021). Similarly, the Academy of Applied Preschool Teaching and Health Studies in Kruševac offers an applied bachelor's engineering degrees in environmental protection and occupational safety, whereby the latter is named *zaštita na radu* (Academy of Applied Preschool Teaching and Health Studies, n.d.).

However, some HEIs have probably decided to adhere both to the aforementioned law and to the aforementioned regulation. Thus, the Academy of Applied Technical Studies in Belgrade offers an applied bachelor's study programme called *Bezbednost i zdravlje na radu*, even though the degree and the scientific field contain the phrase *zaštita na radu* (Academy of Applied Technical Studies in Belgrade, n.d. -a) and an applied master's programme entitled *Inženjerstvo zaštite životne sredine i zaštite na radu*, but with a module called *Bezbednost i zdravlje na radu* (Academy of Applied Technical Studies in Belgrade, n.d. -b). Another such example is the Western Serbia Academy of Applied Studies, which offers a master's programme *Bezbednost i zdravlje na radu* with the degree title containing *zaštita na radu* (Western Serbia Academy of Applied Studies, 2023).

Adding to the confusion, there is an HEI in Serbia called the Faculty of Security Studies. Its Serbian name is *Fakultet bezbednosti*, which is an example of the other most common meaning of the word *bezbednost* (safety, security). Even though it operates within the field of management, rather than engineering, the faculty offers an elective subject within its bachelor academic studies called *Bezbednost i zdravlje na radu* (Occupational Safety and Health), which deals exactly with what its name suggests, only with a greater focus on the normative side of this field (Faculty of Security Studies, 2023). Another elective subject is called *Industrijska bezbednost i zaštita* (Industrial Security and Safety) and more than ten other required or elective subjects contain the word *bezbednost* denoting *security* (Faculty of Security Studies, 2023).

The inconsistencies presented above may confuse not only laypersons, but also prospective/current students, who would be right to wonder what it is that they will be / are actually studying.

LINGUISTIC PERSPECTIVE

In 2008, a citizen wrote a letter to the Serbian Committee for Standardisation of the Serbian Language, which operates under the auspices of the Institute for the Serbian Language of the Serbian Academy of Sciences and Arts, querying how English terms *safety, security,* and *safety management (system)* should be translated into Serbian (Klajn, 2018). The query pertained to the use of the terms in the field of aviation. Ivan Klajn, a renowned Serbian linguist,

responded to the letter, and the response was later adopted as an official Committee decision. There is no specific mention in the letter of the issue discussed here, but there are some points worth mentioning. First, Klajn (2018) states that it has always been the stance of Serbian linguists that the once adopted terminology in any profession should not be changed, unless there was a change in the very things or phenomena the terms refer to. In the field of occupational safety, many things have indeed changed, such as technology, methodologies, and legislation, but the goal and purpose of occupational safety have always been the same. This argument goes in favour of retaining the word *zaštita* within this context. Second, it is confirmed that Serbian *bezbednost* is commonly used as the translation of both *safety* and *security*. Regarding this note, the same also applies to the present case: *zaštita* is used as the translation for both *protection* and *safety*, as evidenced by dictionary entries and usage in professional and academic practice. Finally, Klajn also differentiates between *safety*, referring to the protection (*zaštita*) from accidental unwanted events, and *security*, referring to the protection (*zaštita*) from intentional damage (Klajn, 2018). According to him, this difference, among other dictionary examples, is reflected in the phrase *safety at work* (*zaštita na radu*) as opposed to, for example, *security guard*. The main takeaway here is that *zaštita na radu* was provided as an example, but not *bezbednost na radu*.

CONCLUSION

This paper discussed the inconsistencies of Serbian translations of the English word *safety* in the context of occupational safety (and health). The biggest one is the parallel use of the Serbian words *zaštita* and *bezbednost* to denote *safety* in *occupational safety*. The inconsistencies are present in professional as well as academic usage. On the one hand, this may indicate indifference or indecisiveness among the professionals, which could leave an unfavourable impression of the entire profession, and on the other hand, it may have ramifications on the academic study of the field. Indeed, translators would immensely benefit from a uniform choice. Thus far, neither the usage in practice nor the national linguistic authorities have offered a definitive solution to the issue, and this may be the case for as long as there are official legislative acts and government naming conventions that are not fully harmonised. In this author's opinion, any consistent solution would be acceptable, provided it has been reached methodically and with due diligence.

The problem of inconsistency in this field is not specific to the Serbian language. The interchangeability of *fire safety* and *fire protection* was touched upon in the paper, and there is also the case of environmental protection and environmental safety, which is defined as being more specific than environmental protection (Anderson Engineering, 2023). Furthermore, environment, health, and safety, abbreviated *EHS*, are commonly integrated into a single group for practical purposes, but the order is not necessarily the same, as *HSE* and *SHE* are also common, sometimes even with an added quality (Q) or security (S) aspect. The variations depend on numerous factors, including the geographical location (Daley, 2021).

For a future study, a hypothesis could be made that *safety* is usually translated into Serbian as *zaštita* in the phrase *occupational safety* (*zaštita na radu*) and as *bezbednost* in the phrase *occupational safety and health* (*bezbednost i zdravlje na radu*), as the small set of examples presented in this paper suggests. If a more substantial set of data should confirm the hypothesis, then a new issue would be raised – one regarding the rationale behind such choices.

REFERENCES

A1. (2023). *Zaštita životne sredine, bezbednosti i zdravlja na radu* [Protection of the environment, safety and health at work]. https://a1.rs/o-a1/o_nama/politika_zastite_zivotne_sredine

Academy of Applied Preschool Teaching and Health Studies. (n.d.). *Zaštita životne sredine i zaštita na radu* [Environmental Protection and Occupational Safety]. Retrieved 7 June 2023, from https://www.vhts.edu.rs/studijski-programi/zastita-zivotne-sredine-i-zastita-na-radu/

Academy of Applied Technical Studies in Belgrade. (n.d. -a). *Bezbednost i zdravlje na radu* [Occupational Safety and Health]. Retrieved 7 June 2023, from https://atssb.edu.rs/os-bezbednost-i-zdravlje-na-radu/

Academy of Applied Technical Studies in Belgrade. (n.d. -b). *Inženjerstvo zaštite životne sredine i zaštite na radu* [Environmental and Occupational Safety Engineering]. Retrieved 7 June 2023, from https://atssb.edu.rs/ms-inzenjerstvo-zastite-zivotne-sredine-i-zastite-na-radu/

Anderson Engineering. (2023). *What is Environmental Safety?* https://www.andersoneng.com/what-is-environmental-safety/#:~:text=Environmental%20safety%20is%20defined%20by,the%20prevention%20of%20accidental%20environmental

Atlas. (2007). *Bezbednost i zdravlje na radu* [Occupational safety and health]. Atlas – Agency for Occupational Safety and Health, Fire Safety, and Environmental Protection. https://atlaszastita.com/bezbednost-i-zdravlje-na-radu

Benson, M. (2003). *Serbian-English and English-Serbian Dictionary* (Version 0.001) [Computer software]. MarcoSoft.

Cvetković, D., Spasić, D., Živković, Lj., Anđelković, B., Živković, N., Janković, Ž., Blagojević, M., Miltojević, V., Glišović, S., Raos, M., Stojiljković, E., & Krstić, I. (Eds.). (2018). *50 godina Fakulteta zaštite na radu u Nišu: Monografija* [50 years of the Faculty of Occupational Safety in Niš: A monograph]. Faculty of Occupational Safety.

Daley, V. (2021, 26 March). Is it EHS, SHE, HSE, HSSE, SHEQ or OHS and what's the difference? Libryo, an ERM Group company. Retrieved on 5 June 2023, from https://blog.libryo.com/is-it-ehs-she-hse-hsse-sheq-or-ohs-and-whats-the-difference

Faculty of Security Studies. (2023). *Studije nauka bezbednosti – program* [Security studies – programme]. Retrieved 7 June 2023, from

https://fb.bg.ac.rs/studije/oas/osnovne-akademske-studije/?script=lat

Faculty of Technical Sciences. (2021, 8 November). *Studijski programi (akreditacija 2020)* [Study programmes (2020 accreditation)]. Retrieved 7 June 2023, from http://www.ftn.uns.ac.rs/520597434/studijski-programi--akreditacija-2020-

Georgievski, J. (2023, 4 April). *Srbija i zaštita na radu: Šta donosi novi Zakon o bezbednosti i zaštiti na radu* [Serbia and occupational safety: What changes are introduced by the new Law on Occupational Safety and Protection]. BBC News na srpskom. https://www.bbc.com/serbian/lat/srbija-65112848

Institute for Occupational Safety. (2013). *Misija* [Our mission]. http://www.institut.co.rs/?l=sr_SR

Institute for Prevention, Occupational Safety, Fire Safety, and Development. (2013). *O nama* [About us]. https://www.izp.co.rs/page.php?ndx=19

KESZ International. (n.d.). *Zaštita na radu* [Labor Protection, *sic*]. https://www.kesz.rs/o-nama/zastita-na-radu

Klajn, I. (2018, 27 December). *Српски еквиваленти енглеских израза safety, security и safety management* [Serbian equivalents of English terms safety, security and safety management] (Letter written on 29 October 2008). Committee for Standardisation of the Serbian Language [in Cyrillic]. https://www.ossj.rs/odluke-i-saopstenja/srpski-ekvivalenti-engleskih-izraza-safety-security-i-safety-management/?fbclid=IwAR0GJUlIRnGvpiiIKQUAHXlUU1Md3zpZB5n7m_UD7sFTkKaIobCEBtk2y3s

Letač. (2022, 16 June). *Bezbednost i zaštita na radu* [Safety and Health at Work]. Retrieved 6 June 2023, from https://letac.rs/bezbednost-i-zastita-na-radu/

Ministry of Labour, Employment, and Veteran and Social Affairs. (2019). *Organi uprave u sastavu ministarstva* [Administrative bodies within the ministry]. Retrieved 5 June 2023, from https://www.minrzs.gov.rs/srb-lat/struktura/organi-uprave-u-sastavu-ministarstva

Oxford University Press. (2017). *Oxford English-Serbian student's dictionary.*

Pravilnik o listi stručnih, akademskih i naučnih naziva [Regulation on the List of Professional, Academic, and Scientific Titles]. (2023). Official Gazette of the Republic of Serbia, No. 53/2017, 114/2017, 52/2018, 21/2019, 34/2019, 6/2020, 24/2020, 152/2020, 10/2021, 48/2021, 47/2023, 51/2023, 55/2023, 59/2023, 66/2023 – rev., and 85/2023. https://www.paragraf.rs/propisi/pravilnik-o-listi-strucnih-akademskih-naucnih-naziva.html

Putevi Srbije. (n.d.). *Odeljenje za bezbednost i zdravlje, zaštitu od požara i spasavanje na radu* [Department for Occupational Safety and Health, Fire Protection and Rescue at Work]. Retrieved 5 June 2023, from https://www.putevi-srbije.rs/index.php/sr/organizacija/sektor-za-upravlja%C4%8Dko-informacione-sisteme-u-saobra%C4%87aju/odeljenje-za-bezbednost-i-zdravlje,-za%C5%A1titu-od-po%C5%BEara-i-spasavanje-na-radu

Secut. (2021). *Bezbednost i zdravlje na radu* [Safety and Health at Work]. Retrieved 6 June 2023, from https://secut.rs/bezbednost-i-zdravlje-na-radu/

Sindikat poljoprivrede. (n.d.). *Bezbednost i zdravlje na radu* [Occupational Safety and Health]. Independent Trade Union of Employees in Agriculture and Food, Tobacco, and Water Industries. Retrieved 5 June 2023, from https://sindikatpoljoprivrede.rs/zastita-na-radu/

Tehpro. (2023). *Bezbednost i zdravlje na radu* [Occupational Health and Safety]. Retrieved 6 June 2023, from https://tehpro.rs/delatnosti/bezbednost-i-zdravlje-na-radu/

Šipka, D. (2013a). *Contemporary English-Serbian dictionary.* Prometej.

Šipka, D. (2013b). *Contemporary Serbian-English dictionary.* Prometej.

Vujanić, M., Gortan Premk, D., Dešić, M., Dragićević, R., Nikolić, M., Nogo, Lj., Pavković, V., Ramić, N., Stijović, R., Radović Tešić, M., & Fekete, E. (2011). *Rečnik srpskoga jezika – izmenjeno i popravljeno izdanje* [Dictionary of the Serbian language, amended and corrected edition]. Matica srpska.

Western Serbia Academy of Applied Studies. (2023). *Master studije* [Master's degree studies]. Retrieved 7 June 2023, from https://akademijazs.edu.rs/master-studije/

Zakon o bezbednosti i zdravlju na radu [Law on Occupational Safety and Health]. (2005). Official Gazette of the Republic of Serbia, No. 101/05. http://www.ekoregistar.sepa.gov.rs/en/zakon-o-bezbednosti-i-zdravlju-na-radu-sl-glasnik-rs-br-10105

Zakon o bezbednosti i zdravlju na radu [Law on Occupational Safety and Health]. (2023). Official Gazette of the Republic of Serbia, No. 35/2023. https://www.paragraf.rs/propisi/zakon_o_bezbednosti_i_zdravlju_na_radu.html

Zakon o zaštiti na radu [Law on Occupational Safety]. (1998). Official Gazette of the Republic of Serbia, No. 42/91, 53/93, 67/93, 48/94, and 42/98. http://www.podaci.net/_z1/9108666/Z-zraduu03v9142-05A1.html

20th International Conference Man and Working Environment
SEMSIE
Safety Engineering & Management – Science, Industry, Education

www.znrfak.ni.ac.rs/semsie

MILAN VELJKOVIĆ[1]
MILJANA STRATIJEV[2]
ALEKSANDRA ILIĆ PETKOVIĆ[3]

[1,3] University of Niš,
Faculty of Occupational Safety
[2]Attorney at law, Niš

[1]*milan.veljkovic@znrfak.ni.ac.rs*
[2]*miljana@stratijev.com*
[3]*aleksandra.ilic@znrfak.ni.ac.rs*

SEM ANALYSIS OF ENVIRONMENTAL ATTITUDES, MOTIVES, AND REUSE BEHAVIOR AMONG STUDENTS

Abstract: *The presented research examined the structure of the relationship between ecological attitudes defined by the HEP-NEP scale, environmental motives, and reuse behavior. In the sample, which includes 194 students of the Faculty of Occupational Safety in Nis (116 males and 78 females) aged 19 to 27, the research instruments used are the HEP-NEP scale, scale of environmental motives and scale of reuse behavior. It was discovered by testing the hypothesized structural model that environmental motives can directly predict the reuse behavior, and that the degree of expression of the environmental motives can be predicted based on the level of environmental attitudes indicated by the HEP-NEP scale. Environmental motives are a partial mediator of NEP and reuse behavior factors. We can assume that environmental motives are not the only cause but that there are some other factors that have not been examined in this model. Environmental motives were found to be a greater predictor of reuse behavior in older students and students studying environmental protection than in students studying occupational safety. These results confirmed the main research hypothesis, based on theoretical and empirical data.*

Keywords: *NEP-HEP, environmental motives, environmental protection, reuse behavior, structural equations model-SEM*

INTRODUCTION

Individuals exhibit ecological behavior through diverse actions such as recycling, using public transport, and choosing eco-friendly products. These behaviors are consistent with the desire to preserve the environment and are driven by shared values. Human values and stable aspects of personalities, influence environmental actions. Some values promote sustainable behaviors, recycling, and political engagement, highlighting positive involvement in environmental protection (Petrović and Škrbić, 2016). The 1970s theoretical perspectives like interactionism, functionalism, conflict theories, and Marxism separated humans from nature, hindering environmental psychology's response to societal changes. Catton and Dunlap (1978) termed this the Human Exemptionalism Paradigm (HEP), contrasting it with the New Ecological Paradigm (NEP). NEP underscores humanity's interdependence with nature, prompting both individual and collective actions to solve environmental issues. Despite NEP's significance, the relationship between environmental attitudes and behavior is complex. Studies by Scott and Willits (1994), Corral-Verdugo et al. (2010), and Putrawan (2017) showed correlations between NEP and environmental behavior but revealed discrepancies in certain aspects. This complexity might stem from the multifaceted nature of ecological behavior and suggests the need for further research using advanced methods like structural equation modeling.

Environmental motives drive individuals to engage in environmentally responsible behavior, with intrinsic and extrinsic factors influencing intentions to act (Stern et al., 1993). These motives are shaped by environmental attitudes and beliefs, impacting conservation efforts (Goldenhar and Connell, 1993). Studies show significant differences in environmental motives based on NEP scale scores (Kim et al., 2006). Reuse behavior, a vital aspect of ecological behavior, aims to prevent pollution by altering products for different uses without significant chemical changes (Corral-Verdugo, 1996; De Young, 2000). Research consistently shows a positive correlation between age and pro-environmental behavior (Wiernik et al., 2013). While older individuals tend to exhibit more environmentally conscious actions, the underlying reasons have lacked a comprehensive explanation. In a study by Otto and Kaiser in 2014, it was found that continuous learning, rather than mere maturation, accounts for the link between age and environmental behavior. Prolonged exposure to pro-ecological information plays a significant role in shaping environmentally conscious behaviors among older individuals.

The main goal of this study was to set up and determine a model that predicts reuse behavior based on environmental motives and environmental attitudes. Hypotheses included direct prediction of reuse behavior by environmental factors (Stern et al., 1993). NEP was hypothesized as a positive predictor of environmental motives, while HEP was a negative predictor (Corral-Verdugo and Armendariz, 2000; Goldenhar and Connell, 1993; Kim et al., 2006; Catton and Dunlap, 1978). Mediation was expected between NEP and reuse

behavior, and HEP and reuse behavior, through environmental motives, supported by prior research (Putrawan, 2017; Thomson, 2013; Scott and Willits, 1994; Corral-Verdugo, 1996; Berger, 1997; Stern et al., 1993; Goldenhar and Connell, 1993; De Young, 2000). Moderating effects of age and field of study were also explored, aligning with previous studies (Wang and Liu, 2021; Otto and Kaiser, 2014; Wiernik et al., 2013).

General problem

The general problem of this research was to examine the structure of the relationship between ecological attitudes defined by the HEP-NEP scale, motives for environmental protection, and reuse behavior in a sample of students at the Faculty of Occupational Safety at the University of Nis.

Variables and Instruments

HEP and NEP: The study employed the Human Exemptionalism Paradigm (HEP) and New Ecological Paradigm (NEP) scales developed by Dunlap and Van Liere (1978). HEP represents the belief that humans are above nature and can exploit resources without concern, while NEP signifies the belief that humans are part of nature and must protect it. The scale included 6 items, with respondents indicating their agreement on a 4-point Likert scale. Cronbach's alpha coefficient for NEP is 0.657, while for HEP Cronbach's alpha coefficient is 0.613. There are authors who consider acceptably reliable and tests in which the alpha is 0.6 or even 0.5.

Motives for Environmental Protection: This construct included 20 items categorized into 4 subscales related to reasons for reusing glass, paper, clothes, and plastic. Respondents rated their agreement on an 11-point Likert scale. The reliability of the test, determined through internal consistency, was moderate, with Cronbach's alpha coefficients ranging from 0.749 to 0.806.

Reuse Behavior: The construct comprised 6 items assessing participants' reuse habits, including actions like using reusable bags and containers. Responses were collected on a 5-point Likert scale. The reliability, determined through internal consistency, was low, with a Cronbach's alpha coefficient of 0.753.

Sample: The study involved 194 students from the Faculty of Occupational Safety at the University of Nis, with 116 males (59.8%) and 78 females (40.2%). Participants were categorized into two age groups: 19 to 21 years (55.7% of the sample) and 22 to 27 years (44.3% of the sample). Additionally, 90 students were from the environmental protection field, and 104 were from the occupational safety field.

Data processing

The hypothesized model was tested using the structural equation method. All variables were standardized in the SPSS matrix, further data processing was performed in the AMOS program.

RESULTS

Figure 1. illustrates the assumed model, depicting the relationships where HEP and NEP predict environmental motives, which in turn predict reuse behavior. Preservation motives are hypothesized as mediators between NEP and HEP and reuse behavior.

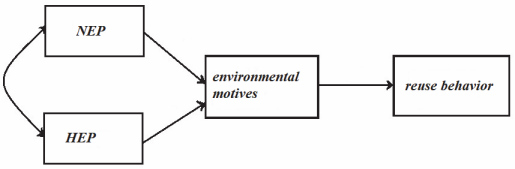


Figure 1. *Tested assumed model of HEP NEP scale, environmental motives and behavior-reuse*

Measure	Estimate	Threshold	Interpretation
CMIN	3.594	--	--
DF	2	--	--
CMIN/DF	1.797	Between 1 and 3	Excellent
CFI	0.976	>0.95	Excellent
SRMR	0.047	<0.08	Excellent
RMSEA	0.064	<0.06	Acceptable
PClose	0.305	>0.05	Excellent

Table 1. *Indicators of data fit into the assumed model*

Based on the results presented in Table 11, it is evident that the model aligns well with the empirical data. All indices fall below critical threshold values, indicating an excellent fit to the data. While the RMSEA index is acceptable, falling between 0.06 and 0.08 (Hu and Bentler, 1999), all other indices demonstrate excellent fit.

Hypothesis 1: Reuse behavior can be directly predicted by environmental motives. Result: Supported. Environmental motives significantly predict reuse behavior (effect = 0.504, p = 0.001).
Hypothesis 2: NEP is a predictor of environmental motives with a positive correlation. Result: Not Supported. NEP is not a statistically significant predictor of environmental motives (effect = 0.145, p = 0.38).
Hypothesis 3: HEP is a predictor of environmental motives with a negative correlation. Result: Supported. HEP is a statistically significant predictor of environmental motives with a negative correlation (effect = -0.199, p = 0.004).
Hypothesis 4: There is a correlation between HEP and NEP. Result: Not Supported (at a statistically significant level). The correlation between HEP and NEP factors was 0.46, but it was not statistically significant.

The results of the study of the mediator effects of environmental motives factors are given in Table 2.

Relationship	Direct without Mediator	Direct with Mediator	Interpretation
(environmental motives mediate the relationship between HEP and Reuse behavior)	-.116 (0.007)	-.199 (0.004)	Partial mediation
(environmental motives mediate the relationship between NEP and Reuse behavior)	.188 (NS)	0.118 (0.038)	Complete mediation

Table 2. *Indicators of mediator effects of environmental motives on NEP and HEP*

Hypothesis 5: Environmental motives mediate the relationship between NEP and reuse behavior. Result: Supported (as a complete mediator). Environmental motives completely mediate the relationship between NEP factors and reuse behavior factors.
Hypothesis 6: Environmental motives mediate the relationship between HEP and reuse behavior. Result: Supported (as a partial mediator). Environmental motives partially mediate the relationship between HEP factors and reuse behavior factors.

The results of the study of the moderator effect of age are given in Table 3.

	Younger (19-21)		Older (22-27)		
	Estimate	*p*	Estimate	*p*	z Score
EM → R	0.023	0.000	0.041	0.000	2.415**
NEP → EM	2.148	0.108	2.175	0.180	0.13
HEP → EM	-5.582	0.000	1.060	0.651	2.385**

***$p < 0.01$; **$p < 0.05$; *$p < 0.10$
Note: arrows represent the connection direction assumed in the model we tested

Table 3. *Indicators of group moderation of younger and older*

Hypothesis 7: There are moderating effects of age on the relationships between environmental motives, NEP, HEP, and reuse behavior. Results: Partially Supported.
Environmental motives → Reuse behavior: Moderation is statistically significant. Environmental motives are a better predictor of reuse behavior in older respondents than in younger ones.
NEP → Environmental motives: Moderation is not statistically significant.
HEP → Environmental motives: Moderation is statistically significant. HEP is a statistically significant negative predictor of environmental motives in younger respondents, while in older respondents, it is positive but not statistically significant.
These results indicate that the relationship between environmental motives and reuse behavior is influenced by age, with a stronger predictive effect observed in older individuals. Additionally, the relationship between HEP and environmental motives is influenced by age, with a significant negative association found in younger respondents and a non-significant positive association in older respondents. The relationship between NEP and environmental motives does not show significant age-related differences in prediction.

The results of the study of the moderator effect of the study field are given in Table 4.

	Environmental protection		Occupational safety		
	Estimate	*p*	Estimate	*p*	z Score
EM → R	0.043	0.000	0.021	0.000	-2.972***
NEP → EM	1.883	0.214	2.508	0.079	0.300
HEP → EM	-2.011	0.223	-6.240	0.002	-1.628

***$p < 0.01$; **$p < 0.05$; *$p < 0.10$
Note: arrows represent the connection direction assumed in the model we tested

Table 4. *Indicators of group moderation between students majoring in environmental protection and occupational safety*

Hypothesis 8: There is a moderating effect of the field of study on the relationships between environmental motives, NEP, HEP, and reuse behavior.Results: Partially Supported.
Environmental motives → Reuse behavior: Moderation is statistically significant. Environmental motives are a better predictor of reuse behavior among students majoring in environmental protection compared to students in the field of occupational safety.
NEP → Environmental motives: Moderation is not statistically significant for either group.
HEP → Environmental motives: Moderation is statistically significant. HEP is a statistically significant negative predictor of environmental motives for students majoring in occupational safety, while for students majoring in environmental protection, it is a negative predictor but not statistically significant.
These results suggest that students majoring in environmental protection are more impacted by environmental motives in predicting their reuse behavior compared to students in the field of occupational safety. Furthermore, the negative influence of HEP on environmental motives is significant among students of occupational safety, indicating a stronger resistance to ecologically friendly attitudes among these students.

DISCUSSION

In this study, the relationships between environmental attitudes, motives for environmental protection, and reuse behavior were explored. The findings provide valuable insights into the complex interplay of these factors among students majoring in environmental protection and occupational safety. The study confirmed that environmental motives are a direct

predictor of reuse behavior, aligning with prior research indicating a connection between intrinsic motivation and pro-environmental behavior (De Young, 1985). People with stronger environmental motives are more inclined to reuse objects, emphasizing the significance of intrinsic motivations in promoting ecological behaviors (Corral-Verdugo, 1996). Contrary to expectations, the study did not find a significant positive correlation between NEP and environmental motives. While previous research supported this connection (Kim et al., 2006; Leung and Rice, 2002), the current study's results did not align. This discrepancy might stem from the sample characteristics or measurement limitations of the NEP instrument used. However, the study did confirm the negative correlation between HEP and environmental motives, indicating that individuals who perceive humans as exempt from environmental concerns are less motivated to engage in pro-environmental actions. This aligns with the theoretical distinction between HEP and NEP and emphasizes the impact of anthropocentric views on environmental motivations and behaviors (McDonald and Patterson, 2007; Simmons and Widmar, 1986). The study partially supported the hypothesis that environmental motives mediate the relationship between HEP and reuse behavior. This partial mediation suggests the presence of other factors influencing reuse behavior that were not accounted for in the model. Regarding age, the findings supported the idea that older individuals tend to exhibit more pro-environmental behavior (Wiernik et al., 2013). This result emphasizes the importance of continuous learning and exposure to pro-ecological information in shaping environmentally conscious behaviors, as suggested by Otto and Kaiser (2014). Additionally, this research revealed that the field of study moderates the relationship between environmental motives and reuse behavior. Environmental protection students, being more immersed in environmental issues, demonstrated stronger environmental motives, further emphasizing the role of education and knowledge in promoting pro-environmental attitudes and behaviors.

CONCLUSION

The results confirm the main hypothesis of the research, based on theoretical and empirical data. The conclusion is that on the basis of the model, the reuse behavior can be predicted with environmental motives and ecological attitudes. The findings contribute valuable insights into the complex interplay between attitudes, motives, and behaviors related to environmental conservation and reuse.

The research makes a significant contribution by delving into the intricate relationships between ecological attitudes, environmental motives, and reuse behavior. These findings can serve as a foundation for educational and training programs aimed at fostering pro-environmental behaviors, especially in the context of waste reduction and sustainable consumption.

Acknowledging the limitations of the study, particularly the sample size and the reliability of the HEP-NEP scale, it's important to interpret the results with caution. Future research endeavors could focus on addressing these limitations. Increasing the sample size, incorporating additional variables representing diverse environmental behaviors, and employing more reliable and contemporary measurement tools are essential steps for refining the model further.

Educationally, these findings underscore the significance of addressing not only environmental attitudes but also underlying motives when designing interventions and educational initiatives. Tailoring programs to enhance both environmental attitudes and intrinsic motivations can potentially lead to more sustainable behaviors, such as reuse, among individuals.

From a policy perspective, understanding the mediating and moderating factors at play in pro-environmental behaviors can inform the development of targeted policies and practices. By recognizing the impact of education, age, and specific fields of study, policymakers can tailor initiatives to different demographic groups effectively, encouraging widespread adoption of eco-friendly practices.

In essence, this study lays the groundwork for more comprehensive and nuanced investigations into the complexities of environmental attitudes, motives, and behaviors. As we move forward, continuing research in this area will undoubtedly provide valuable insights, shaping educational strategies, policy decisions, and societal attitudes toward a more sustainable future.

ACKNOWLEDGEMENTS

This paper is the result of research funded by the Ministry of Education, Science and Technological Development of the Republic of Serbia.

REFERENCES

Berger, I. (1997). The demographics of recycling and the structure of environmental behavior. *Environment and Behavior, 29,* 515 –531.

Catton, W. R. and Dunlap, R. E. (1978). "Environmental Sociology: A New Paradigm". *The American Sociologist*, 13(1), 41–49.

Catton, W. R., & Dunlap, R. E. (1978). Paradigms, theories, and the primacy of the HEP-NEP distinction. *The American Sociologist*, 256-259.

Corral-Verdugo, V. (1996). A structural model of reuse and recycling in Mexico. Environment and Behavior, 28(5), 665-696.

Corral-Verdugo, V., & Armendariz, L. I. (2000). The “new environmental paradigm” in a Mexican community. *The Journal of Environmental Education*, *31*(3), 25-31.

Corral-Verdugo, V., Bonnes, M., Carrus, G., Moser, G., & Sinha, J. (2010). Environmental Worldviews and Water Conservation. *Environment, Health, and Sustainable Development*, *1*, 275.

De Young, R. (1985) Encouraging environmentally appropriate behavior: The role of intrinsic motivation. Journal of Environmental Systems, 15, 4, 281-292 <http://hdl.handle.net/2027.42/83711>

De Young, R. (2000). New ways to promote proenvironmental behavior: Expanding and evaluating motives for environmentally responsible behavior. Journal of social issues, 56(3), 509-526.

Dunlap, R. E., & Van Liere, K. D. (1978). The "new environmental paradigm". *The journal of environmental education*, *9*(4), 10-19.

Goldenhar, L. M., & Connell, C. M. (1993). Understanding and predicting recycling behavior: An application of the theory of reasoned action. *Journal of Environmental Systems, 22,* 91–103.

Hu, L. T., & Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural equation modeling: a multidisciplinary journal*, *6*(1), 1-55.

Kim, H., Borges, M. C., & Chon, J. (2006). Impacts of environmental values on tourism motivation: The case of FICA, Brazil. *Tourism management*, *27*(5), 957-967.

Leung, C., & Rice, J. (2002). Comparison of Chinese-Australian and Anglo-Australian environmental attitudes and behavior. Social Behavior and Personality, 30, 251-262

McDonald, G. W., & Patterson, M. G. (2007). Bridging the divide in urban sustainability: from human exemptionalism to the new ecological paradigm. *Urban ecosystems*, *10*(2), 169-192.

Otto, S., & Kaiser, F. G. (2014). Ecological behavior across the lifespan: Why environmentalism increases as people grow older. *Journal of Environmental Psychology*, *40*, 331-338.

Petrović, N., & Škrbić, B. (2016). Ecological value orientations and readiness for activism in Serbia. *Zbornik radova-Geografski fakultet Univerziteta u Beogradu*, (64), 47-71.

Putrawan, I. (2017). Predicting students' Responsible Environmental Behavior (REB) based on personality, students' New Environmental Paradigm (NEP) and naturalistic intelligence. *Advanced Science Letters*, *23*(9), 8586-8593.

Scott, D., & Willits, F. K. (1994). Environmental attitudes and behavior: A Pennsylvania survey. *Environment and behavior*, *26*(2), 239-260.

Simmons, D. A., & Widmar, R. (1986). Tapping Satisfactions to Promote Energy Conservation Behavior. *Environmental Education and Information*, *5*(2), 70-76.

Stern, P. C., Dietz, T., & Kalof, L. (1993). Value orientations, gender, and environmental concern. Environment and behavior, 25(5), 322-348.

Thomson, J. (2013). *New ecological paradigm survey 2008: Analysis of the NEP Results*. Waikato Regional Council.

Wang, Y., Hao, F., & Liu, Y. (2021). Pro-Environmental Behavior in an Aging World: Evidence from 31 Countries. *International Journal of Environmental Research and Public Health*, *18*(4), 1748.

Wiernik, B. M., Ones, D. S., & Dilchert, S. (2013). Age and environmental sustainability: a meta-analysis. *Journal of Managerial Psychology.*

20th International Conference Man and Working Environment
SEMSIE
Safety Engineering & Management – Science, Industry, Education

www.znrfak.ni.ac.rs/semsie

DRAGOSLAV TOMOVIĆ [1]
DAVID TOMOVIĆ [2]

[1,2] Serbian Association of Occupational Safety and Health

[1] *tdfpreving@mts.rs*
[2] *tomovic.safety@gmail.com*

COMPETENCES OF OCCUPATIONAL SAFETY AND HEALTH EXPERTS IN THE INTEGRATED MANAGEMENT SYSTEM

Abstract: *Although the terms "competent expert" and "competent occupational health and safety expert" do have similarities, they are often used in different contexts and have slightly different meanings. The term competent professional refers to a person who possesses the necessary skills, knowledge, experience and ability to perform a specific job or task. It can be applied to any profession or field, not just to occupational health and safety. The term competent occupational health and safety expert refers to a person who is professionally trained and qualified for work in the field of occupational health and safety. Hence, the main difference between the two terms is in their scope and specificity. While a competent expert can be any person who is qualified to perform a specific job, a competent occupational health and safety expert is a person specifically trained and qualified for tasks related to the activity preserving the safety and health of employees at the workplace.*

Key words: occupational safety and health, OHS expert, competences.

INTRODUCTION

The requirements of conventions and directives have been transposed in the Republic of Serbia, and within the framework of organizing all the work in the organization, an employer is obliged to organize workplace health and safety. Employers accomplish this by designating a specialist who would carry out all of their work in compliance with the Occupational Safety and Health Law.

The relevant law gives the employer the freedom to choose how best to manage the execution of safety and health-related tasks at work, which include the following options: performing these tasks themselves, designating a professional among their employees (one or more), or outsourcing a person or a company with a license in the field of safety and health at work. The employer decides how to organize these jobs, but must consider the following: type of the activity i.e. technological process and tools used for the job, organization, nature and scope of the work, number of employees, their expertise, age structure, standardized work, work shifts, assessed risks, the number of units separated by location, the type of activity, as well as other factors that can affect the organization of tasks and activities related to safety and health at work.

The Law allows employers who operate in the following sectors: retail trade; lodging and food services; information and communications; financial affairs and insurance; real estate business; professional, scientific, innovative; administrative and auxiliary services; mandatory social security insurance; education; art; entertainment and recreation; and other service-related fields to undertake workplace health and safety tasks in-house without having to take an exam for OHS professional. This option is being considered for employers with up to 20 employees because the volume of these jobs is smaller and the risks in these activities are considered to be lower. These employers must take an exam for OHS professionals.

Based on the lessons learned from implementing the Law on Occupational Safety and Health, it was observed that it is necessary to improve the competences of occupational safety and health professionals in certain activities. In this regard, "the employer in the fields of construction activities, agriculture, forestry and fishing, mining, processing industry, electricity supply, gas, steam and air conditioning (except trade in electricity and gas fuels through the gas network), water supply, wastewater management, control of waste disposal processes, wholesale trade, traffic and storage and similar activities, as well as in health and social protection activities - is obliged to appoint Occupational Health and Safety Adviser, a person who completed at least higher education, with a minimum of 240 ECTS points in academic or vocational studies within the educational and scientific field of technical-technological sciences, and natural sciences and mathematics, namely: biological sciences, environmental sciences, physical sciences, physical-chemical and chemical sciences. An employer in health and social protection can appoint an occupational health and safety adviser, a person who has at least a higher education, with a minimum of 240 ECTS points in academic or professional studies within the educational-scientific field of medical science ("Official Gazette of RS", no.35/2023).

In accordance with the Law on Occupational Safety and Health, "in case of the activities that are not listed as high-risk, if the employer does not perform occupational safety and health tasks himself, they are obliged to designate an Occupational Safety and Health Associate, i.e. a person who has completed at least higher education, with a minimum of 180 ECTS points within the educational-scientific field of technical-

technological sciences, natural sciences and mathematical, medical sciences or in the field of social sciences and humanities" ("Official Gazette of RS", no.35/2023). The Occupational Health and Safety Adviser authorized to perform occupational safety and health tasks in the activities listed in Article 47 of this Law.

One of the novelties in the Law on Occupational Safety and Health is the introduction of mandatory continuous improvement of the knowledge of occupational safety and health experts. A requirement for license renewal is continuous improvement of the knowledge of occupational safety and health experts - Occupational Safety and Health Associates, Occupational Safety and Health Coordinators in the project development phase, Occupational Safety and Health Coordinators in the construction phase, the person responsible for performing inspections and checking work equipment and inspecting and testing electrical and lightning protection installations, the person responsible for testing the conditions of the working environment, i.e. chemical and physical hazards (except for ionizing radiation), microclimate and lighting, and the person responsible for testing the conditions of the working environment - biological hazards. The programme, method, procedure and duration of the continuous improvement of knowledge described above, as well as other issues related to continuous improvement of knowledge of occupational safety and health experts, are prescribed by the Minister responsible for labour affairs. Another novelty is that an occupational safety and health expert - an Occupational Safety and Health Advisor, an Occupational Safety and Health Associate, an Occupational Safety and Health Coordinator in the project development phase, and an Occupational Safety snd Health Coordinator in the construction phase in addition to having passed the OHS professional exam, should have a license and be registered in the Register of OHS professionals.

The Law on Occupational Safety and Health defines the following issues:

- A license is a document that a legal or natural person receives from the minister in charge of labor affairs authorizing them to carry out specific duties related to workplace safety and health in compliance with this Law;
- the license register is a unique, computerized database that contains all legally issued, renewed, and revoked licenses.

An OSH Adviser, or OSH Associate performs tasks in accordance with this Law, in particular the following tasks "implements and takes part in the risk assessment proces; participates in the development of employee training programmes for safe and healthy work, as well as training programs for employee representatives and managers' training programs; controls and makes recommendations to the employer in planning, selection, use and maintenance of work equipment, chemical substances and personal protective equipment; participates in the preparation and organization of the workplace in order to ensure safe and healthy working conditions; organizes preventive and periodic inspections of working environment conditions; organizes preventive and periodic inspections and examinations of work equipment and inspections and tests of electrical and lightning protection installations; suggests measures to improve working conditions, especially at workplaces with increased risk; monitors and controls the application of workplace safety and health measures in compliance with the workplace safety and health organization; monitors the situation related to work injuries and occupational diseases, as well as work-related diseases, participates in the investigation of their causes and prepares reports outlining proposed solutions for their elimination; organizes and conducts training of employees and other people in accordance with the law, employee representatives, managers; prepares and supervises the implementation of safe and healthy work instructions; prohibits the use of work equipment in case he determines an immediate danger to the life or health of the employee and suspends work on the work equipment until the observed defects are eliminated during the inspection of the work equipment from Article 15, paragraph 4 of this law; organizes medical examinations of employees; cooperates and coordinates work with a health institution that performs occupational medical activities on all issues in the field of safety and health at work; cooperates with employee representatives and the Occupational Safety and Health Committee on all issues in the field of occupational safety and health; keeps records in the field of safety and health at work with the employer; monitors changes in regulations and performs coordination of employer acts, monitors standards and technical progress in the field of occupational safety and health" ("Official Gazette of RS", no.35/2023).

When it comes to high-risk activities, the OHS Adviser is obliged to monitor, control and report to the employer on a daily basis the implementation of occupational health and safety measures at the employer in accordance with the organization of occupational health and safety affairs at the employer and the general act.

The new law's provisions guarantee that experts in occupational safety and health maintain a high level of knowledge in the field by means of a knowledge improvement program introduced by the minister in charge of work, taking into account the complexity and breadth of the work they do, the need for ongoing innovation in regulations related to this field, and the need to coordinate domestic regulations with those of the European Union. This legal provision, which emphasizes the value of work done by occupational safety and health experts, attempts to provide employers with safe and healthy work environments so as to lower the rate of work-related accidents and illnesses and to take proactive measures to protect workers' health.

Because of the legal requirements, obtaining a license to perform safety and health at work is subject to

stricter requirements. Legal entities and entrepreneurs who perform safety and health at work are only eligible to apply for a license if they can demonstrate that they have at least two full-time employees under permanent contract who have a licence for OHS Advisers, and at least three years of work experience in those positions after obtaining the appropriate education and and fulfilling the legal requirements. The duration of the license, as well as the conditions under which it can be renewed, are also specified.

REQUIREMENTS FOR STRICTER COMPETENCES

In order to meet the requirements of strengthening competencies and protecting license holders who carry out work in compliance with the law, individuals with special responsibility for workplace safety and health can take more effective and legal action, which improves the system as a whole.

The new solution that is offered is of significant interest to employers in the Republic of Serbia. The ultimate goal of these legislative provisions is to ensure that entrepreneurs, legal entities, and organizations licensed to perform safety and health-related tasks carry out their duties in accordance with workplace safety and health regulations.

The effectiveness of occupational safety and health depends on the level of employee engagement. No matter how skilled, motivated, or professional they are, it is unrealistic to expect one person or a professional team to complete the tasks in this area. This is especially true if all workers are not covered by the occupational safety and health system, in which the person responsible for workplace safety and health is the carrier of professional, organizational, and operational work. Whether and how the occupational health and safety system will function depends on the ability and professional attitude of this person or people. However, there is one fundamental requirement: the employer must declare a policy and encourage all employees to participate in the ongoing improvement of occupational health and safety. Unfortunately, many employers who make decisions about occupational health and safety are unaware of its significance. That is the reason why the whole area is often neglected, and why occupational health and safety jobs are marginalized and not given the importance they deserve by the nature of the job. This further highlights the fact that experts in occupational safety and health did not struggle to be recognized as highly qualified individuals. Part of the responsibility for this state of affairs can be attributed to the occupational health and safety experts themselves (Bulat, 2018).

According to the data of the Occupational Safety and Health Administration, in the period from August 2006 until June 2017, 9331 candidates took the professional exam and 7467 candidates successfully passed it. By analyzing the educational structure of the experts who passed the professional exam, it can be seen that 3102 of them (41.5%) did not have a university degree. Keeping in mind that as technology advances and the field of occupational safety and health becomes more complex, a shortage of qualified personnel may pose a barrier to further development in this area. The number of candidates who passed the exam for occupational safety and health according to the professional training in the period between 2006 and 2017 was 7467, and the distribution according to the education level is as follows: three-year vocational school -106 candidates, high school education (four years) -1167 candidates, high school of vocational education -61 candidates, college or high school of vocational education -1768, university degree level one -4055 candidates, university degree, undergraduate studies -10 candidates, university degree, postgraduate studies -59. At the end of 2009, there were 3,632 individuals who passed the professional exam, and in 2014, this number increased to 6,142.

In this period, there were about 1,334 people with a secondary education (who did not obtain university degrees), who make up about 17.87% of the total number of experts who passed the professional exam. It would be interesting to analyze OSH experts who have passed the professional exam and who obtained college or university degrees in the fields other than technical or technological sciences; however, this cannot be done due to a lack of data. Specifically, we would like to draw attention to the fact that 3,632 individuals passed the exam for OSH professional between 2006 and 2009. In that period, 8 of the 19 by-laws were implemented, and none of the 5 regulations were implemented. In the meantime, the law underwent two changes, and numerous by-laws and decrees were adopted.

According to unofficial data, about 12,000 participants passed the professional exam for occupational safety and health. At the end of July 2023, 903 coordinators for the execution of works and 479 coordinators for the design of the project were hired on 128,387 construction sites.

Upon observation of the situation, a problem was identified. This problem mainly relates to the fact that candidates are not adequately prepared for professional exams; that is, the method of preparation is not predetermined or prescribed; additionally, there is a problem with the lack of continuous training of these professionals.

Another problem that has been observed is that the employer formally appoints an OSH expert without taking into account the activity, technological process, risks, and other similar aspects while performing these tasks.

Unfortunately, many companies, particularly small and medium-sized businesses, do not recognize the significance of occupational health and safety policy. As a result, the entire field is frequently overlooked; occupational health and safety jobs are marginalized,

and they are not given the importance they deserve due to the nature of the job. As a result, engineers of occupational safety and health and other professionals working in this field did not receive the status of highly professional personnel. The individuals working on this project bear some of the responsibility for the current situation, as not enough people have influenced the awareness and broadening of the horizons of those who are most responsible (Radonjić, Tomović, 2001).

The employer develops the company's safety and health policy, and the level of safety and health at work is determined by the leader and thier associates. If they understand that safety and health at work of their employees is an inseparable part of the work process and a integral part for the success of the production, then OSH experts can start their mission of creating working environments where occupational illnesses and work-related injuries are anticipated with the intention of preventing them. (Praštalo, 2010).

THE ROLE OF SAFETY AND HEALTH AT WORK EXPERTS (OHS)?

The Occupational Safety and Health (OHS) professional has a key role in maintaining a safe and healthy work environment. In order to perform his function effectively, an OHS specialist should have various competences. A few of the most important competencies include the following, as shown in Figure 1:

A framework of competences – Occupational safety

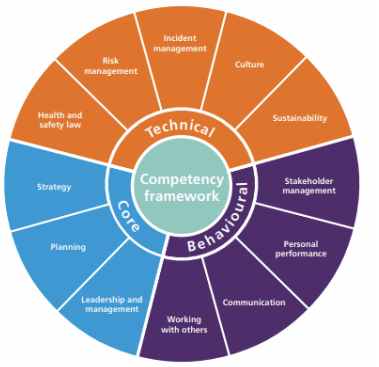


Figure 1. *Framework of competences*

and health professional standards contain: technical competences, key competences, and behavioural competences.

Technical competences – This part of the competence framework includes the collection of technical competences for occupational safety and health which are the basis for the competences of OSH advisory roles. These include a clear understanding of legislation, policy, risk management, incident management, and the impact of health, safety and welfare on people. This part also includes new technical competences such as sustainability, ethical practice, human capital, and community impact.

Professionals in the field of OSH must have a key role in the organizational position of ethical management, which is an integral part of sustainability. This will help contribute to building employee and public trust in the organization.

Key competences - This is the set of skills needed to support and enable good decision-making in the workplace. They include competences covering strategy, planning, leadership and management. Developing these skills will greatly improve the employability and overall effectiveness of OSH professionals.

Behavioural competences - These competences define professional OSH officers' behaviour in the workplace. They include working with stakeholders, ensuring good personal performance and professionalism, communicating and working effectively with others. These competences encourage building successful working relationships.

The competence framework of OSH experts includes: education, specialized training, knowledge of legislation, risk assessment skills, planning and implementation of measures, communication skills, continuous improvement, ethical obligations, monitoring and evaluation. These competencies are illustrative and can be further defined based on the particular sector or place of employment. It should be noted that legislation is subject to change, so it is always a good idea to consult current regulations or experts in the field for the most up-to-date information.

OSH professionals must possess a specific set of skills in order to ensure proper and effective employee protection (Radonjić, Tomović, Tomovič, 2001).

The legal framework for these competences is regulated through numerous regulations, the most important of which is the Occupational Safety and Health Act.

An OSH professional has a key role in preserving the health and safety of employees and must have certain key competences in order to effectively perform their duties, namely: technical knowledge - the ability to identify, analyse and assess workplace-related risks; knowledge of legislation - the ability to communicate clearly and effectively with various stakeholders, including employees, management, regulatory authorities and others, the ability to quickly and efficiently identify problems and find practical solutions, leadership skills and skills to motivate teams, as well as to promote a safety culture, the ability to develop and implement long-term strategies for improving safety at work, skills in planning, organising and implementing safety-related projects; ethics – the ability to adhere to high ethical standards and act with integrity in all situations, recognizing the need for continuous professional development and monitoring of the latest trends and practices in the field of occupational safety, adapting to changes in the work environment, and implementing new practices or technologies; the ability to be people-oriented – to understand employees and their safety needs and concerns.

Given the complexity and diversity of industries and jobs, there may be additional specific competences required for certain sectors or roles. However, the

competencies listed above serve as a foundation for every OSH professional (LE18 1NN UK).

Apart from everything stated OHS expertise may include: *risk assessment* (ability to recognize potential hazards in the workplace, assess their potential impacts and propose adequate measures for protection); *knowledge of standards and regulations* (detailed understanding of national and international standards and regulations related to safety and health at work); *use of technical equipment* (ability to use various instruments and equipment for measuring and monitoring conditions at the workplace, such as devices for measuring noise levels, air quality, lighting, etc.); *technical drawing and modeling* (skills in creating technical drawings or models of working spaces, which can be useful for planning and implementing security measures); *knowledge of materials* (understanding the characteristics of various materials used in the workplace, including their potential hazards or toxicity); *first aid and emergency evacuation procedures* (knowledge of basic first aid procedures and the ability to organize and carry out evacuation in emergencies); *use of IT tools* (ability to use OHS management software, such as databases, software for risk analysis, programs for monitoring compliance with regulations, etc.); *knowledge of the fundamentals of ergonomics,* the capacity to identify and address issues at work that could result in illness or injury, and expertise in the development, execution, and assessment of policies and processes to limit exposure to dangerous substances or unfavorable working conditions; *an understanding of the fundamental industrial processes* that occur in the workplace, which is especially important in industries such as chemical, construction, or manufacturing.

Occupational health and safety experts often have to possess competences that go beyond the boundaries of technical knowledge. These "soft" competences are essential when it comes to developing strategies, planning, leadership and management in the field of OHS. In addition to the above, OHS experts are expected to have the following competences: the ability to develop long-term strategies that focus on improving occupational safety and health in the company; skills in setting realistic and measurable goals for OHS, as well as creating action plans for their achievement, leadership - the ability to motivate and lead teams, as well as to promote a safety culture within the company; communication skills with various stakeholders, including management, employees and external parties, such as regulatory bodies or the media; ability to identify needs for changes in OHS policies or practices and manage the implementation of those changes; effective management of budgets, human resources and technical resources related to OHS; skills in analysing data and information in order to make informed decisions in the field of health and safety; the ability to understand and shape the culture of the organization in terms of promoting safety and health at work; skills in resolving disagreements or conflicts that may arise from OHS issues; recognition of the need for continuous professional development and monitoring of the latest trends and practices in the field of health and safety; ability to plan, organize and monitor OHS related projects, ensuring their timely and efficient implementation. These competences enable OHS professionals to work effectively to improve safety standards and practices within the organization, as well as to lead teams and collaborate with different professionals in order to protect employees.

Behaviour competences (often referred to as "soft skills" or interpersonal skills) are essential to occupational health and safety professionals as these roles often relate to interacting with people, promoting a safety culture, and managing changes. While expectations may differ by industry and organisation, the following behavioural competences are essential for OHS professionals: *Communication skills*: the ability to communicate clearly and effectively with a variety of stakeholders, including employees at all levels, management, regulatory authorities and others; *Teamwork:* the ability to effectively cooperate with colleagues, employees and other experts; *Understanding and empathy*: understanding the concerns and needs of employees and the ability to provide support and guidance; *Ethics and integrity*: maintaining high ethical standards in all situations and acting with integrity; *Conflict resolution skills*: the ability to identify, understand and effectively resolve conflicts or misunderstandings; *Leadership skill*s: motivating and leading teams and individuals, as well as promoting a safety culture; *Adaptability*: flexibility in approach and ability to adapt to changing circumstances; *Critical thinkin*g: ability to analyze information from different sources and make informed decisions; *Self-awareness and self-regulation*: awareness of one's own emotions, strengths and weaknesses and the ability to manage them in a professional context; *Proactiveness*: recognizing potential problems or opportunities for improvement and taking the initiative to address them; stress management: the ability to effectively manage stress and maintain professionalism in challenging situations; negotiation skills: effective negotiation with different stakeholders in order to achieve a positive outcome for the safety and health of employees. These competences enable OHS professionals to build positive relationships, communicate effectively, manage change, and promote a culture of safety within the company.

In the following part, we have listed some of the framework competences that an OHS expert should have, which, together with others, form a wider spectrum of activities in the management system, namely:

Personal characteristics. For occupational health and safety experts, apart from technical knowledge and skills, personal qualities play a key role in successful job performance. These qualities enable him to communicate effectively, take action, and create a favorable environment for occupational safety and health. On a global level, the following personal qualities are particularly important for OHS professionals: integrity, responsibility, confidence, patience, empathy, proactivity, analytical skills, adaptability, self-discipline, critical thinking, good

judgment, and self-awareness. These personal traits assist OHS professionals in developing trust with employees, management, and other stakeholders, as well as in effectively promoting and implementing OHS policies and practices.

Ethical business practice is essential for all professionals, including those in the field of health and safety. OHS professionals often deal with sensitive information and situations that require integrity, honesty and professionalism. The following aspects could be identified as OHS professionals' competencies in ethical business practice: integrity, confidentiality, objectivity, honesty, professional responsibility, continuous improvement, transparency, compliance with legislation, responsibility towards the community, and advocacy of ethical standards. Establishing and maintaining high ethical standards is crucial to building trust, which is necessary for the effective implementation of OHS policies and practices. OHS professionals should serve as models of ethical behavior within the company.

Managing incidents. Incident management is a key competence of OHS professionals, since incidents can occur despite the best measures of prevention. Effective incident response, root cause analysis and implementation of measures to prevent future incidents are essential. For OHS professionals, effective incident management not only helps reduce risk and potential harm, but also builds trust among employees and other stakeholders.

Organisational culture refers to a set of values, beliefs, behaviours and norms that shape how employees interact and communicate with one another and with outside personnel. OHS professionals must understand, shape, and promote a culture that prioritizes safety and health.. Promoting and maintaining a positive organizational culture that emphasises occupational safety and health is key to reducing risk and improving the overall well-being of employees. For this reason, OHS professionals should play a central role in this process.

Organisation of education. During the previous period, the Republic of Serbia passed regulations governing workplace safety and health, which are currently being harmonized. The occupational health and safety specialist has an essential role in the application of these regulations. The competence framework of OSH specialists includes: knowledge of relevant laws and regulations, understanding of risks and risk assessment, organization of training and education, communication skills, problem-solving skills, understanding of technical aspects of the workplace, and ability to monitor and report. The organization of learning includes: formal education, continuous professional development, practical experience, and mentoring.

Continuous professional development (CPD) is of crucial importance for occupational safety and health (OHS) professionals. OHS professionals must continuously update their knowledge and skills in order to stay relevant and productive in their work as laws, standards, and technologies evolve.

Interdisciplinary education refers to combining knowledge and skills from a number of different disciplines in order to approach a particular problem or issue. For the OHS professional, interdisciplinary education can provide a broader and deeper insight into safety and health issues, enabling him to perform his function more effectively (Nikolić, Taradi, 2011). Important components of interdisciplinary education for an expert in this field include various aspects of sciences. *Psychology:* Understanding human behaviour, motivation, and perception can help the professional better understand how employees respond to safety protocols, training, and changes in the work environment. *Sociology:* The study of group dynamics, organizational culture, and social structures can provide insights into how safety norms are formed and enforced within a company. *Management:* Management and leadership skills are essential for coordinating teams, implementing safety programs and communicating with senior management. *Engineering:* Technical knowledge of machinery, equipment, and infrastructure can help an expert identify and address potential risks. *Medicine:* Basic knowledge in the field of medicine, especially related to occupational diseases, can help an expert understand and recognize the health risks associated with the workplace**.** *Ecology and environmental protection:* An understanding of environmental issues can be useful, especially in industries where there is potential for harmful emissions or waste. *Law:* Knowing the basic principles of employment and safety law can be crucial, especially when it comes to complying with local and national regulations. *Communication Skills:* Effective communication is key to training, versatility and promoting a culture of safety**.**

Education and Training: The skills and techniques of pedagogy can help a professional develop effective training and educational programs for employees.

Information Technology: In today's digital age, an understanding of IT can be useful for implementing security technology solutions.

An OSH professional can see beyond the conventional boundaries of their knowledge due to interdisciplinary education, which combines various viewpoints and competencies to address problems and challenges related to safety and health issues in a holistic manner. (Nikolić, Taradi, 2011).

Communication skills are of crucial importance for the OHS specialist, because effective communication is the key to promoting and maintaining a culture of safety within the organization. The key aspects of communication skills for an expert in this field are: *Clarity and Conciseness***:** The ability to convey complicated information clearly and concisely, without unnecessary jargon, so that all employees can understand. *Listening:* Actively listening to employees, colleagues and management in order to understand their security concerns, feedback and suggestions. *Verbal Communication:* Effectively conveying information, ideas, and instructions orally, whether through presentations, meetings or during day-to-day interactions. *Written Communication:* Writing clear,

coherent and structured reports, e-mails, trainings and other written materials. *Presentation skills:* Ability to organise and present information in front of a group of people, by using appropriate visual aids and presentation techniques. *Interpersonal Skills*: The ability to build and maintain positive relationships with employees, management and external stakeholders. *Empathy:* Understanding and putting oneself in the shoes of others, showing compassion to employees who may have experienced incidents or have safety concerns. *Negotiation:* The skill of negotiating and reaching compromises, especially when dealing with resistance to security initiatives or changes. *Giving and Accepting Feedback:* Ability to provide and accept constructive feedback to improve safety practices and protocols. *Communication in crises:* The ability to communicate effectively and calmly in emergencies or after serious incidents, providing clear and concise information to resolve the situation. Regardless of the expertise and knowledge of occupational safety, if the expert is unable to communicate ideas, recommendations, and information in an effective manner, it will be challenging to bring about changes and improvements in the organization. Communication skills enable the professional to connect with various stakeholders, promote a culture of safety, and achieve positive results for the health and safety of employees.

Negotiation skills are important for OHS professionals as they are often faced with the need to convince different stakeholders to accept or implement certain safety measures, policies, or changes. An occupational safety expert can reduce risk and enhance the safety culture within the organization by gaining acceptance and support for important safety initiatives through negotiation. This is one of the most important aspects of negotiation skills for an expert in this field. In addition, the ability to negotiate effectively can help build positive relationships with all stakeholders, which is critical to long-term success in occupational safety.

Pedagogical skills are of key importance for an OHS specialist, especially when it comes to training and educating employees regarding safety protocols, procedures, and practices. The key aspects of pedagogical skills for an expert in this field are: knowledge of learning methods, content structuring, motivation, interactivity, evaluation and feedback, adaptation, use of didactic tools, knowledge of pedagogical theories, development of critical thinking, and continuous improvement. Pedagogical skills enable the OHS professional to convey important safety information in a way that is relevant, understandable, and engaging for employees. Through effective training and education, employees are better equipped to recognize and manage risks, which contributes to creating a safer work environment.

Problem-solving is an essential skill for OHS professional, as they often face challenges and situations that require quick and effective interventions. Key aspects of problem-solving skills for an expert in this field are: analytical thinking, identification of root causes, creative thinking, making decisions under pressure, use of technology, teamwork, communication, monitoring and evaluation, preventive action, continuous improvement. The ability to effectively solve problems is not only about responding to current challenges, but also about anticipating future risks and problems and taking steps to prevent them. This ability is essential for an OHS professional to maintain a secure and healthy workplace..

Emotional intelligence (EI) is the ability to recognize, understand, manage, and direct one's own emotions, as well as the emotions of other people. For an OHS specialist, emotional intelligence is of key importance in many aspects of his work. EI manifests as a key competence in this context: empathy, stress management, active listening, self-awareness, interpersonal skills, resolving conflict, motivation, and assertiveness. Emotional intelligence enables an OHS specialist to better understand and communicate with employees, to effectively deal with stressful situations and to develop stronger interpersonal relationships within the organization. When combined with technical knowledge and other key skills, EI can significantly improve the effectiveness of professionals in this field.

Proactivity is an essential competency for an occupational safety specialist. In the context of occupational safety, proactivity refers to the ability to anticipate, identify, and respond to potential risks before they become real problems. Proactivity is manifested as a key competence of occupational safety experts: risk anticipation, planning and preparation, continuous improvement, creation of safety culture, regular checks and audits, cooperation with others, development and updating of incident response plans, and use of technology. Being proactive allows the occupational safety professional to stay one step ahead of potential problems and create an environment where employees are protected and informed. This not only reduces the risk of injury and illness but also contributes to higher productivity and employee satisfaction.

Ethics is a key competency for an OHS professional. In order to better understand why ethics is important and how it manifests itself in this profession, we provide several aspects of the ethical conduct of occupational safety specialists: responsibility towards employees, transparency, objectivity, confidentiality, integrity, continuous improvement, compliance with laws and regulations, impartiality, engagement and care. Ethics is not just a matter of adhering to professional standards; it is also a matter of character and integrity. An OHS professional should act ethically in order to gain the trust of employees and management and to ensure effective health and safety protection in the workplace.

CONCLUSIONS

The future of the manufacturing sector depends on how well businesses address four key issues. These challenges include: changing the nature of productive work; the aging of the workforce resulting in increased retirements and employment of younger workers; accelerated pace of technological changes; and economic globalization that is developing in unpredictable ways. These challenges bring up new

concerns for occupational safety and health. The way in which employers, under the guidance of their occupational health and safety professionals, respond to these risks will shape the success of that sector. Certainly, another condition should be added to this condition - that the work of an occupational safety and health expert is performed by a competent, professional and motivated person (Manufacturing Safety Alliance of BC, 2021).

According to the International Organization for Standardization (ISO), "competence" is defined as "the ability to apply knowledge and skills to achieve planned results." In the context of OHS professionals, there is a wide range of knowledge and skills in which competence is required to be effective and to 'achieve intended results'. For the purposes of developing this framework, "competent" is defined as a measured state in which a worker possesses the necessary qualifications, necessary experience, and demonstrated skills required to work without direct supervision or without supervision in general.

Based on this definition, competence is an outcome-based unit of knowledge or a set of related skills that can be demonstrated to a predefined standard. This outcome-based demonstration of competency is used as evidence to support an OHS professional's claim that they are able to achieve the intended results of a particular task or a particular job function. Today, the OHS profession is multidisciplinary, and it includes occupational and environmental medicine, epidemiology, occupational health and safety, occupational and industrial hygiene, mental health and well-being, and human factors. The role of OHS professionals on the construction site increasingly requires knowledge and collaboration with other disciplines, including environmental protection, product safety, emergency response, security, rehabilitation, law and insurance. OHS professionals advise policymakers and industry on a wide range of issues, including workplace risk and hazard assessment, injury and fatality prevention, effective return-to-work practices for injured workers, and the associated human and business costs of unsafe and unhealthy workplaces (Radonjić, Tomović, Tomovič, 2001).

While the focus on regulatory compliance remains important, the OHS profession is shifting to a preventative and holistic approach. OSH professionals must be able to influence, engage, and train managers, employees, and employee representatives on how to create and maintain a safety culture, in addition to advising their employers on prevention and improvement practices using a much larger database. As a result, OHS professionals need interpersonal, industrial and technical skills, along with management skills directly relevant to the nature of the job.

Today, the OHS profession in Serbia is regulated by law. We recognise certain problems in the training of professionals involved in occupational safety and health. There is a lack of consistent and trustworthy information regarding the competencies of an accredited individual due to the wide range of certifications and credentials. Defining the body of knowledge and skills for the OHS profession is a crucial first step towards establishing standards for the OHS profession. Finally, establishing accredited pathways for professionals to develop robust OHS competencies will improve workplace safety. The accreditation process, as well as continuous training and periodic verification, should encourage the development of occupational safety and health experts' competence. As the system is currently configured, the mere motivation of practical training of occupational safety and health experts and the manner in which it is carried out is insufficient; additional technical knowledge must be provided.

The creation of the register and licensing should allow for continuous professional development and improvement of the work of occupational safety and health experts, not only for those who work for employers, but also for those who work for authorized legal entities/entrepreneurs.

Based on what has been stated, it is required that this crucial issue be regulated more closely or specifically.

REFERENCES

Bulat, P. (2018). *Povećanje kapaciteta i jačanje uloge regionalnih organizacija civilnog društva za poboljšanje uslova rada i socijalnog dijaloga sa javnim institucijama.* Beograd: Projekat „EuropeAid / 150147 / DH / ACT / PRAREG.

LE18 1NN UK. *Competency framework.* Professional standards for safety and health at work IOSH. The Grange Highfield Drive Wigston Leicestershire LE18 1NN UK.

Nikolić, V., Taradi, J. (2011). Comparative analysis of the higher education system of occupational safety engineers in Serbia and Croatia. Proceedings: *The 16th conference of the series Man and Working Environment, International Conference Safety of Technical Systems in Living and Working Environment.* Nis: Faculty of Occupational Safety in Nis, pp.455-462.

Manufacturing Safety Alliance of BC (2021). *Occupational Health and Safety Competency Framework*.

Praštalo, R. (2010). *Kompetencije i karijera*. Ljubljana: Narodna univerzitetna knjižnica.

Radonjić, B., Tomović, D., (2001). *Menadžer bezbednosti i zdravlja na radu u sistemu integrisanog upravljanja rizicima*. Kragujevac: Udruženje za bezbednost i zdravlje na radu Srbije.

Radonjić, B., Tomović, D., Tomović, D. (2001). *Funkcija i profil menadžera za bezbednost i zdravlje na radu.* Kragujevac: Udruženje za bezbednost i zdravlje na radu Srbije.

Zakon o bezbednosti i zdravlju na radu („Sl. glasnik RS“ br.35/2023).

20th International Conference Man and Working Environment
SEMSIE
Safety Engineering & Management – Science, Industry, Education
www.znrfak.ni.ac.rs/semsie

SAŠA MILOJEVIĆ[1]
GORAN BOŠKOVIĆ[2]
SLOBODAN SAVIĆ[3]
BLAŽA STOJANOVIĆ[4]

[1-4]University of Kragujevac,
Faculty of Engineering

[1]sasa.milojevic@kg.ac.rs
[2]goran.boskovic@kg.ac.rs
[3]ssavic@kg.ac.rs
[4]blaza@kg.ac.rs

CONDITIONS FOR SAFE APPLICATION OF LIQUEFIED NATURAL GAS IN HEAVY-DUTY GARBAGE TRUCKS

Abstract: *When using alternative fuels in mobile systems, it is important to know that truck transport and shipping, as examples of transport modes, require a higher fuel energy density in the reservoirs. The physical and chemical properties of liquefied natural gas as an alternative fuel present some advantages (higher energy density, range of flammability, etc.). This paper systematizes the possibilities for the application of liquefied natural gas in mobile systems for transportation for longer distances.*

Keywords: emission, natural gas, safe transport, vehicles

INTRODUCTION

The increased amount of energy demand produces a large amount of greenhouse gases, specifically carbon dioxide emissions by the burning of fossil fuels, which ultimately causes global warming (Gil-Lopez & Verdu-Vazquez, 2021; Gnap & Dočkalik, 2021; Jhawar, 2022; Marotta et al., 2015).

In order to meet the proposed targets of the Paris Climate Agreement, multiple strategies are available to reduce emissions from transport. New technologies have been developed and applied to vehicles and their propulsion systems for higher fuel economy and lower raw emissions of toxic gasses (Livaniou & Papadopoulos, 2022; Milojević et al., 2023; Skrúcaný et al., 2018).

In countries such as Serbia (with a large river port, many tourist centres and the transportation of goods by trucks due to the connection with international companies, etc.), the demand for alternative fuels that are suitable for long distance applications is expected to remain high. Natural gas is a high-quality fuel available for propulsion systems. Currently, in Serbia, there are 878 natural gas-powered vehicles on the roads (792 passenger and light duty vehicles, 58 buses, and 28 medium and heavy-duty trucks). The fuel cost savings for owners of natural gas vehicles are higher, due to the difference between the cost of a cubic meter of natural gas and a litre of traditional fuels – petrol and diesel (Milojević, 2017).

The growing number of vehicles powered by natural gas required that new regulations and rulebooks regulating this field be adopted. The requirements related to the aspect of safety and functionality of installation of gas devices and equipment have been defined under the regulations UN ECE 110R and UN ECE 115R. Laws and by-laws applicable in Serbia for natural gas vehicles are the Law on Road Traffic Safety, the Rulebook on the Classification of Motor Vehicles and Trailers and Technical Conditions for Vehicles in Road Traffic, and Vehicle Testing Rulebook (Milojević et al., 2016).

LIQUEFIED NATURAL GAS AS FUEL IN HEAVY-DUTY VEHICLES

Liquefied natural gas (LNG) is predominantly 92-98% methane that has been liquefied by condensation at cryogenic temperatures. At atmospheric pressure, the condensation temperature of natural gas is about -162 °C. In the process of natural gas liquefication, its volume decreases approximately 600 times (Jhawar, 2022).

Another way to increase the energy of stored natural gas in vehicles is under higher pressure of 20 MPa onboard in cylinders as CNG (compressed natural gas), (Jurkovič et al., 2020; Lähde et al., 2021). In Serbia, natural gas was used for the first time in serially produced MAZ-BIK buses for the purpose of public transportation in Kragujevac, about which numerous studies were published (Milojević et al., 2018; Skrúcaný et al., 2019).

The autonomy equivalence of one litre of diesel oil is 5 litres of CNG, meaning that, concerning heavy vehicles, CNG is mainly recommended for urban fleets, with daily refuelling by night. LNG, by its liquid state, is the natural gas with a higher energy density, needing only a volume of 1.8 litres to give the same autonomy as one litre of diesel fuel. This significant characteristic opens the way for the medium- and long-distance road transport using LNG (Jurkovič et al., 2020; Zhao et al. 2021; Pavlović et al., 2021).

Gas engine power supply system

Natural gas as fuel for vehicle drive systems in road transport is applied in new vehicles with original natural gas engines or by converting existing engines so as to use gaseous fuels.

Figure 1 shows the main components that are added to vehicles when an LNG conversion kit is installed. Diesel blend system makes it possible to convert diesel engines to dual-fuel operation by substituting cleaner and cheaper LNG for some of the diesel fuel that would normally be injected into the engine. In principle, this system is suitable for all diesel engines.

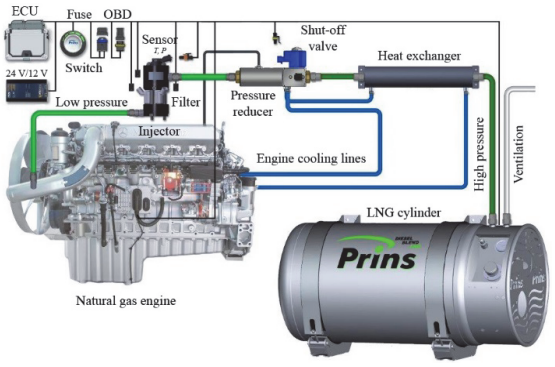


Figure 1. *Components for LNG diesel blend dual-fuel system*

Figure 2 shows the position of the installed devices and equipment on a heavy-duty truck, with a natural gas (LNG) propulsion system.

LNG fuel tanks are made of aluminium alloy and covered with polyurethane foam thermal insulation with a thickness of about 50 mm. Such tanks not only maintain a low temperature (–162 °C), but also withstand overpressure up to 0.2 MPa.

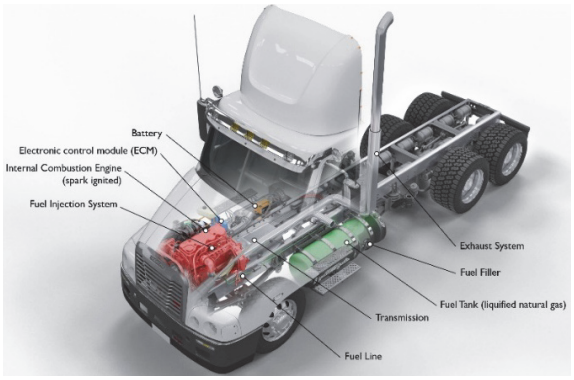


Figure 2. *Fuel system of an LNG truck*

Heavy-duty LNG vehicles work much like petrol-powered vehicles with a spark-ignited internal combustion engine. The natural gas is super-cooled and cryogenically stored in liquid form, usually in a tank on the side of the truck. LNG is typically a more expensive option than CNG and is most often used in heavy-duty vehicles to meet longer range requirements. Because it is a liquid, the energy density of LNG is greater than CNG, so more fuel can be stored on board the vehicle.

The main disadvantage of CNG power is the increased curb weight of the vehicle, which reduces its carrying capacity by the same amount.

The main disadvantage of LNG is the volatility of the gas and, as a result, its periodic venting into the atmosphere. This problem manifests itself only during long-term downtime of vehicles, and with its constant use, there are no gas losses.

REGULATIONS RELATED TO THE VEHICLES POWERED BY GAS

International Regulations

From the aspect of safety and proper installation of gas equipment, the requirements to be met by CNG and LNG vehicles have been prescribed within two ECE regulations (United Nations Economic Commission for Europe, 2011):

a) Regulation No. 110 (UN ECE 110R) – Uniform provisions concerning the approval of:

- specific components of motor vehicles using CNG and/or LNG in their propulsion system;
- Vehicles with regard to the installation of specific components of an approved type for the use of CNG and/or LNG in their propulsion system.

b) Regulation No. 115 (UN ECE 115R) – Uniform provisions concerning the approval of:

- specific retrofit systems to be installed in motor vehicles for the use of LPG in propulsion system;
- specific CNG retrofit systems to be installed in motor vehicles for the use of CNG in their propulsion system.

National Regulations

The following laws and by-laws apply to the vehicles in Serbia:

- Law on Road Traffic Safety;
- Rulebook on the Classification of Motor Vehicles and Trailers and Technical Conditions for Vehicles in Road Traffic;
- Vehicle testing regulations.

SAFE INSTALLATION OF LNG EQUIPMENT IN VEHICLES

On each tank, the manufacturer shall provide clear permanent markings not less than 6 mm high. Marking shall be made either by labels attached by adhesive or plates attached by welds. Each tank shall be marked as follows:

a) Mandatory information:

- "LNG ONLY";
- manufacturer's identification;
- tank identification (applicable part number and a serial number unique for every cylinder);
- working pressure and temperature;
- regulation number, along with tank type and certification registration number;
- the pressure relief devices or valves, qualified for use with the tank or the means for obtaining information on qualified fire protection systems;
- when labels are used, all tanks shall have a unique identification number stamped on an exposed metal surface to permit tracing in the event that the label is destroyed.

b) Non-mandatory information. On a separate label(s) the following non-mandatory information may be provided:

- gas temperature range;
- nominal water capacity of the tank to two significant numbers;
- date of original pressure test (month and year).

The markings shall be placed in the listed sequence but the specific arrangement may be varied to match the space available. An acceptable example of mandatory information is given in Table 1.

Table 1. *Example of mandatory information on an LNG tank plate*

LNG ONLY
Manufacturer/part number/serial number
1.6 MPa (16 bar) / (-162 °C)
ECE R 110 LNG (registration No. …)
Use only manufacturer approved pressure relief device

The LNG tanks shall be type approved, also with provisions on components fitted to the LNG tank. A system shall be provided for preventing the fuel tank from being overfilled.

The LNG tank shall be equipped at least with the following components, which may be either separate or combined (special care shall be taken to prevent LNG trapping):

- pressure relief valve;
- manual valve;
- automatic valve;
- excess flow device;
- the tank may be equipped with a gas-tight housing, if necessary.

The other LNG system components shown below shall be type approved:

- LNG heat exchanger – vaporizer;
- LNG filling receptacle;
- pressure control regulator;
- LNG pressure and/or temperature sensor/indicator;
- natural gas detector;
- automatic valve, check valve, the pressure relief valve, excess flow valve, manual valve and non-return valve;
- fuel pump and electronic control unit.

Installation of the LNG tanks

Every LNG tank shall be tested at a minimum pressure of 1.3 times (the working pressure plus 0.1 MPa). The tank shall be permanently installed in the vehicle and shall not be installed in the engine compartment. The tank shall be installed such that there is no metal-to-metal contact, with the exception of the fixing points of the tank(s). When the vehicle is ready for use, the fuel tank shall not be less than 200 mm above the road surface (Figure 2).

The fuel tank(s) shall be mounted and fixed so that the following accelerations can be absorbed (without damage occurring) when the tank(s) is full (Table 2).

Table 2. *Prescribed accelerations of the LNG tank*

Categories of Vehicles	M1 and N1	M2 and N2	M3 and N3
Accelerations in the direction of travel	$20 \cdot g$	$10 \cdot g$	$6.6 \cdot g$
Accelerations horizontally perpendicular to the direction of travel	$8 \cdot g$	$5 \cdot g$	

A calculation method can be used instead of practical testing if its equivalence can be demonstrated by the applicant for approval to the satisfaction of the Technical Service.

LNG component type approval mark

Figure 3 shows an example of approval mark affixed on the LNG component.

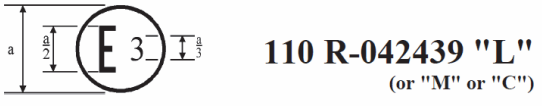


Figure 3. *Example of approval mark affixed on the LNG component caption*

The above approval mark affixed to the LNG component shows that this component has been approved in Italy (E 3), pursuant to Regulation No. 110 under approval number 042439 (United Nations Economic Commission for Europe, 2011). The first two digits of the approval number indicate that the approval was granted in accordance with the requirements of Regulation No. 110 as amended by the 04 series of amendments. The letter "L" indicates that the product is suitable for use with LNG. The letter "M" indicates that the product is suitable in moderate temperatures. The letter "C" indicates that the product is suitable in cold temperatures.

TECHNICAL INSPECTION OF LNG-POWERED VEHICLES

"Periodical technical inspection" means a periodical administrative uniform procedure by which the authorized technical inspection centres responsible for conducting the inspection tests declare, after carrying out the required verifications, that the wheeled vehicle submitted conforms to the requirements.

"International Technical Inspection Certificate" means a certificate about the first registration after manufacture and the periodical technical inspections of wheeled vehicles in compliance with the provisions.

"Wheeled vehicle" means motor vehicles of categories M_1, M_2, M_3, N_1, N_2, and N_3, as specified in Consolidated Resolution on the Construction of Vehicles (RE.3) (TRANS/WP.29/78/Rev.6, as amended), used in international transport.

Wheeled vehicles used in international transports shall satisfy the requirements set out below when they are fitted with LPG, LNG, or CNG engines according to UN Regulations Nos. 67, 110, 115, or 143 (Table 3).

Table 3. *Periodicity of technical inspection*

Categories of Vehicles	Maximum inspection intervals
✓ Passenger-carrying motor vehicles: M_1, except taxis and ambulances ✓ Goods vehicles: N_1	Four years after the first entry into service of the first registration and every two years thereafter
✓ [Taxis and ambulances] ✓ Passenger-carrying motor vehicles: M_2 above 3.500 kg and M_3 ✓ Goods vehicles: N_2 and N_3	One year after the first registration (or if the vehicle is not required to be registered, date of first use) and annually thereafter

"Verification" means the proof of compliance with the requirements set out in Table 4 through tests and checks carried out using techniques and equipment currently available, and without the use of tools to dismantle or remove any part of the vehicle.

For the purpose concerning the uniform conditions for periodical technical inspections of wheeled vehicles and the reciprocal recognition of such inspections, the items to be inspected are related to safety requirements of motor vehicles using CNG, LPG, and LNG in their propulsion system (Table 4).

The method of inspection shall be the minimum requirement. Where a method of inspection is given as visual, it means that in addition to looking at the items, the inspector can also handle them, evaluate noise, etc.

"Inappropriate repair or modification" means a repair or modification that adversely affects the road safety of the vehicle.

Recommendations for the main reasons for rejection are also given in the annex. The three criteria for assessment of defects are defined as follows:

- "Minor defects" (MiD) are technical defects that have no significant effect on the safety of the vehicle and other minor non-compliances. The vehicle does not have to be re-examined as it can reasonably be expected that the detected defects will be rectified without delay;
- "Major defects" (MaD) are defects that may prejudice the safety of the vehicle and/or put other road users at risk and other more significant non-compliances. Further use of the vehicle on the road without repair of the detected defects is not allowed although it still may be driven to a place for repair and afterwards to a specified location for the repair to be checked;
- "Dangerous defects" (DD) are defects that constitute a direct and immediate risk to road safety such that the vehicle should not be used on the road under any circumstances.

Table 4. *Minimum inspection requirements*

Item Method and Main reasons for rejection	Defect assessment		
	MiD	MaD	DD
Legal requirements; visual inspection; documentation Installation is not approved according to UN Reg. Nos. 67, 110, 115, or 143, etc.		X	
Fuel control command; visual inspection or by operation Operation not possible Not clear marking that may confuse the driver		X X	
Ventilation housing and its ventilation pipes Visual inspection with the vehicle, on a hoist when appropriate Not adequately secured with risk of detachment, gas leakage or fire Components missing, damaged, corroded, or not appropriated Blocked ventilation pipes		 X 	 X X
Other components of gas filling system: valves, pipes, injectors, etc. Visual inspection Discharge valves with blocked discharge holes Pipes without an appropriate protection		 X	 X
Electronic control unit Visual inspection Warning device malfunctioning Warning device shows system malfunction		 	 X X
Leakage; Inspection and use of leak detecting devices Presence of gas		 	 X
Marking; Visual control Marking and data plate or component marking not in accordance with the requirements		 X	

CONCLUSION

In the future, more intensive use of environmentally cleaner alternative fuels is expected. In this regard, the paper presented the logistics of using liquefied natural gas as a fuel in garbage trucks.

The following three conclusions were made after the presented discussion:

1. Natural gas is a high-quality fuel for propulsion systems. Available reserves equal the known oil reserves; the negative influence upon the environment is lower than that of fuels derived from oil, as is the price. Therefore, natural gas as a fuel has been increasingly used in motor vehicles.
2. The advantage of using and storing natural gas in a liquid state in tanks on motor vehicles is reflected in the fact that in the process of natural gas liquefaction, its volume decreases by approximately 600 times. Consequently, using liquefied natural gas as fuel, it is possible to cover approximately the same distance in kilometres with a single filling of the tank as with diesel-powered vehicles.
3. From the aspect of safety and proper installation of gas equipment, the requirements to be met by CNG and LNG vehicles have been prescribed within ECE Regulation No. 110 (UN ECE 110R).

ACKNOWLEDGEMENTS

This paper is the result of the research within the project TR35041, financed by the Serbian Ministry of Science, Technological Development and Innovation.

REFERENCES

Gil-Lopez, T., & Verdu-Vazquez, A. (2021). Environmental Analysis of the Use of Liquefied Natural Gas in Maritime Transport within the Port Environment. *Sustainability*, *13*(21), 11989. http://dx.doi.org/10.3390/su132111989

Gnap, J. & Dočkalik, M. (2021). Impact of the operation of LNG trucks on the environment. *Open Engineering*, *11*(1), 937-947. https://doi.org/10.1515/eng-2021-0096

Jhawar, P. S. (2022, May 05). *Natural gas (CNG) vs. LPG, LNG, RNG and diesel*. Cummins Newsroom. https://www.cummins.com/news/2022/05/05/natural-gas-cng-vs-lpg-lng-rng-and-diesel

Jurkovič, M., Kalina, T., Skrúcaný, T., Gorzelanczyk, P., & Ľupták, V. (2020). Environmental Impacts of Introducing LNG as Alternative Fuel for Urban Buses – Case Study in Slovakia. *Promet – Traffic & Transportation*, *32*(6), 837-847. https://doi.org/10.7307/ptt.v32i6.3564

Lähde, T., & Giechaskiel, B. (2021). Particle Number Emissions of Gasoline, Compressed Natural Gas (CNG) and Liquefied Petroleum Gas (LPG) Fueled Vehicles at Different Ambient Temperatures. *Atmosphere*, *12*(7), 893. http://dx.doi.org/10.3390/atmos12070893

Livaniou, S., & Papadopoulos, G. A. (2022). Liquefied Natural Gas (LNG) as a Transitional Choice Replacing Marine Conventional Fuels (Heavy Fuel Oil/Marine Diesel Oil), towards the Era of Decarbonisation. *Sustainability*, *14*(24), 16364. http://dx.doi.org/10.3390/su142416364

Marotta, A., Pavlovic, J., Ciuffo, B., Serra, S., & Fontaras, G. (2015). Gaseous Emissions from Light-Duty Vehicles: Moving from NEDC to the New WLTP Test Procedure. *Environmental Science & Technology, 49*(14), 8315-8322. https://doi.org/10.1021/acs.est.5b01364

Milojević, S., Gročić, D., & Dragojlović, D. (2016). CNG propulsion system for reducing noise of existing city buses, *Journal of Applied Engineering Science, 14*(3), 377-382. https://doi.org/10.5937/jaes14-10991

Milojević, S. (2017). Sustainable application of natural gas as engine fuel in city buses: Benefit and restrictions, *Journal of Applied Engineering Science, 15*(1), 81-88. https://doi.org/10.5937/jaes15-12268

Milojevic, S., Skrucany, T., Miloševic, H., Stanojevic, D., Pantic, M., & Stojanovic, B. (2018). Alternative drive systems and environmentally friendly public passengers transport. *Applied Engineering Letters, 3*(3), 105-113. https://doi.org/10.18485/aeletters.2018.3.3.4

Milojević, S., Savić, S., Mitrović, S., Marić, D., Krstić, B., Stojanović, B., & Popović, V. (2023). Solving the Problem of Friction and Wear in Auxiliary Devices of Internal Combustion Engines on the Example of Reciprocating Air Compressor for Vehicles. *Tehnički vjesnik, 30*(1), 122-130. https://doi.org/10.17559/TV-20220414105757

Pavlović, A., Nestić, S., & Bošković, G. (2021). Upravljanje cirkularnom ekonomijom u poslovnim organizacijama primenom digitalnih tehnologija. *Serbian Journal of Engineering Management*, *6*(1), 22-29. https://doi.org/10.5937/SJEM2101022P

Skrúcaný, T., Milojević, S., Semanová, Š., Čechovič, T., Figlus, T., & Synák, F. (2018). The Energy Efficiency of Electric Energy as a Traction Used in Transport. *Transport technic and technology, 14*(2), 9-14. https://doi.org/10.2478/ttt-2018-0005

Skrucany, T., Semanova, S., Milojević, S., & Ašonja, A. (2019). New Technologies Improving Aerodynamic Properties of Freight Vehicles. *Applied Engineering Letters*, *4*(2), 48-54. https://doi.org/10.18485/aeletters.2019.4.2.2

United Nations Economic Commission for Europe. (2011). Regulation No. 110 of the Economic Commission for Europe of the United Nations (UN/ECE) – Uniform provisions concerning the approval of I. specific components of motor vehicles using compressed natural gas (CNG) in their propulsion system; - II. vehicles with regard to the installation of specific components of an approved type for the use of compressed natural gas (CNG) in their propulsion system. http://data.europa.eu/eli/reg/2011/110(2)/oj

Zhao, Q., Huang, W., Hu, M., Xu, X., & Wu, W. (2021). Characterizing the Economic and Environmental Benefits of LNG Heavy-Duty Trucks: A Case Study in Shenzhen, China. *Sustainability*, *13*(24), 13522. http://dx.doi.org/10.3390/su132413522

Safety Engineering & Management in Industry

20th International Conference Man and Working Environment

SEMSIE

Safety Engineering & Management – Science, Industry, Education

20th International Conference Man and Working Environment

SEMSIE

Safety Engineering & Management – Science, Industry, Education

20th International Conference Man and Working Environment

SEMSIE

Safety Engineering & Management – Science, Industry, Education

20th International Conference Man and Working Environment
SEMSIE
Safety Engineering & Management – Science, Industry, Education

www.znrfak.ni.ac.rs/semsie

ANA STOJKOVIĆ[1]
NENAD KRSTIĆ[2]
DRAGAN ĐORĐEVIĆ[3]
MIODRAG STANISAVLJEVIĆ[4]
NIKOLA IGIĆ[5]
IVAN KRSTIĆ[6]

[1,6]University of Niš,
Faculty of Occupational Safety
[2,3] University of Nis,
Faculty of Sciences and Mathematics
[4]The Academy of Applied Technical Studies, Department - Applied Engineering Sciences
[5] Kvalitet a.d.
Joint-stock company for quality testing

[1] ana.stojkovic@znrfak.ni.ac.rs
[2] nenadkrstic1984@gmail.com
[3] dragance73@yahoo.com
[4] msvode@gmail.com
[5] nikola.igic@kvalitet.co.rs
[6] ivan.krstic@znrfak.ni.ac.rs

LABORATORY ACCREDITATION AS A TOOL FOR IMPROVING QUALITY SYSTEMS IN INDUSTRY

Abstract: *Accredited laboratories for testing and/or calibration with a recognizable work and management system in compliance with ISO/IEC 17025:2017 provide the foundation of the entire quality assurance system, which is essential for integrated management and technical competence. Laboratory accreditation is frequently used in industry as a method for validating technical competence when performing certain types of testing or calibration. According to market trends, interested parties want proof that products and services meet quality and safety requirements, or that they comply with unique requirements and specifications outlined in standards or regulations. Choosing a technically competent laboratory reduces the degree of risk for manufacturers and suppliers when it comes to production or procurement, thereby reducing costs, and health and safety risks, preserving the company's reputation and ensuring compliance with legal or customer requirements. The paper presents an analysis of the accreditation of laboratories in the industry from the aspect of implementation and maintenance of the ISO/IEC 17025:2017 standard.*

Keywords: accreditation, laboratories, industry, ISO/IEC 17025:2017.

INTRODUCTION

The International Standard ISO/IEC 17025:2017, which contains general requirements for the competence of testing, sampling, and calibration laboratories, can be applied by all institutions engaged in laboratory activities. Accreditation is an important assurance to interested parties that an organization provides relevant services, thereby gaining their trust. ISO/IEC 17025:2017 enables laboratories to continuously maintain and enhance the complex quality management process of products and services. In modern business, the validation of work results is of great importance, and this is achieved through testing in accredited laboratories. On the other hand, besides commercial needs, laboratories can make a scientific contribution (Sterzinger, 2006). Testing service laboratories must be accredited and compliant with the laboratory standard (ISO/IEC 17025:2017) to ensure their competence in conducting tests. ISO/IEC 17025:2017 includes a quality management system and technical requirements for the accreditation process (Sadikoglu, 2012). There are several benefits that laboratories can gain by meeting this standard, such as the ability to produce consistent results and satisfactory performance (Beckett, 2011), overall improvement in laboratory operations (Honsa, 2003), the ability to demonstrate the reliability of test results and technical competence (Vlachos, 2002), and enhanced competitiveness in the market through the quality, reliability, accuracy, and consistency of products, services, and processes (Sadikoglu, 2012).

As every country acknowledges the importance of quality in daily life, the development of quality infrastructure became a top priority. Countries have created a legal framework - laws, regulations, guidelines, and technical standards - as well as national institutions responsible for managing and monitoring the development of quality infrastructure within society. Continuous interaction between neighboring societies has led to harmonization and adaptation of quality requirements to facilitate and accelerate the flow of information, goods, and people. This phenomenon has imposed the need for the internationalization of the quality infrastructure, leading to the creation of international institutions that prioritize quality as a fundamental human need.

Conformity assessment is the term used for processes that demonstrate that a product, process, service, management system, or the body assessing it, meets

defined requirements. Accreditation, in a broader sense, is a formal confirmation undertaken by a third party, referring to a conformity assessment body, providing formal evidence of its competence to perform specific tasks according to pre-defined standards. The Accreditation Body of Serbia is the national accreditation body entrusted with the task of determining the competence of conformity assessment bodies for performing tasks such as testing, calibration, inspection, product certification, management system certification, and personnel certification.

The requirements for technical competence are defined in international standards by ISO and IEC, as well as in other documents from relevant organizations. Establishing and maintaining a competent, impartial, and independent accreditation system is a strategic national task. The accreditation body is responsible for these tasks so that interested parties can have trust in

the services provided by accredited organizations and economic entities. Obtaining an accreditation certificate means that the conformity assessment body is competent to perform these tasks (Ljubičić, 2018).

ISO/IEC 17025:2017 AS A QUALITY IMPROVEMENT TOOL

ISO/IEC 17025:2017 is an international standard that refers to testing and calibration laboratories' competence. The standard specifies the requirements for laboratory quality, technical competence, and quality system management. ISO/IEC 17025:2017 is widely used in many industries and is necessary for producing trustworthy test and calibration results.

Figure 1. *Requirements of ISO/IEC 17025:2017 standard*

Accreditation according to ISO/IEC 17025:2017 standard is of exceptional importance for several reasons:

- Reliability and accuracy of results: ISO/IEC 17025:2017 accreditation ensures that the laboratory possesses technical competence and a quality management system, meaning that testing and calibration results will be reliable and accurate. This is essential for ensuring product quality, consumer safety, and protection. International recognition: A laboratory accredited to the ISO/IEC 17025:2017 standard has internationally recognized credentials. For businesses that export goods, this is essential since the results of these laboratories are more reliable in the eyes of their partners and clients.
- Competitive advantage: ISO/IEC 17025:2017 accreditation can be key to gaining a competitive edge. Companies using the services of accredited laboratories can be confident that their products will comply with quality and safety requirements, which can attract more customers.
- Compliance with regulatory requirements: Many industries are subject to stringent regulatory requirements. ISO/IEC 17025:2017 accreditation helps laboratories align with these requirements, which can prevent legal issues and penalties.
- Risk reduction: A laboratory accredited to ISO/IEC 17025:2017 is less prone to errors and accidents. This reduces the risk of employee injuries, material losses, and damage to the company's reputation.
- Improvement of internal management: The accreditation process requires the laboratory to develop and implement a quality management system, which can enhance internal operations and efficiency.
- Building public trust: ISO/IEC 17025:2017 accreditation helps build trust among consumers, partners, and regulatory bodies. Laboratories adhering to this standard are considered responsible and expert organizations.

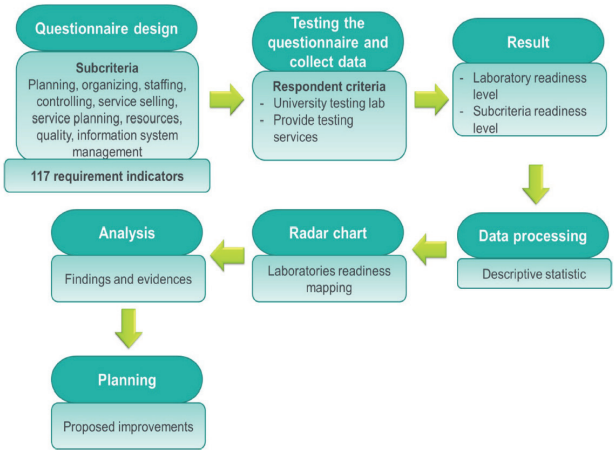


Figure 2. *Examination procedure* [7]

In essence, accreditation to the ISO/IEC 17025:2017 standard enhances the integrity of laboratories, improves the quality of testing and calibration, and provides numerous benefits for laboratories and their clients. This is especially important in industries where accuracy, reliability, and safety are of paramount importance.

IMPROVING QUALITY MANAGEMENT IN INDUSTRIES THROUGH LABORATORY WORK

Laboratories play a crucial role in improving the functioning of factories in several ways, such as quality control, material testing, product development, process monitoring, product safety, equipment maintenance, environmental impact, and employee training.

Laboratories are often used in industry for quality control of raw materials, semi-finished products, and finished goods. Analyses and tests are conducted to ensure compliance with specifications and quality standards. Additionally, laboratories can analyse the physical, chemical, and mechanical characteristics of

materials used in the production process. This helps in selecting appropriate materials and reducing waste. Moreover, they have a significant impact on the research and development of new products or the improvement of existing ones. This includes testing new formulas, materials, and technologies to enhance the competitive advantage of the reference factory. Laboratories monitor production processes to identify potential issues or variations in processes. As a result, factories can respond more quickly and reduce product rejection.

Laboratories conduct product testing to ensure consumer safety. This is especially crucial in industries such as food, pharmaceuticals, and chemicals. In addition, 'laboratories can test the condition and performance of equipment to predict failures and facilitate regular maintenance, which helps reduce production downtime.

From an environmental perspective, laboratories can analyse a factory's impact on the environment, including monitoring emissions, wastewater, and other ecological factors. This helps factories adhere to regulations and reduce their environmental footprint. On the other hand, implementing laboratory standards enhances the competence of employees in using new equipment, technologies, and methods. Competent employees are crucial for the efficient operation of the factory.

All these activities help factories increase efficiency, reduce costs, improve product quality, and meet regulatory requirements. Laboratories play a pivotal role in modern industries and contribute to their advancement. The activities undertaken by accredited laboratories for business purposes are presented in Table 1.

Table 1. *Activities according to the ISO/IEC 17025:2017 standard [7]*

Activities	Process/ Indicator	Requirement of standards
Collect, receive, identify, control, protect, and receive goods tested. Implement or subcontract testing. Analyse test data. Record, protect, and send test reports.	Testing	5.8, 4.5, 5.10
Evaluate suppliers. Maintain approved suppliers. Develop requirements for purchasing activities. Carry out purchasing activities. Check items received with the desired specifications.	Purcha-sing	4.6
Supervise, control, and record environmental conditions. Adjust laboratory facilities, control access, and use of laboratory areas.	Infrastru-cture	5.1, 5.3
Study, create, validate applying and use testing methods and related procedures. Estimate measurement uncertainty	Method	5.1, 5.4
Study, identify, supervise, maintain, and calibrate equipment. Outlines procedures for maintenance, transfer, storage, safe use, and scheduling maintenance of measurement equipment.	Equi-pment	5.1, 5.5
Develop programs and procedures for equipment calibration and standard setting. Participate in a collaborative study program or testing expertise and analysing laboratory performance.	External quality control	5.1, 5.6, 5.9
Provide intermediate checks to maintain confidence in the calibration status of the tool and reference standards. Develop comparisons in the laboratory. Establish quality control procedures when regular use of reference materials is certified, replicates testing or repeats testing of retained samples. Analyse collected data.	Internal quality control	5.5, 5.6, 5.9
Publish, approve, distribute, and manage quality management system documents. Identify, collect, compile, store, maintain, and tidy up documents related to quality and technical details.	Infor-mation Mana-gement	4.3, 4.13, 5.4, 5.10

Laboratories play a crucial role in various industries and sectors, enabling research, development, quality control, innovation, and other key activities.

In the following lines, there are some examples of laboratories in various industries. Each of them has its specific focus and goals that support the development and progress in their respective industries.

Pharmaceutical Industry: Laboratories in pharmaceutical companies conduct research and development of new drugs, testing for drug safety and efficacy, and monitoring product quality.

Petrochemical Industry: Laboratories in this industry deal with the analysis of raw materials, quality control of fuels and chemicals, research of new materials, and the development of processes for oil and natural gas processing.

Food and Beverage: Quality control laboratories for food and beverages test ingredients, monitor microbiological safety, and conduct analyses of the nutritional composition of products.

Automotive Industry: Research and development laboratories of automotive manufacturers work on innovations and the development of new vehicle technologies, including safety, energy efficiency, and environmental aspects.

Energy Industry: Laboratories in the energy industry conduct analyses of oil, gas, and electrical energy, research renewable energy sources, and develop technologies to reduce greenhouse gas emissions.

Electronics and Technology: Laboratories in electronic companies are involved in the development and testing of new products, including smartphones, computer equipment, and components.

Metals Processing Industry: Laboratories in this industry conduct analyses of metals, alloys, and other materials to ensure they meet specific technical specifications and standards.

Healthcare: Clinical laboratories in hospitals and diagnostic centers conduct tests for disease diagnosis and monitoring patients' health parameters.

Agricultural Industry: Laboratories in agriculture work on researching and developing new plant varieties, quality control of seeds, and provide soil analysis services.

Chemicals and Materials: Laboratories in this industry carry out research in new chemicals, materials, and polymers, and conduct analyses to ensure safety and compliance with legal regulations.

CONCLUSION

Laboratory sampling, testing, and conformity assessment are crucial factors that enable the advancement of science, technology, and trade. The ISO/IEC 17025:2017 standard helps align procedures and standard methods, facilitates collaboration between laboratories and other bodies, and promotes the acceptance of results across different countries. Compliance with the ISO/IEC 17025:2017 standard provides: increased reliability of testing results generated by the laboratory, the establishment of technical competence, improved laboratory efficiency, reduced client complaints, a strong competitive advantage for the laboratory, and a decrease in operational costs. The standard facilitates traceability of measurement and calibration equipment, establishes the technical competence of staff, maintains records of testing equipment, ensures the accuracy of testing results, the correctness of testing and calibration methods, proper handling and movement of test items, and the quality of the testing and sampling environment.

ACKNOWLEDGEMENTS

This research was supported by the Ministry of Education, Science and Technological Development of the Republic of Serbia, contract no. 451-03-68/2022-14/200148.

REFERENCES

Sterzinger, C.H. (2006). Technology Marketing Plan for Laboratory Services to Sustain a Translational Research Centre. *Ph.D. Thesis, Simon Fraser University*, Burnaby, BC, Canada

Sadikoglu, E. & Temur, T. (2012). The Relationship Between ISO 17025 Quality Management System Accreditation and Laboratory Performance. *Quality Management and Practices*, 221-230.

ISO/IEC 17025:2017. General Requirements for the Competence of Testing and Calibration Laboratories; *International Organization for Standardization: Geneva, Switzerland*

Beckett, J. & Slay, J. (2011). Scientific underpinnings and background to standards and accreditation in digital forensics. *Digital Investigation*. 8, 114-121

Honsa, J.D. & McIntyre, D.A. (2003) ISO 17025: Practical Benefits of Implementing a Quality System. Journal of AOAC International, 86, 1038-1044

Vlachos, N.A., Michail, C. & Sotiropoulou, D. (2002). Is ISO/IEC 17025 Accreditation a Benefit or Hindrance to Testing Laboratories? The Greek Experience. *Journal of Food Composition and Analysis,* 15, 749-757

Aqidawati E. F., Sutopo W. Zakaria R. (2019). Model to Measure the Readiness of University Testing Laboratories to Fulfill ISO/IEC 17025 Requirements (A Case Study). *Journal of Open Innovation: Technology, Market, and Complexity*, 1-19

Ljubičić A., Domanović M., Denić LJ., Dopuđa Glišić T., Nadeždić M. & Veljković N. (2018). Technical competence for testing the elements of environmental quality - accreditation of the Environmental Protection Agency, Engineering - IMS quality, *Standardization and Metrology* 18, 163-168, 2018.

20th International Conference Man and Working Environment
SEMSIE
Safety Engineering & Management – Science, Industry, Education
www.znrfak.ni.ac.rs/semsie

TEODORA TOPČEVA[1]
MARIJA HADŽI-NIKOLOVA[2]
NIKOLINKA DONEVA[2]
AFRODITA ZENDELSKA[2]
ANA MIHAILOVSKA[2]
BOBAN SAMARIDŽISKI[2]

[1]Goce Delčev University, Faculty of Mechanical Engineering, Štip, North Macedonia
[2]Goce Delčev University, Faculty of Natural and Technical Sciences, Štip, North Macedonia

[1]teodora3263@student.ugd.edu.mk
[2]marija.hadzi-nikolova@ugd.edu.mk
[2]nikolinka.doneva@ugd.edu.mk
[2]afrodita.zendelska@ugd.edu.mk
[2]ana.133207@student.ugd.edu.mk
[2]boban.samarziski@ugd.edu.mk

PERSONAL NOISE EXPOSURE LEVEL AMONG EMPLOYEES IN SCHOOLS, AUTOMOTIVE AND MINING INDUSTRY

Abstract: *Occupational exposure to high noise levels is a problem in almost all industries, including the services sector. The exposure level varies depending on the noise sources. According to the available research studies, this problem often appears in industries like transportation, mining, production, and construction. The risk of negative health effects is proportional to the exposure level and the frequency of noise exposure. The negative effects of high noise exposure levels often include decreased concentration, risk of accidents, stress, and cardiovascular diseases. A noise exposure measurement in real-world conditions was carried out to determine the noise exposure level of the schoolteachers, as well as automotive and mining industry workers. The results of this research show that there might be a risk to workers' health and safety in three different workplaces, including both industry and education.*

Keywords: mining industry, automotive industry, schools, exposure level, noise measurements

INTRODUCTION

Exposure to high noise levels is often considered a cause of hearing problems. As noise intensity increases, so does the risk of damage to the sensory hair cells of the inner ear, which can result in permanent hearing loss (Mikulski & Radosz, 2011). The results from the literature on personal noise exposure show that high levels of exposure can cause tinnitus (Nelson et al., 2005).

Noise in industry is mainly generated by the machines and tools used in the production and maintenance processes. The worker operating a specific machine is exposed to the noise of the machine, but it also affects other workers nearby or in the entire workspace.

The various types of equipment used in the industry sector generate high noise levels due to many factors, such as the type of used equipment, operational life, and the operational speed of the machines. A large percentage of the labour force employed in the industry is exposed to noise. For this reason, improving workplace conditions in terms of noise control will have a positive effect on humans and their productivity.

The noise generated in schools is an important factor that has an impact on both the schoolteachers and the students. It affects the hearing organs and causes problems with speech reception and comprehension (Bradley & Sato, 2008; Kreisman et al., 2010). In some cases, it may impact not just the career but also the social life by reducing opportunities for employment or promotions (Alberti, 1998).

The purpose of this paper is to conduct a measurement of personal noise exposure levels in schools and industry and compare the obtained results. The overall aim is to determine whether the results are within the acceptable ranges and whether there is a risk of adverse effects on the workforce in these two distinct sectors - industry and education.

MATERIALS AND METHODS

The purpose of this study is to compare the personal noise exposure levels in three different places - an automotive plant, a mine and a school. For this purpose, noise level measurements were first performed. The national standard MKS EN ISO 9612: 2010 Acoustics - Determination of noise exposure in the working environment provides the basis to carry out noise measurements using the right approach and strategy.

The A-weighted equivalent-continuous sound pressure level (LAeq) was obtained during the measurements conducted with 3 schoolteachers, 3 mining workers, and 3 workers in an industrial plant. The unit of measuring the noise level is dB.

For successful measurement, equipment that complies with IEC 61762-1: 2002 instrument class 1 was used (Nesevski et al., 2022). Noise levels were captured with dosimeters and the results were downloaded with a software tool for noise data management. Dosimeters, small devices that contain a microphone to capture the level of personal noise exposure, should be placed near the exposed ear, usually on the shoulder, in order to capture the real exposure level.

CASELLA Dbadge2 is the type of dosimeter used for the measurements of personal noise exposure. The software tool for noise data management used in the research is NoiseSafe. The participants in the research were explained how to use the dosimeters during the working day, and what the purpose of this measurement equipment is.

After the measurements had been completed, an equation according to the MKS EN ISO 9612: 2010 was used for calculating the normalized 8-hour exposure ($L_{EX,8}$ h) level, equation (1):

$$L_{EX,\ 8h} = L_{Aeq,\ Te} + 10 \log T_e/T_0 \text{ dB} \quad (1)$$

T_e is the daily duration of the workforce exposure,

T_0 is 8 hours of reference time, and

$L_{Aeq,\ Te}$ is the equivalent noise level during T_e.

The exposure levels obtained with the research for schools and industry were compared to determine the difference in noise exposure due to the different noise sources in these sectors. The results are presented in the following section.

RESULTS AND DISCUSSION

Once the measurements were completed, a summary of the results was provided. The Occupational Health and Safety Regulations in North Macedonia outline exposure limit values and action values in relation to the daily noise exposure levels presented in the table below (Regulations for limits of the environmental noise levels, 2008).

The peak values of the sound pressure are presented in Table 1. The manufacturing companies must adopt the recommendations and maintain noise exposure levels under the limit values in accordance with the Rulebook.

Table 1. *Occupational Health and Safety Regulations in North Macedonia*

Exposure level	$L_{EX,8h}$ (dB)	$L_{p,\ Cpeak}$ (dB)	p_{Cpeak} (Pa)
Exposure limit values	87	140	200
Upper exposure level values	85	137	140
Lower exposure level values	80	135	112

The results of the schoolteacher's exposure level while performing the usual daily tasks are presented in Table 2. Results in Table 2 clearly indicate that the daily personal noise level exposure in schools is in line with the limit values outlined in the Regulations on Occupational Health and Safety and exposure to noise in North Macedonia (Hadzi-Nikolova et al., 2013).

Considering the fact that the daily 8-hour exposure level has to be a maximum of 85 dB, the exposure levels in Table 2 are close to the limit values. High noise levels in schools are typically observed during breaks and sports activities. In these periods, schoolteachers are exposed to noise levels above the limit value of 85 dB (Hadzi-Nikolova et al, 2013).

Table 2. *Personal noise exposure level of the employees in the schools*

Exposure level	Min (dB)	Max (dB)	$L_{EX,8h}$ (dB)
Measurement point S 1	77	85	78.8
Measurement point S 2	75	84	78.6
Measurement point S 3	74	83	77.5

The data displayed in the tables strongly suggest that an action plan must be implemented immediately. The high exposure level in schools requires further investigations into this problem, as well as the need to identify the sources and periods with the highest impact on the results. The absence of regular monitoring of the exposure level could lead to serious health consequences.

The second round of measurements was performed in an automotive plant. The main sources of noise in the industrial plant are machines and tools used in the production process. In addition, the results obtained for all the departments included in the research will be presented.

Table 3 shows the noise exposure levels in an automotive production plant. The measured noise levels do not exceed the limit values presented in the Occupational Health and Safety Regulations in the Republic of North Macedonia.

Anyway, the results indicate that there is a risk of exceeding the limit values. The daily tasks in the industrial plant require exposure to noise generated by the machines and equipment.

Table 3. Personal noise exposure *level of the employees in the automotive industry*

Exposure level	Min (dB)	Max (dB)	$L_{EX,8h}$ (dB)
Measurement point A 1	71	81.3	76.4
Measurement point A 2	71.9	79.9	74.2
Measurement point A 3	79.4	83.1	79.6

The third round of measurements was performed in the mining industry. The primary sources of noise in the mining industry are the machines and tools used, the mining process itself, and mining mechanization. The results obtained by these measurements will also be presented.

Table 4 shows the noise exposure levels in the mining industry. The measured noise level at one measurement point exceeds the limit values presented in the Occupational Health and Safety Regulations in the Republic of North Macedonia.

The results show that there is a risk of exceeding the limit values at the other measurement points as well. As a result, mining workers must wear personal protective equipment.

Table 4. *Personal noise exposure level of the employees in the mining industry*

Exposure level	Min (dB)	Max (dB)	$L_{EX,8h}$ (dB)
Measurement point M 1	83.2	85.5	84.7
Measurement point M 2	83.6	87.6	86.3
Measurement point M 3	73.7	882.2	80.4

The percentage of the labour force exposed to noise in industry is very high, and according to the literature research, a very huge portion of the industry generates noise that exceeds the limit exposure level, which on average ranges between 70-118 dB. There has been much debate and research into how the duration of noise exposure can affect employee performance and perception (Errett et al., 2006).

When the results obtained from the measurements in the three different sectors - automotive industry, mining industry and education - are compared, very similar exposure levels can be noticed. The highest $L_{EX,8h}$ value has been calculated in the mine, at measurement point M 1. However, constant high exposure levels can be observed in the school, almost the same at three different measurement points.

Noise can be a serious problem in many workplaces. However, there are three important steps that should be taken to reduce the risks associated with noise exposure:

1. Carry out a detailed risk assessment, identifying the sources and exposed workplaces
2. Design and implement an action plan to prevent or control the risks
3. Measure the effectiveness of the action plan.

CONCLUSION

Considering the results of the measurements, the noise exposure level among employees in three sectors - schoolteachers, mining workers, and automotive industry workers - is high but still within acceptable limits. s. Because of the high exposure level, Regular control measurements are necessary due to the high exposure level, as there exists a potential risk factor that could negatively impact the workers' health and safety. There can be very serious health consequences caused by noise exposure at the workplace in an industrial plant, mine, or school. In addition to affecting workers' health and safety, noise also has a socioeconomic impact. Exposure to high levels will result in hearing loss, cardiovascular disease, stress, and anxiety, affecting the social life of teachers and workers in industrial plants.

Implementing hearing conservation programs will mitigate or eliminate the health risk. In addition, performing regular measurements and risk assessments of personal noise exposure levels, as well as tracking the implementation of action plans will help maintain a safe and healthy work environment.

REFERENCES

Alagapan, P., Hassan, M.Z., Ibrahim M.H., Daud M.Y., Bani N.A., & Kutt, R. M., (2019). Measurement of hazardous personal noise exposure in the spice manufacturing industry, *IOP Conf. Series: Journal of Physics, Conf. Ser. 1150 012021.* https://doi.org/10.1088/1742-6596/1150/1/012021

Alberti P. (1998). *Noise-induced hearing loss – A global problem,* [Advances in noise research, Vol 1, Protection against noise, Luxon L., Prasher D.], 7-15.

Bradley J.S., Sato H. (2008). The intelligibility of speech in elementary school classrooms*, Journal of Acoustical Society of America*, *123(4),* 2078–2086.

Errett J., Bowden E.E., Choiniere M., and Wang L.M., (2006). *Effects of noise on productivity: does performance decrease over time?* Architectural Engineering - Faculty Publications. https://doi.org/10.1061/40798(190)18

Hadzi-Nikolova M., Mirakovski D., Zdravkovska M., Angelovska B., Doneva N., (2013). *Noise exposure of schoolteachers – exposure levels and health effects.* Archives of Acoustics Vol. 38(2), 259–264. https://doi.org/10.2478/aoa-2013-0031

Hadzi-Nikolova M., Mirakovski D., Doneva N., Bakreska N., (2019). Environmental and occupational noise management process in the cement industry. *Safety Engineering, 9(1),*7-12. https://doi.org/10.7562/SE2019.9.01.02

Kreisman B.M., Mazevski A.G., Schum D.J., Sockalingam R. (2010). Improvements in speech understanding with wireless binaural broadband digital hearing instruments in adults with sensorineural hearing loss*, Trends In Amplification* 14(1), 3–11.

Mikulski W., Radosz J. (2011). Acoustics of classrooms in primary schools-result of the reverberation time and the speech transmission index assessment in selected buidings, *Archives of Acoustics*, 36(4), 777–794.

Nelson D.I., Nelson R.Y., Concha-Barrientos M., Fingerhut M. (2005). The global burden of occupational noise-induced hearing loss, *American Journal of Industrial Medicine 48*, 446–458.

Nesevski S., Hadzi-Nikolova M., Mirakovski D., Doneva N., Zendelska A. (2022). Personal noise exposure of underground mining workers*, Natural Resources and Technology 16(1),* 77 – 81.

Niquette P.A. (2009), *Noise Exposure: Explanation of OSHA and NIOSH Safe-Exposure Limits and the Importance of Noise Dosimetry*, Etimotic Research Inc.

Regulations for limits of the environmental noise levels (2008). Official Gazette of Republic of Macedonia, No. 147/08.

Rikhotso O., Harmse J.L., Engelbrecht J.C., (2019). Noise Sources and Control, and Exposure Groups in Chemical Manufacturing Plants. *Applied Science 1(27*). https://doi.org/10.3390/app9173523

Trendova L., Hadzi-Nikolova M., Mirakovski D., Timovski R., (2022). Personal noise exposure on industry workers" Natural respurces and techonologies Vol 16, No. 1, 83 – 87. https://doi.org10.46763/NRT22161083

20th International Conference Man and Working Environment
SEMSIE
Safety Engineering & Management – Science, Industry, Education

www.znrfak.ni.ac.rs/semsie

DARIO JAVOR[1]
NEBOJŠA RAIČEVIĆ[2]
DEJAN KRSTIĆ[3]

[1,3]University of Niš,
Faculty of Occupational Safety
[2]University of Niš,
Faculty of Electronic Engineering

[1]*dario.javor@znrfak.ni.ac.rs*
[2]*nebojsa.raicevic@elfak.ni.ac.rs*
[3]*dejan.krstic@znrfak.ni.ac.rs*

RANKING OF ENERGY SOURCES USING THE BEST-WORST WEIGHTING METHOD AND THE MCDM METHODS

Abstract: *The criteria for energy sources operation in a microgrid are not only economic (capital costs, operational and maintenance costs, fuel costs, costs of starting and shutting down, etc.), but also environmental, such as emissions of particulate matter (PM) and harmful gasses: CO_2, CO, SO_2, NO_X, HC, etc. In this paper the Best-Worst Method (BWM) is used as the weighting method to determine the weights of the chosen environomic criteria. Afterwards, Multi-Criteria Decision Making (MCDM) methods are applied for the ranking of energy sources. The alternatives for the energy production are a diesel generator, a microturbine, fuel cells, and a main grid. MCDM methods: PROMETHEE (Preference Ranking Organization METHod for Enrichment of Evaluations), TOPSIS (The Technique for Order of Preference by Similarity to Ideal Solution) and VIKOR (in Serbian: Višekriterijumska optimizacija i kompromisno rešenje) are used for the ranking of energy sources in the microgrid. The results of these methods are presented and analysed in this paper.*

Keywords: distributed energy resources, microgrid, multi-criteria decision making, weighting methods

INTRODUCTION

Microgrids are relatively small power systems with clearly defined electrical boundaries, which can operate either connected to the main grid or isolated from it. They can include non-dispatchable distributed energy resources (DERs): photovoltaic panels, wind generators and small run-of-river hydropower plants, as well as dispatchable DERs: gas turbines, microturbines, fuel cells, gas internal combustion engines (ICEs), diesel ICEs, etc.

The Best-Worst Method (BWM), as one of the weighting methods, is applied to determine the weights of environomic (environmental/economic) criteria for the DERs' ranking. The BWM belongs to the group of subjective methods wherein the decision maker has to evaluate the attributes and compare them to one another. The chosen DERs' alternatives are a diesel generator, a microturbine, fuel cells, and a main grid. Their attributes used for ranking are the following: (1) operational, maintenance and fuel costs (OMF costs); emissions of harmful gasses: (2) CO_2, (3) SO_2, (4) NO_X, (5) CO; and (6) particulate matter (PM), as chosen by Javor (2023). Application of the BWM and the results of computation are presented in the second section of this paper.

Afterwards, Multi-Criteria Decision Making (MCDM) methods are used for the ranking of energy sources. The applied methods are: PROMETHEE (Preference Ranking Organization METHod for Enrichment of Evaluations), TOPSIS (The Technique for Order of Preference by Similarity to Ideal Solution) and VIKOR method (in Serbian: *Višekriterijumska optimizacija i kompromisno rešenje*). These methods are used for the ranking of the energy sources in the microgrid. The results of DERs' ranking according to the environomic criteria are presented in this paper.

THE BEST-WORST METHOD

The BWM is the subjective weighting method used for determining the weight coefficients of the alternatives' criteria. This method was proposed by Rezaei (2015). The BWM is based on the comparison of decision criteria, where the decision maker determines the best criterion (most desirable/important), the worst criterion (least desirable/important), and the preferences between the criteria. There are linear and nonlinear BWM methods developed by Rezaei (2016, 2020) whose consistency is proven by Liang (2020).

In the first step, a decision-making matrix is formed as given in Table 1. It is of dimensions $m \times n$, its columns correspond to the alternatives a_i, for $i = 1, 2, \ldots, n$, and its rows to the attributes A_j, for $j = 1, 2, \ldots, m$. The alternatives are: a_1 (diesel generator), a_2 (microturbine), a_3 (fuel cell), and a_4 (main grid). The criteria (attributes) and their values are defined. The attributes' values to be minimized in the chosen scenario are: A_1 (operational, maintenance and fuel costs), A_2 (CO_2 emissions), A_3 (SO_2 emissions), A_4 (NO_X emissions), A_5 (CO emissions), and A_6 (PM emissions). The values of the costs and emissions are taken from the EPRI report (2003), Marti (2005), Şahin (2021), and SEE Power Exchange (2022).

In the second step, the most important criterion is chosen: in this example A_1 – OMF costs, and the least important criterion: in this example A_5 – CO emissions.

In the third step, the decision maker determines the preferences of all other criteria in relation to the best one (Fig. 1), i.e. to the most important criterion, using grades from 1 to 9. Equal importance is denoted by 1, whereas greater grades mean greater importance.

In the fourth step, the preferences of other criteria are determined in relation to the worst one (Fig. 1), i.e. to the least important criterion, using grades from 1 to 9.

In the fifth step, BWM Linear Solver v2.0 (2023) is applied and the results for the criteria weights are presented in Fig. 1 and Fig. 2, whereby the consistency of the solution is achieved.

The weight coefficients of the criteria obtained by applying the BWM method are: 47.32% for OMF costs, 17.63% for CO_2 emissions, 13.22% for SO_2 emissions, 10.58% for NO_X emissions, 4.64% for CO emissions, and 6.61% for PM emissions.

Table 1. *Decision-making matrix for the electricity production alternatives in the microgrid and their characteristics*

	a_1 (DG)	a_2 (MT)	a_3 (FC)	a_4 (MG)
A_1 (OMF) [$/kWh]	0.15	0.11	0.242	0.2
A_2 (CO_2) [g/kWh]	697	670	441	889
A_3 (SO_2) [g/kWh]	0.22	0.0036	0.0022	1.8
A_4 (NO_X) [g/kWh]	0.5	0.186	0.0136	1.6
A_5 (CO) [g/kWh]	1	0.4	0.01	0.01
A_6 (PM) [g/kWh]	0.2	0	0.01	0.3

Best to Others	OMF	CO2	SO2	NOX	CO	PM
OMF	1	3	4	5	9	8

Others to the Worst	CO
OMF	9
CO2	5
SO2	4
NOX	3
CO	1
PM	2

Weights	OMF	CO2	SO2	NOX	CO	PM
	0,47320807	0,1762932	0,1322199	0,10577592	0,04639295	0,06610995

Figure 1. *Grades and weights of the criteria*

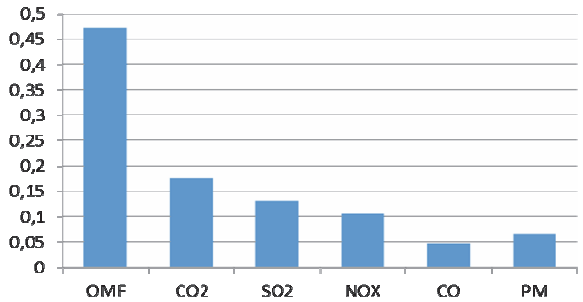


Figure 2. *Diagram of the criteria weights*

RANKING OF THE ENERGY SOURCES USING THE BWM-PROMETHEE METHOD

The PROMETHEE method was proposed by Brans (1982, 1984, 2005) and the program PROMETHEE-GAIA was developed by Mareschal (2011-2023). The result of the ranking of the four alternatives of energy sources using the PROMETHEE II method is shown in Fig. 3. A microturbine is the best choice, as shown in Table 2, followed by a fuel cell, a diesel generator, and a main grid.

The net flows are calculated from the positive and negative flows for each alternative *i*, as given in:

$$\mathrm{Ph}_i = \mathrm{Ph}_i^{+} - \mathrm{Ph}_i^{-}. \quad (1)$$

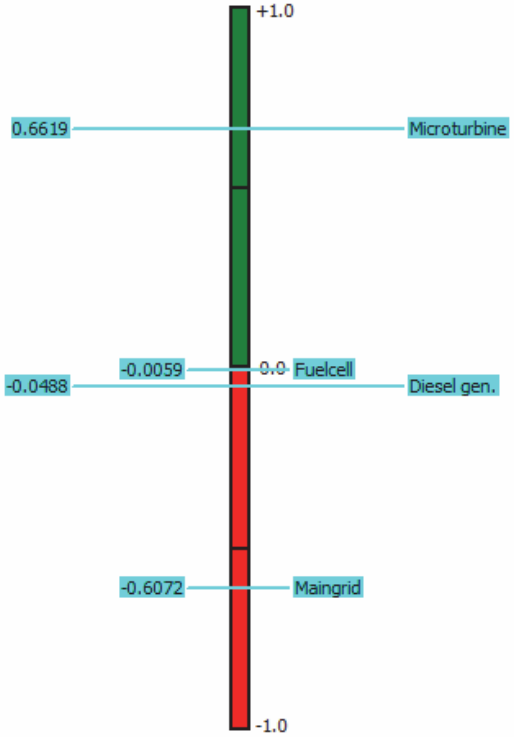


Figure 3. *Complete ranking of energy sources and the net flows of the four alternatives*

Table 2. *Results of the BWM-PROMETHEE II complete ranking and the positive, negative, and net flows of the four alternatives*

Rank	Alternative	Ph_i	Ph_i^{+}	Ph_i^{-}
1	Microturbine	0.6619	0.8310	0.1690
2	Fuel cell	-0.0059	0.4893	0.4952
3	Diesel generator	-0.0488	0.4756	0.5244

4	Main grid	-0.6072	0.1887	0.7959

RANKING OF THE ENERGY SOURCES USING THE BWM-TOPSIS METHOD

The TOPSIS method, proposed by Hwang (1981, 1993), Huang (2011), can also be applied as the MCDM method. The ranking of the energy sources is based on the weight coefficients: w_1 = 0.4732, w_2 = 0.1763, w_3 = 0.1322, w_4 = 0.1058, w_5 = 0.0464, w_6 = 0.0661, obtained by BWM. Weighted normalized decision-making matrix **V**, as given in Eqn. (2), is obtained by multiplying the normalized matrix **N** and the diagonal matrix **W** with the weight coefficients on the diagonal.

$$\mathbf{V} = \mathbf{N} \cdot \mathbf{W} = \begin{bmatrix} n_{11}w_1 & n_{12}w_2 & n_{13}w_3 & n_{14}w_4 & n_{15}w_5 & n_{16}w_6 \\ n_{21}w_1 & n_{22}w_2 & n_{23}w_3 & n_{24}w_4 & n_{25}w_5 & n_{26}w_6 \\ n_{31}w_1 & n_{32}w_2 & n_{33}w_3 & n_{34}w_4 & n_{35}w_5 & n_{36}w_6 \\ n_{41}w_1 & n_{42}w_2 & n_{43}w_3 & n_{44}w_4 & n_{45}w_5 & n_{46}w_6 \end{bmatrix} =$$

$$= \begin{bmatrix} v_{11} & v_{12} & v_{13} & v_{14} & v_{15} & v_{16} \\ v_{21} & v_{22} & v_{23} & v_{24} & v_{25} & v_{26} \\ v_{31} & v_{32} & v_{33} & v_{34} & v_{35} & v_{36} \\ v_{41} & v_{42} & v_{43} & v_{44} & v_{45} & v_{46} \end{bmatrix} =$$

$$= \begin{bmatrix} 0.19451 & 0.088693 & 0.016038 & 0.031364 & 0.043078 & 0.036652 \\ 0.142641 & 0.085257 & 0.000262 & 0.011667 & 0.017231 & 0 \\ 0.31381 & 0.056117 & 0.00016 & 0.000853 & 0.000431 & 0.001833 \\ 0.259347 & 0.113125 & 0.131223 & 0.100365 & 0.000431 & 0.054977 \end{bmatrix}. \quad (2)$$

The ideal best values are: A_1^+ = 0.142641, A_2^+ = 0.056117, A_3^+ = 0.00016, A_4^+ = 0.000853, A_5^+ = 0.000431, and A_6^+ = 0, and the ideal worst values are: A_1^- = 0.31381, A_2^- = 0.113125, A_3^- = 0.131223, A_4^- = 0.100365, A_5^- = 0.043078, and A_6^- = 0.054977.

The distances S_i^+ from the ideal best values are calculated from Eqn. (3) as the root mean square values of the differences between the values of the elements v_{ij} of the matrix **V** and the ideal best values:

$$S_i^+ = \sqrt{\sum_{j=1}^{n} \left(v_{ij} - A_j^+\right)^2}, \quad \text{for } i=1, \ldots, 4. \quad (3)$$

The distances S_i^- from the ideal worst values are calculated from Eqn. (4):

$$S_i^- = \sqrt{\sum_{j=1}^{n} \left(v_{ij} - A_j^-\right)^2}, \quad \text{for } i=1, \ldots, 4. \quad (4)$$

For each alternative, the similarity coefficient is calculated from Eqn. (5):

$$CC_i = \frac{S_i^-}{S_i^+ + S_i^-}, \quad \text{for } i=1, \ldots, 4. \quad (5)$$

The distances S_i^+ from the ideal best values, the distances S_i^- from the ideal worst values, and the similarity coefficients CC_i are given in Table 3, for each alternative. The alternatives are ranked based on CC_i values. The best ranked alternative of the energy sources is the microturbine and the worst ranked is the main grid, as was the case with the BWM-PROMETHEE method.

Table 3. *Results of the BWM-TOPSIS ranking of the four alternatives of energy sources*

Rank	Alternative	*CCi*	Si^+	Si^-
1	Micro turbine	0.87281	0.03533	0.24245
2	Diesel generator	0.66940	0.08998	0.18219
3	Fuel cell	0.52210	0.17118	0.18701
4	Main grid	0.24195	0.21673	0.06917

RANKING OF THE ENERGY SOURCES USING THE BWM-VIKOR METHOD

The VIKOR method, as one of the MCDM methods, can be also applied for the same weight coefficients as obtained by the BWM.

The VIKOR method was developed by Opricović (2004, 2007), having originally been presented in the paper with Duckstein (Duckstein & Opricović, 1980).

In the first step, a decision-making matrix (DMM) of dimensions *m* x *n* is formed, the elements of which are given in Table 1.

In the second step, the best value f_j^+ and the worst value f_j^- are determined according to the *j*-th criterion, for *j* = 1, ... , 6. In doing so, the best value is determined as the highest value of all alternatives for the *j*-th criterion

$$f_j^+ = \max_i x_{ij} \quad (6)$$

if the higher value is more desirable, or as the lowest value of all alternatives for the *j*-th criterion

$$f_j^+ = \min_i x_{ij} \quad (7)$$

if the lower value for that criterion is more desirable.

The worst value f_j^- is determined as the smallest value of all alternatives for the *j*-th criterion

$$f_j^- = \min_i x_{ij} \quad (8)$$

if the higher value is more desirable, or as the highest value of all alternatives for the *j*-th criterion

$$f_j^- = \max_i x_{ij} \tag{9}$$

if the lower value for that criterion is more desirable.

Based on these values, in the third step, S_i values are determined as the normalized Manhattan distances multiplied by the appropriate weights:

$$S_i = \sum_{j=1}^{n} \left(\frac{f_j^+ - f_{ij}}{f_j^+ - f_j^-} w_j \right), \tag{10}$$

and R_i values as the normalized Chebychev distances multiplied by the appropriate weights:

$$R_i = \max_j \left(\frac{f_j^+ - f_{ij}}{f_j^+ - f_j^-} w_j \right). \tag{11}$$

These values are given in Table 4, for i=1, ... , 4.

In the fourth step, the values Q_i are determined from:

$$Q_i = \nu \frac{S_i - S^+}{S^- - S^+} + (1-\nu) \frac{R_i - R^+}{R^- - R^+},$$

for

$$S^+ = \min_j S_j, S^- = \max_j S_j, R^+ = \min_j R_j, R^- = \max_j R_j. \tag{12}$$

In the chosen example, the following values are obtained: $S^+ = 0.119997$, $S^- = 0.803036$, $R^+ = 0.090118$ and $R^- = 0.4732$. For the coefficient $\nu = 0.5$, the values Q_i, for i =1, ... , 4, are given in Table 4. For different values of the coefficient ν the same result is obtained for the best compromise solution. For ν = {0.5, 0.6, 0.8, 1} the order of alternatives is: microturbine – diesel generator – fuel cell – main grid, but for ν = {0, 0.2, 0.4} the order is: microturbine – diesel generator – main grid – fuel cell. It should be noted that ν = 0.5 is the usually used value for the coefficient ν.

The alternatives are ranked based on Q_i values, and the first and the second ranked alternatives of the four energy sources are the same as ranked by the BWM-TOPSIS method.

Table 4. *Results of the BWM-VIKOR ranking of the four alternatives of energy sources*

Rank	Alternative	*Si*	*Ri*	*Qi*
1	Micro turbine	0.12000	0.09012	0
2	Diesel generator	0.38306	0.14339	0.26210
3	Fuel cell	0.47540	0.47320	0.76017
4	Main grid	0.80304	0.32264	0.80348

CONCLUSION

Energy management of power systems is used for smart control of microgrids so as to increase energy efficiency, decrease the costs of energy production, and reduce environmental pollution and emissions of harmful gases. Multi-criteria optimization methods are useful in improving management of energy resources in the microgrid by taking into account various criteria.

This paper presented the application of the BWM as a subjective method to evaluate the environomic (economic as well as environmental) criteria of energy sources. Afterwards, the obtained weights were used in MCDM methods for ranking microgrid energy sources as alternatives. The best ranked energy source from the environomic perspective is the microturbine, according to all three methods: BWM-PROMETHEE, BWM-TOPSIS, and BWM-VIKOR. However, the results of the BWM-PROMETHEE ranking for the fuel cell and the diesel generator differ if compared to the results of BWM-TOPSIS and BWM-VIKOR.

ACKNOWLEDGEMENTS

This research is financially supported by the Ministry of Science, Technological Development and Innovation of the Republic of Serbia, according to the contract No. 451-03-47/2023-01/ 200148.

REFERENCES

Best Worst Method, Retrieved 7 July 2023, from https://bestworstmethod.com

Brans, J. P. (1982). L'ingénièrie de la décision; Elaboration d'instruments d'aide à la décision. La méthode PROMETHEE. In: R. Nadeau & M. Landry (Eds.), *L'aide à la décision: Nature, Instruments et Perspectives d'Avenir* (pp. 183–213) [in French]. Presses de l'Université Laval.

Brans, J. P., & Mareschal, B. (2005). PROMETHEE methods. In: J Figueira., S. Greco, & M. Ehrgott (Eds.), *Multiple Criteria Decision Analysis: State of the Art Surveys* (pp. 163–196). Springer Science & Business Media, Inc.

Brans, J. P., Mareschal, B., & Vincke, Ph. (1984). PROMETHEE: A new family of outranking methods in multicriteria analysis. In: J. P. Brans (Ed.), *Operational Research '84, North-Holland, Amsterdam* (pp. 477-490).

Duckstein, L., & Opricović, S. (1980). Multiobjective Optimization in River Basin Development. *Water Resources Research, 16*(1), 14–20.

EPRI report. (2003). Installation, Operation, and Maintenance Costs for Distributed Generation Technologies. EPRI, Palo Alto, CA. 1007675.

Huang, I. B., Keisler, J., & Linkov, I. (2011). Multi-criteria decision analysis in environmental science: ten years of applications and trends. *Science of the Total Environment, 409*(19), 3578–94, doi:10.1016/j.scitotenv.2011.06.022, PMID 21764422.

Hwang, C. L., & Yoon, K. (1981). *Multiple Attribute Decision Making: Methods and Applications*. New York: Springer-Verlag.

Hwang, C. L., Lai, Y. J., & Liu, T. Y. (1993). A new approach for multiple objective decision making. *Computers and Operational Research, 20*(8), 889–899, doi:10.1016/0305-0548(93)90109-v.

Javor, D., Krstić, D., & Raičević, N. (2023, 15-17 March). Optimal Selection of Dispatchable Generators in the Microgrid. 22nd International Symposium INFOTEH-Jahorina, Paper 209, 1–5.

Liang, F., Brunelli, M., & Rezaei, J. (2020). Consistency issues in the Best Worst Method: Measurements and thresholds. *Omega, 96*, 102-175.

Mareschal, B. (2011-2023), Retrieved 12 August 2022, from http://en.promethee-gaia.net

Marti, B. (2005). Emissions of Power Delivery Systems. Semester Thesis PSL0502 EEH – Power Systems Laboratory, Swiss Federal Institute of Technology (ETH) Zurich.

Opricović, S., & Tzeng, G.-H. (2004). The Compromise solution by MCDM methods: A comparative analysis of VIKOR and TOPSIS. *European Journal of Operational Research, 156*(2), 445–455.

Opricović, S., & Tzeng, G.-H. (2007). Extended VIKOR Method in Comparison with Outranking Methods. *European Journal of Operational Research, 178*(2), 514–529.

Rezaei, J. (2015). Best-worst multi-criteria decision-making method. *Omega, 53*, 49–57. https://doi.org/10.1016/j.omega.2014.11.009

Rezaei, J. (2016). Best-worst multi-criteria decision-making method: Some properties and a linear model. *Omega, 64*, 126-130.

Rezaei, J. (2020). A Concentration Ratio for Non-Linear Best Worst Method. *International Journal of Information Technology & Decision Making, 19*(3), 891-907. https://pure.tudelft.nl/ws/portalfiles/portal/75547515/s0219622020500170.pdf

Şahin, M. A. (2021). Comprehensive analysis of weighting and multicriteria methods in the context of sustainable energy. *Int. Journal Environ. Sci. Technol., 18*, 1591–1616. https://doi.org/10.1007/s13762-020-02922-7

SEE Power Exchange, Retrieved 26 August 2022, from: http://www.seepex-spot.rs/sr

20th International Conference Man and Working Environment
SEMSIE
Safety Engineering & Management – Science, Industry, Education
www.znrfak.ni.ac.rs/semsie

IVANA ILIĆ KRSTIĆ[1]
JELENA MALENOVIĆ NIKOLIĆ[2]
LIDIJA MILOŠEVIĆ[3]
MILOŠ CVETKOVIĆ[4]

[1, 2, 3,4] University of Niš, Faculty of Occupational Safety

[1]ivana.ilic@znrfak.ni.ac.rs
[2]jelena.malenovic@znrfak.ni.ac.rs
[3]lidija.milosevic@znrfak.ni.ac.rs
[4]milos.cvetkovic@znrfak.ni.ac.rs

CAUSES OF OCCUPATIONAL INJURIES IN COAL MINES IN SERBIA

Abstract: *Occupational injuries and professional diseases are a common occurrence in the mining sector in Serbia and globally. The most frequent causes of occupational injuries in coal mining are explosions, landslides, pit fires, and technical failures of transport and machinery. An analysis of occupational injuries within the consideration of socio-demographic factors will help understand the actual causes of such accidents, which are believed to inevitably occur due to technical deficiencies or failures. Inadequate work conditions, governed by maximum profit and minimum cost, are associated with strategic operating preferences and public policies of the managing authorities. The evidence that mining accidents are more frequent in mines where no occupational safety and health measures are implemented and where inspections are conducted improperly or not at all is supported by the fact that it is a requirement that production be as fast, as cost-effective, and as profitable as possible. With this knowledge, it is possible to take concrete steps to prevent potential mining accidents in the future.*

Keywords: coal mine, occupational injuries, occupational safety and health

INTRODUCTION

Around 2.3 million employees die each year globally, with 350,000 of those fatalities attributable to workplace accidents and another 2 million to occupational illnesses [http://www.ilo.org/global/topics/safety-and-health-at-work/lang--en/index.htm]. Occupational health is the field dealing with how working life affects one's health. A public health approach that defines the workplace and work life as not being part of public health does so by employing the idea of occupational health, which only provides a partial knowledge of health. Citizens are now viewed more as customers than as employees, and the healthcare industry is no longer where people go to work. When planning healthcare services, occupational health is separated from public health as a result (The Dictionary of Critical Health Sociology, 2006).

There are a number of risks to the health and safety of workers associated with the work of coal mining using the underground exploitation system, including: the presence and sudden occurrence of various explosive, poisonous, and suffocating gases; potential dangers of fire and explosions in terms of character and intensity; sudden intrusions of underground and surface water and mud; large and frequent temperature and microclimate changes of work conditions; and potential fire and explosion hazards.

Since most of these influences are persistent, extensive efforts are required to reduce or completely eliminate their impact. Despite adopting technological precautions, it is still possible that some elements might have damaging and hazardous consequences on employees' work conditions, leading to accidents and injuries.

The data from the monthly and yearly injury reports were utilized as sources, and they were statistically processed and evaluated. This paper specifically discusses the underground coal mines in Serbia.

In Serbia, layers of hard, dark, and brown lignite coal are extracted from 11 pits employing technical methods of underground exploitation, including several variations of column and column-chamber mining systems. It primarily concerns the excavation of thick coal seams, which has an important effect on worker protection and safety.

MINING INJURIES AND COLLECTIVE ACCIDENTS

The technological procedure for mining underground coal entails a number of work operations that are linked and coordinated in time and space, starting with research, opening, preparation, excavation, transport, export, and processing as the main processes, together with ventilation, drainage, delivery and dispatch of raw materials, employee transportation, etc. A contemporary mine is an intricately interconnected industrial system for coal mining and processing. Modern scientific and technological advancements are considered while building such a complicated manufacturing system, taking into consideration their adaptation to the working conditions.

The causes of injuries can be divided into three categories: (1) natural, which depend on the natural and geological conditions in the deposit; (2) technical and technological, which depend on the level of applied technology; and (3) subjective, which depend on the participants in the work process. Collective accidents and individual injuries can be the result of a variety of influencing factors.

Since there is a clear geographical and temporal link between all the aforementioned sources of injuries, it follows that workplace injuries and collective accidents are the consequence of an adverse confluence of circumstances from each of the three groups of sources of injuries. Each set of potential causes must be dissected into smaller units and monitored and studied independently in order to appropriately determine the zone of influence in a scenario and conduct preventative actions. A realistic assessment of the potential negative effects on the functioning of the technological process and the emergence of potential workplace hazards for employees is required when solving any real problem relating to protection and work safety in the mine. This analysis must include both natural and technical/technological factors. To ensure that an employee error (lack of attention, inappropriate operation, etc.) does not activate the hazard and have unintended repercussions, the degree of hazard needs to be decreased or fully eliminated. In fact, according to the research of Europen Agency for Safety and Healt at Work, human error accounts for approximately 80% of injury causes [https://oshwiki.osha.europa.eu/en/themes/human-error]. But the truth is that as technology has advanced, so have methods of both collective and individual protection. As a result, fewer people are injured at work and collective accidents have virtually disappeared. The awareness and attitude toward safety and technical protection in underground coal mines also increases since current technical methods call for staff with a greater degree of education and professionalism.

Statistical data on socio-demographic characteristics of injuries in coal mines in Serbia

The primary energy source used in the residential and commercial sectors is coal. The production of coal significantly contributes to economic growth, but it also exposes coal mine employees to significant risk. Around the world, coal mining is regarded as one of the riskiest professions (Margolis, 2010). Due to the unfavourable state of occupational safety and health in mines, many coal miners lost their lives or suffered permanent disabilities as a result of work-related accidents and injuries. Coal miners face a variety of health issues, including respiratory, cardiovascular, gastro-intestinal, bone/joint, skin, and foot issues, among others.

Mining has long been a risky industry (David, 2009). The primary contributors to occupational illness and death were strenuous physical labour, harsh working conditions, disregard for personal protective equipment, ignorance of modern machinery and coal mining, and workplace injuries and accidents (Stojadinovic, 2011).

An injury may be avoided by taking preventative action, which also delays the emergence of negative consequences that, as a result of the injury, impact the entire system. This makes the prediction of events that endanger the safety and health of employees particularly crucial. Injury has a negative ripple effect that affects both the company and employees, as well as the state, the community at large, and the social security and health systems. Most businesses use statistical analysis of data on injuries that have already happened when reviewing workplace accidents. Accordingly, the study of information on workplace injuries in Serbian coal mines in 2013 will be the focus of this research. These data are complete and can help predict future injuries in coal mines in Serbia. An in-depth examination of worker injuries in Serbian underground coal mines reveals a number of flaws in the exploitation technology that led to a high rate of accidents and a dangerous working environment.

The categorization of injuries can be recorded via different indicators in addition to the number of injuries per mine and their severity classification (minor, severe, fatal, and total). The following table shows the research findings according to various factors and mines for 2013 (Ivković, 2014).

Table 1. *Injuries according to severity*

Mine	Severity of injury			
	Minor	Major	Fatal	**Total**
Vrška Čuka	15	-	-	15
Ibarski mines	5	1	-	6
Rembas	142	20	1	163
Bogovina	22	3	-	25
Soko	83	4	1	88
Jasenovac	19	5	-	24
Lubnica	38	1	-	39
Štavalj	55	6	-	61
Aleksinac	99	9	-	109
Total	479	49	2	530

Source: Adapted from Ivković et al. (2014)

Table 1 shows that minor injuries are prevalent in the total score, more precisely 479 minor injuries of 530 total injuries in all coal mines in Serbia. Rembas is the mine with most major injuries (20) and one fatal injury. Two coal miners died from their injuries, one at the Soko mine and the other in the Rembas mine. We can confirm that Soko and Rembas mines pose a greater danger to miners' safety.

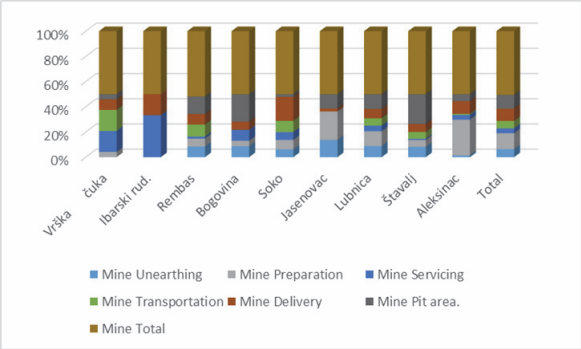


Figure 1. *Injuries according to the technological process of mining;*

Source: Adapted from Ivković et al. (2014)

Figure 1 is especially important because it shows that most injuries occurred in the preparation phase of coal exploitation.

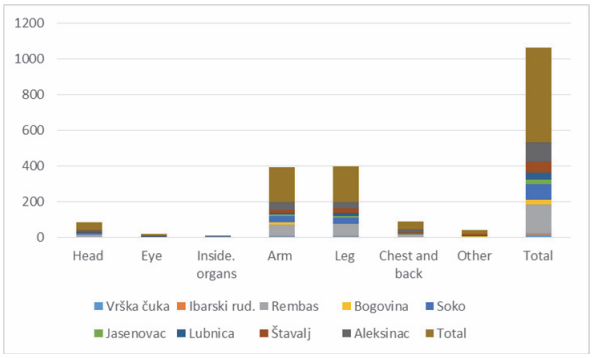
Table 2. *Injuries according to the qualification of employees*

Mine	Qualification of employees				
	HSW	SSW	SW	USW	**Total**
Vrška Čuka	-	7	2	6	15
Ibarski mines	-	2	1	3	6
Rembas	5	62	32	59	163
Bogovina	-	13	3	7	25
Soko	-	31	15	40	88
Jasenovac	-	11	7	6	24
Lubnica	1	16	5	16	39
Štavalj	-	26	5	28	61
Aleksinac	2	55	27	23	109
Total	8	223	92	193	530

Source: Adapted from Ivković et al. (2014)

Statistical data in Table 2 show that semi-skilled workers (SSW) are injured most frequently, while skilled workers (SW) are among the least frequently injured. Highly skilled (HSW) miners are injured less often than workers with lower qualifications.

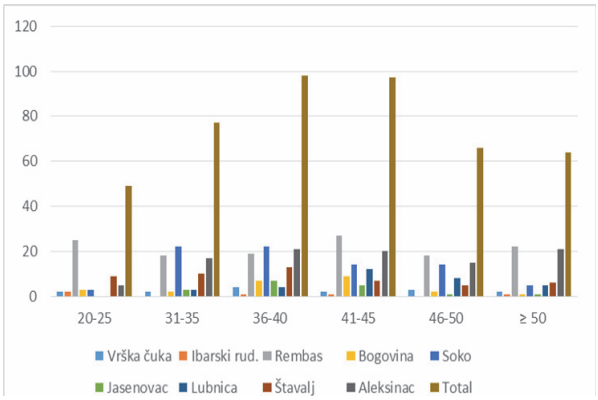
Figure 2. *Injuries according to the injured body parts*



Source: Adapted from Ivković et al. (2014)

Figure 2 shows that miners most often injure their upper and lower extremities, specifically, they most often injure their legs. However, it is an interesting fact that coal miners in Serbia rarely injure internal organs. The ineffective protective equipment to which Serbian miners have access might be the cause of their frequent extremity injuries.

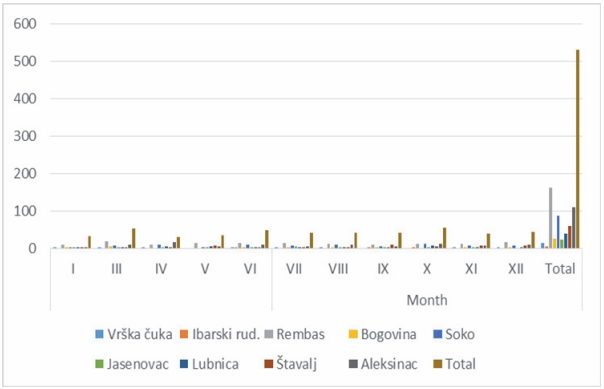
Figure 3. *Injuries according to the age structure of miners*



Source: Adapted from Ivković et al. (2014)

The statistical data of Figure 3 show that miners in full strength and aged 36 to 45 are most often injured. The frequent injuries of coal miners who work full-time can be attributed to overconfidence in one's ability to complete the task safely and a lack of awareness of possible risks.

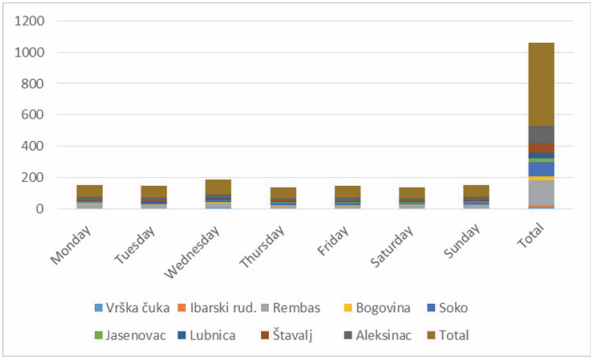
Figure 4. *Injuries by month*



Source: Adapted from Ivković et al. (2014)

Coal miners in Serbia were most often injured in October 2013, as shown in Figure 4. The increased number of injuries in mining near the end of the calendar year can be explained by the fatigue of the workers that accumulated during the year; nevertheless, it is necessary to determine the causes of such distribution of injuries during the year.

Figure 5. *Injuries in coal mines by day of the week*



Source: Adapted from Ivković et al. (2014)

Coal miners in Serbia are most often injured in the middle of the work week, specifically on Wednesday, according to Figure 5.

Table 3. *Injuries at work by shift*

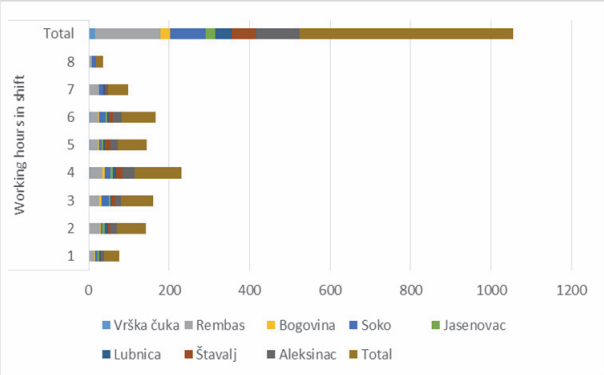
Mine	Shifts			
	I	II	III	**Total**
Vrška Čuka	11	2	2	15
Ibarski mines	3	2	1	6
Rembas	19	50	34	163
Bogovina	13	8	4	25
Soko	28	33	27	88
Jasenovac	16	7	1	24
Lubnica	17	11	11	39
Štavalj	23	27	11	61
Aleksinac	34	43	32	109
Total	224	183	123	530

Source: Adapted from Ivković et al. (2014)

According to Table 3, coal miners in Serbia were most often injured during the first (morning) shift.

Insufficient concentration and preparation of the miners for the work process can explain their injuries during the first shift, but further explanation of this phenomenon is required.

Figure 6. *Injuries in coal mines per hour in shift*



Source: Adapted from Ivković et al. (2014)

Coal miners in Serbia were most often injured in the fourth working hour of the shift, according to Figure 6. The majority of injuries of Serbian coal miners occur in the middle of their shifts, probably because this is the peak hour and tiredness is slowly starting to set in, but additional research is needed to confirm this.

Analysis of coal mine injuries in Serbia

It is clear from the analysed data that the majority of injuries occur as a result of negligent and risky work practices used during the excavation and building of underground mining sites. The technological steps of excavation and delivery of raw materials, which are primarily mechanized, have an extremely high frequency of casualties, which suggests subjective failures. It also suggests that the focus should be on increasing the automation of work processes and improving staff training in order to reduce individual injuries in mines.

While it should be noted that the number of injuries among unskilled, semi-skilled, and skilled employees is proportional to the number of employees, it can be seen that the majority of injuries occurred among unskilled and semi-skilled employees.

The most frequently injured miners are fully operational and between the ages of 36 and 45. These miners usually injure their arms and legs, especially their lower limbs. The middle of the workweek, specifically Wednesday, is when miners commonly get injured. Additionally, Serbian coal miners were most frequently injured during the first shift of the work day and during the fourth working hour of the shift.

The low level of automation and obsolete technologies that are found in all mines result in subpar productivity and unfavourable economic conditions. Mining is a highly physically demanding job, which raises the risk of employee injuries.

By its very nature, underground coal mining poses a risk of personal injury. However, when subpar equipment and inadequate worker training are added to the equation, the risk to miners' wellbeing considerably increases.

A higher level of safety and health for employees, as well as an increase in general safety in the underground mine facilities, are unquestionably necessary for reducing the number of workplace injuries. To achieve this goal, it is imperative to systematically and consistently carry out the prescribed and designed protection measures, which include preventive and current measures.

CONCLUSION

The mining industry has become recognizable by the large number of injuries, frequent collective accidents, and difficult working conditions. The specificity of underground exploitation and the mutual interaction between humans, machines, and a confined working space led to frequent accidents in which workers were injured, machines were damaged, and production losses occured. The joint task of the state authorities, mining companies, and their employees is to reduce the number of injured workers. The state has a stake in this, since it enacts rules and bylaws and oversees how they are implemented. The management of mining companies should put rules and regulations into effect and create a workplace that is safe to work in, with little risk of injury and guarantees that personnel receive quality training so that they are prepared for any risky situation. In order to protect their own and the health and lives of other people, employees must adhere to all guidelines and conduct their work with diligence and caution. Although the situation in this line of work is far better than it was in the past, mining continues to have the highest rate of workplace injuries when compared to other sectors.

ACKNOWLEDGEMENTS

This paper is part of the project financed by the Ministry of Science, Technological Development and Innovation in accordance with the agreement no. 451-03-47/2023-01/ 200148.

REFERENCES

David, R. (2009). Faces of Coal. The Federation for American Coal, *Energy and Security* (pp. 65-78).

Ivković, M., Miljanović, J., Figun, Lj., & Kovačević, Ž. (2014). Sistematizacija povreda na radu u podzemnim rudnicima uglja u Srbiji u 2013. godini. *Mining Engineering*. No 3. (pp. 26–35). www.irmbor.co.rs/mining-metallurgy-engineering-bor-br-3-2014

Ivković, M. & Miljanović J. (2011). „Istraživanje uzroka i posledica povređivanja zaposlenih u jamama RMU "Rembas" – Resavica za period 2000-2010", II Simpozijum sa međunarodnim učešćem "Rudarstvo 2011". V. Banja.

Ivković, M. (2010). „Sistem degazacije kao preventivna zaštita pri radu u izbojnoj radnoj sredini u rudnicima uglja". *Arhiv za tehničke nauke,* Bijeljina.

Miljanović, J., Kovačević, Ž. & Tošić D. (2013). „Rezultati primene tehnologije podgrađivanja AT visećom podgradom u RMU „Soko". Resavica: *Rudarski radovi.* br. 2-3/2013.

Margolis, K. A. (2010). Underground coal mining injury: A look at how age and experience relate to days lost from work following an injury. *Safety Science.* No 48. (pp. 417-21).

Stojadinovic, S., Svrkota, I., Petrovic, D., Denic, M., Pantovic, R. & Milic, V. (2011). Mining injuries in Serbian underground coal mines – A 10-year study. *Journal of Injury. Safety and Health at Work*.

http://www.ilo.org/global/topics/safety-and-health-at-work/lang--en/index.htm [Retrieved 30 Sep 2023].
The Dictionary of Critical Health Sociology. Sol Meclis, NK Kitaplığı: April 2006.

World Health Organization. http://www.who.int/en/ [Retrieved 11 Sep 2023].

[Internet] http://www.worldcoal.org/resources/coal-statistics/ [Retrieved 30 Aug 2023].

[Internet] https://oshwiki.osha.europa.eu/en/themes/human-error
[Retrieved 30 Aug 2023].

20th International Conference Man and Working Environment
SEMSIE
Safety Engineering & Management – Science, Industry, Education
www.znrfak.ni.ac.rs/semsie

DEJAN BOGDANOVIĆ[1]

[1]Belgrade University,
Technical Faculty in Bor

[1]*dbogdanovic@tfbor.bg.ac.rs*

A MULTICRITERIA ANALYSIS OF THE WORK ENVIRONMENT PARAMETERS IN OPEN PIT MINES

Abstract: *Working conditions in open pit mines are quite difficult. Workers are exposed to both physical and chemical hazards. Accordingly, a ranked list of work environment parameters was established to identify the most difficult parameters of working conditions. The six most important work environment parameters that determine working conditions in open pit mines were analyzed: air temperature, light, noise, dust, chemical hazards (petroleum), and vibrations from 25 Hz. The AHP method was used as the ranking method. The ranking process was performed by workers and managers of different open pit mines in Serbia using the group decision method. The obtained results show a clear distinction between individual parameters of working conditions. The results clearly show the importance of the ranking process for both management and workers to identify the most harmful parameters of the work environment in open pit mines.*

Keywords: work environment parameters, AHP, mining, open pit

INTRODUCTION

The main operations in a mine are performed by powerful machines operated by skilled workers. These jobs are characterized by very difficult working conditions (Naeini, 2023). Workers are exposed to physical and chemical hazards in these workplaces and must make great mental efforts. The main parameters that potentially endanger the health of workers in these workplaces include high or low temperatures, vibration, noise, dust, oil fumes, poor lighting, shift work, prolonged sitting, awkward postures, repetitive movements, and the complexity of the job (Buchholz et al., 1997; Stern and Haring-Sweeney, 1997; Zimmerman et al., 1997; Eger et al., 2014).

In their study, Dupuis and Zerlett (1987) pointed out a link between working with earthmoving machines and the health problems of workers operating these machines. Onate and Meyer (2012) studied the relationships between the risks and harmfulness of mines, on the one hand, and the mental and emotional exhaustion of workers, on the other hand. Scott et al. (2009) analysed the chemical hazards encountered in U.S. mines and the illnesses that workers suffered as a result. The above studies and many others show that mine workers were exposed to numerous hazards that led to health problems and caused many diseases (Hulshof and Veldhuijzen van Zanten, 1987; Kittusamy and Buchholz, 2001; Wikstrom et al., 1994).

Mining companies are required to conduct regular tests to increase the safety of their workers (Trade Union Congress, 2001). In Serbia, the procedure for measuring working conditions is specified in the Regulation on Testing of Work Equipment and Work environment Conditions (Official Gazette of the Republic of Serbia No. 15/23). The aim of the regulations is to take appropriate measures for better protection of workers, to determine their performance, etc.

Considering the fact that many risks originating from the work environment simultaneously pose a threat to human health, the permissible values of the parameters are regulated by the relevant laws and directives, the regulations of the Republic of Serbia, as well as by the standards (Occupational Health and Safety - Code of the Republic of Serbia; Directive 89/391/ EEC, 1989; Directive 2003/10/ EC, 2003; ISO 1999:2013, 2013; SRPS EN ISO 9612:2016, 2016; SRPS EN ISO 7726:2008, 2008; ISO 7730:2005, 2005; SRPS EN 12464-2:2014, 2014). The aim of these laws is to create optimal working conditions and reduce risks in the workplace.

In this paper, the ranking of the most important work environment parameters in mines is presented. The aim of the ranking is to identify the most difficult parameters that pose the greatest risk to workers' health. The AHP method was used to create the ranking list.

MATERIAL AND METHODS

The studies are carried out in different conventional mines in Serbia. The main operations are drilling, blasting, loading, transportation and crushing.

Both new and old equipment and mechanization are used for the operations in these mines. Regardless of whether the machines are old or new or of the work process, there are certain work environment parameters for these machines and mining processes that are often above the permissible limits, which seriously affects the health of workers.

AHP method

AHP is a quantitative technique that develops and analyses complex decision problems in a multidimensional hierarchical structure (Saaty, 1980). The hierarchical structure consists of objectives, criteria, and alternatives.

AHP uses a comparison matrix to evaluate the impact of each criterion and the comparison of alternatives with respect to each criterion. The comparison of criteria and alternatives is based on scores from 1 to 9 (Table 1).

Table 1. *Pair-wise comparison scale for AHP method*

Verbal Judgement	Numerical Rating
Equally preferred	1
Moderately preferred	3
Strongly preferred	5
Very strongly preferred	7
Extremely preferred	9
2, 4, 6, and 8 are intermediate values	

Based on a comparison of decision elements, the application of appropriate evaluation leads to a final ranking of alternatives.

In this paper, only the first step is used to rank the criteria (the most important work environment parameters) – calculating the strength of each criterion.

The research method

In order to rank the most important parameters of the work environment and evaluate the degree of their influence on workers, the original research method was developed. This method includes the following three basic steps: (1) data collection, (2) AHP calculations, and (3) results and discussion (Figure 1).

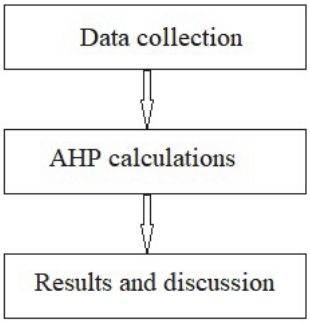


Figure 1. *Schematic overview of the research method*

Figure 1 shows that the study began with interviews with workers and managers of mining companies. The questions were designed to collect the necessary data on the main parameters of the work environment. After the interviews, the final list of the most important work environment parameters was prepared.

Then, the most important work environment parameters from the list were ranked to determine their impact on jobs. Ranking was done using the AHP method, and ratings were made using the group decision method (author with managers of mining companies and workers-operators). The aggregation of individual judgments (AIJ) method of group decision making was performed. At the first meeting, the main parameters of the work environment were discussed and established. Then, at the next meeting (via the Zoom platform, since several mines are involved), the parameters were discussed and ranked until a consensus was reached for each rating, which is shown in Table 3.

After obtaining the results of the ranking, the most important work environment parameters were identified in order to take appropriate actions based on the established priorities.

THE OBTAINED RESULTS

Data collection

As mentioned above, the parameters of the work environment that determine working conditions are measured regularly. Based on interviews with managers and workers, the six most important parameters were identified: air temperature (parameter C1), light (parameter C2), noise (parameter C3), dust generation (parameter C4), chemical hazards (parameter C5), and vibration (parameter C6).

Air temperature is one of the most important microclimatic parameters. The air temperature test is performed in summer when the outdoor temperature is higher than 15°C and in winter when the outdoor temperature is lower than 5°C.

Light is a very important parameter of the work environment and has a significant impact on the quality of work processes and the health of workers (Steidle and Werth, 2014).

Noise, vibration, and harmful radiation – with the exception of ionising radiation – belong to the group of physical hazards. Because of all these causes, noise, vibration, and harmful radiation should be measured in every workplace. Elevated levels of physical hazards also affect workers' health (Faramarzi et al., 2014; Petavratzi et al., 2005).

Chemical hazards include gases, vapours, fumes, and dusts. Humidity and wind speed have a major impact on the concentration of chemical hazards (Csavina et al., 2014).

In order to protect the health of workers, the specific permissible values of the work environment are set by laws and directives (Law on Occupational Safety and Health of the Republic of Serbia, Directive 89/391/ EEC and Directive 2003/10/ EC), the regulations of the Republic of Serbia, and the standards (ISO 1999:2013, SRPS EN ISO 9612:2016, SRPS EN ISO 7726:2008, ISO 7730:2005, and SRPS EN 12464-2:2014). Table 2 shows the parameters of the work environment (the criteria), the permissible values within the work environment and the impact on the health of workers.

AHP calculations

The weighting coefficient for the work environment parameters can be determined by applying the AHP

method. It is the basis for creating the comparison matrix using the scale given in Table 1. Figure 2 shows the hierarchical structure of the AHP problem. Table 3 shows the comparative matrix (6x6) created based on the empirical assessment of the decision makers in order to determine the importance of each parameter. The maximum significance vector for the work environment parameters was obtained using the SuperDecisions software.

Table 2. *Work environment parameters*

	Work environ. parameter	Allowed ranges of work environment parameter	Influence on human health
C1	Air temp.	max 28°	Feeling unease, activity disturbance, chronic disease
C2	Light	min 150Lx	Activity disturbance, eye fatigue, risk of injury, headache
C3	Noise	max 75dBA	Hearing impairment, disrupted reception of sound signals, impossibility of direct and indirect communication, activity disturbance
C4	Dustiness	max 10mg/m^3	Activity disturbance, risk of injury, chronic disease
C5	Chemical Hazards – Petroleum oils	max 300mg/m^3	Activity disturbance, risk of injury, chronic disease, headache
C6	Vibrations ≥ 25Hz	max 1 m/s^2 to 1/3 octave	Activity disturbance, risk of injury, chronic disease, headache, feeling unease

Figure 3 shows the calculation results obtained from the comparison matrix.

From the AHP calculations, it can be seen that the main work environment parameters affecting open pit jobs are ranked as follows: vibration (C6), chemical hazards (C5), temperature (C1), dustiness (C4), noise (C3), and finally light (C2), which has the lowest impact. Since the consistency degree is 0.01514, which is less than 0.1, the obtained results are well consistent for further analysis of their impact on workplaces.

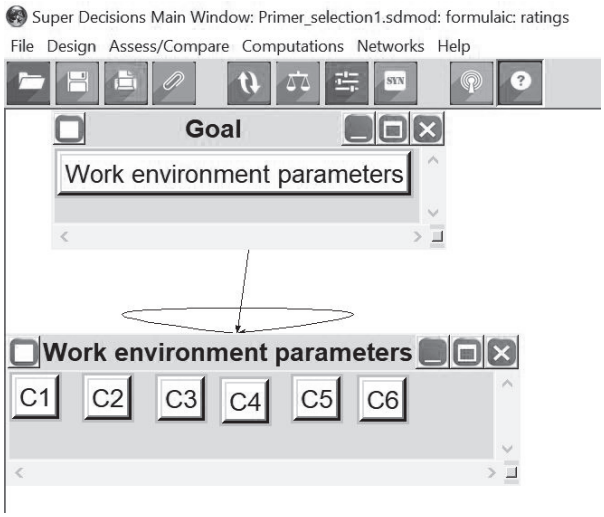


Figure 2. *Hierarchical structure of the AHP problem*

Table 3. *Parameters comparison matrix*

Parameter	C1	C2	C3	C4	C5	C6
C1	1	3	2	1	1	1/2
C2		1	1/3	1/3	1/5	1/5
C3			1	1	1/2	1/3
C4				1	1/2	1/3
C5					1	1/2
C6						1

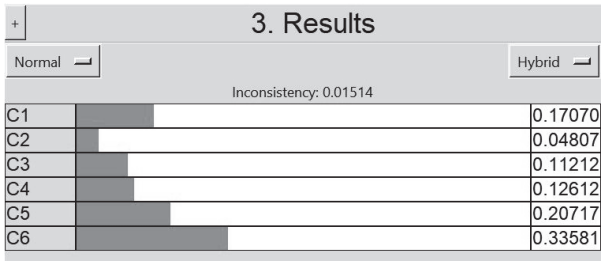


Figure 3. *Results obtained by AHP calculations*

Results and discussion

The obtained results clearly show which parameters of the work environment have the greatest influence on occupational health and safety in mining. The most influential factor is vibration (C6). In workplaces where equipment is used (trucks, drills, crushers, auxiliary equipment, etc.), there are constant vibrations that are harmful to workers' health.

Chemical hazards (C5) are second in the list of adverse effects on occupational health and safety in open pit mines. Chemical hazards occur during work with equipment (fumes, contact with various chemicals), blasting (toxic gases), maintenance and repair of equipment, work in warehouses, etc. These hazards directly affect all employees in the area of open pit mining.

Temperature (C1) is ranked third. Temperature has a great influence on the work in open pit mines. In winter, workers have to deal with low temperatures, while in summer, they have to deal with high

temperatures. Machines that are not equipped with air conditioners or heaters are still used, so workers operating these machines are heavily exposed to this parameter. Workers who work outdoors also face this parameter, which negatively affects their health and safety.

Dustiness (C4) is the fourth most harmful impact on the workplace. All open pit mines generate dust, from blasting to loading, transportation, and crushing. Workers are constantly exposed to this parameter of the work environment. The dust not only affects the open pit mine, but also threatens the immediate and wider surroundings of the mine.

Noise (C3) ranks second to last in negative impacts on mining jobs. Noise is generated by equipment, but also by certain activities (e.g. blasting). However, noise does not affect all workplaces to the same extent as other parameters, so it is much more present in some places and much less in others.

Light (C2) is ranked last. It is considered the least harmful compared to the other parameters of the mining work environment. The reason for this is that all mines are open pit mines, so there is sufficient light during the day for smooth operation. At night and in winter, all mines are equipped with well- lit workplaces, so this parameter has the least harmful impact on workplaces.

Based on the analysis conducted in this way, the influence of each of the considered parameters of the work environment on the jobs in open pit mining becomes clear. Based on the results of the ranking, managers can determine the appropriate measures to prevent accidents and protect health and safety in the workplace. In addition, managers can use the results of the ranking to prioritise the planned prevention and protection measures. When managers are aware of the most dangerous parameters of the work environment, they can implement a set of safety management practices and conduct a risk assessment. For example: the problem of vibrations is due to poorly maintained roads and mobile machinery, which needs to be improved. Unfortunately, the machines in Serbian mines are usually old and poorly maintained, as are the roads. The chemical hazard problem may also be the result of poor protective practices in the mine. Protective practices depend on the mine, but it is clear that vibration, chemical hazards, and air temperature are the problems that need to be monitored and handled when the situation calls for it. In principle, the following measures can improve the work environment parameters: better risk assessment and risk management (Kainat and Shahzadi, 2021), a better monitoring system, better training of employees, and better safety planning in mines. All of this ultimately leads to more effective safety and protection at work in open pit mines.

CONCLUSION

In this paper, the AHP method was applied to evaluate the main parameters of the work environment. Six parameters were considered: air temperature, light, noise, dustiness, chemical hazards, and vibration.

The results of the AHP method show that the parameters vibration, chemical hazards, and air temperature have the greatest impact on open pit mining jobs. The least influential parameter is light.

The results of the ranking can be used as a guide for mining companies to prioritize and apply appropriate safety and protective measures in workplaces in open pit mines.

ACKNOWLEDGEMENTS

The research presented in this paper was carried out with the financial support of the Ministry of Education, Science and Technological Development of the Republic of Serbia, as part of the funding of scientific research work at the University of Belgrade, Technical Faculty in Bor, according to the contract with registration number 451-03-47/2023-01/200131.

REFERENCES

Buchholz, B., Moir, S., & Virji, M.A. (1997). An ergonomic assessment of an operating engineer: a Pilot study of excavator use. *Applied Occupational and Environmental Hygiene*, 12, 23–27 https://doi.org/10.1080/1047322X.1997.10389451

Csavina, J., Field, J., Felix, O., Corral-Avitia, A.Y., Saez, A.E., & Betterton, A.E. (2014). Effect of wind speed and of relative humidity on atmospheric dust concentrations in semi-arid climates. *Science of The Total Environment Journal,* 487, 82-90. https://doi.org/10.1016/j.scitotenv.2014.03.138

Directive 89/391/ EEC. (1989).

Directive 2003/10/ EC. (2003).

Dupuis, H., & Zerlett, G. (1987). Whole-body vibration and disorders of the spine. *International Archives of Occupational and Environmental Health*, 59, 323–336. https://doi.org/10.1007/BF00405276

Eger, T., Thompson, A., Leduc, M., Krajnak, K., Goggins, K., Godwin, A., & House, R. (2014). Vibration induced white-feet: Overview and field study of vibration exposure and reported symptoms in workers. *Work*. 47, 101-110. DOI: 10.3233/WOR-131692

Faramarzi, F., Farsangi, M.A.E., & Mansouri, H. (2014). Simultaneous investigation of blast induced ground vibration and airblast effects on safety level of structures and human in surface blasting. *International Journal of Mining Science and Technology*. 24(5), 663-669. https://doi.org/10.1016/j.ijmst.2014.07.006

Hulshof, C., & Veldhuijzen van Zanten, B.V. (1987). Whole-body *vibration and low-back pain: A review of epidemiologic studies. International Archives of Occupational and Environmental Health*, 59, 205–220. DOI: 10.1007/BF00377733

ISO 1999:2013. (2013).

ISO 7730:2005. (2005).

Kainat, S, & Shahzadi, A. (2021). Managing occupational health and safety in the mining industry. *Agriculture and*

Environment, 2(2):17, 17-22. Article ID: AEN-2021-02-02-006

Kittusamy, N.K., & Buchholz, B. (2001). An ergonomic evaluation of excavating operations: A pilot study. *Applied Occupational and Environmental Hygiene*, 16, 723–726. DOI: 10.1080/10473220120652

Naeini, S.A.B. (2023). Identification and categorization of hazards in the mining industry: A systematic review of the literature. *International Review of Applied Sciences and Engineering*. 41, 5950-5955.
DOI: https://doi.org/10.1556/1848.2023.00621

Onade, E., & Meyer, F. (2012). Ergonomic study of an operator's work of a molybdenum plant. *Work*. 41, 5950-5955. DOI: 10.3233/WOR-2012-0992-5950

Petavratzi, E., Kingman, S., & Lowndes, I. (2005). Particulates from mining operations: A review of sources, effects and regulations. *Minerals Engineering*, 18(12), 1183-1199. https://doi.org/10.1016/j.mineng.2005.06.017

Saaty, T.L. (1980). *The Analytical Hierarchy Process*. McGraw-Hill, New York.

Scott, D.F., Merritt, E.M., Miller, A.L., & Drake, P.L. (2009). Chemical-related injuries and illnesses in U.S. mining. *Mining Engineering*, 61(7), 41-46.

SRPS EN ISO 9612:2016. (2016).

SRPS EN ISO 7726:2008. (2008).

SRPS EN 12464-2:2014. (2014).

Steidle, A., & Werth, L. (2014). In the spotlight: Brightness increases self-awareness and reflective self-regulation. *Journal of Environmental Psychology*, 39, 40-50. https://doi.org/10.1016/j.jenvp.2013.12.007

Stern, F., & Haring-Sweeney, M. (1997). Proportional mortality among unionized construction operating engineers. *American Journal of Industrial Medicine*, 32, 51–65.
DOI:10.1002/(sici)1097-0274(199707)32:1<51::aid-ajim7>3.0.co;2-u

Wikstrom, B.O., Kjellberg, A., & Landstrom, U. (1994). Health effects of long-term occupational exposure to whole-body vibration: A review. *International Journal of Industrial Ergonomics*, 14, 273–292.
https://doi.org/10.1016/0169-8141(94)90017-5

Zimmerman, C.L., & Cook, T.M., Rosecrance J.C. (1997). Operating Engineers: Work-related musculoskeletal disorders and the trade. *Applied Occupational and Environmental Hygiene*, 12, 670–680.
https://doi.org/10.1080/1047322X.1997.10387743

20th International Conference Man and Working Environment
SEMSIE
Safety Engineering & Management – Science, Industry, Education

www.znrfak.ni.ac.rs/semsie

VLADIMIR MIJAKOVSKI[1]
MONIKA LUTOVSKA[2]

[1]University "St. Kliment Ohridski",
Faculty of Technical Sciences – Bitola
[2]University "Mother Theresa",
Faculty of Technical Sciences – Skopje

[1]*vladimir.mijakovski@uklo.edu.mk*
[2]*monika.lutovska@unt.edu.mk*

NON-FATAL INJURY INCIDENCE RATE DURING THE CONSTRUCTION OF THE DEMIR KAPIJA – SMOKVICA HIGHWAY

Abstract: *Incidence rate (IR) is one of many performance measurement tools and is typically used to compare a company's safety performance to the national average. Considering the unrealistic number of reported non-fatal injuries in North Macedonia, it is not possible to compare calculated non-fatal injury IR values at AKTOR construction company contracted for the project of constructing the Pan-European Corridor X –the Demir Kapija – Smokvica highway section, with the corresponding official data. The main objective in this paper is to compare the non-fatal injury IR data obtained from actual activities in AKTOR during 2013 and 2014 with the same parameter data from the construction industry in the EU, published by Eurostat over the same period. Since there were no deaths during project realization, the IR for fatal accidents has not been calculated. European Statistics on Accidents at Work (ESAW) methodology is used to calculate non-fatal injury IR in the project. According to Eurostat, the average annual non-fatal injury IR is 3,245 for the analysed period. This value is more than 6 times higher compared to the calculated average value of 518 for annual non-fatal injury IR in AKTOR. This shows that with good OSH management, modern work equipment, and employee education and investment in their safety at work, a much lower IR, and even zero deaths during the realization of the entire project, can be achieved even in a developing country such as North Macedonia.*

Keywords: non-fatal injury, incidence rate, average value

INTRODUCTION

Monitoring OSH performance reinforces management's commitment to the target objectives and helps develop and raise awareness by rewarding positive work done to control risks (Health and Safety Executive (HSE), 2013,). Accident statistics in developing countries reveal that implementation of laws and regulations, as well as prevention techniques, fall short in their attempts to mitigate or abate accidents involving deaths, injuries and lost working days (BiLİr & Gürcanli, 2018). Employers need to keep records of injuries at work and produce daily, monthly, and annual reports, especially in high-risk industries. Due to the particularly risky nature of workplaces in the construction industry, the companies need to assure safe working conditions through systematic and regular safety audits and risk analysis. Reportable accidents include fatal and major injuries, as well as incapacity for work for more than three days ("more than 3 days injuries"). Data analysis can be used to identify the main causes of injuries and risks that need to be controlled, as well as prevent further accidents (Health and Safety Executive (HSE), 2013).

The data recorded in the monthly and annual reports of injuries and accidents that occurred during the implementation of the Demir Kapija – Smokvica highway section construction project, –in North Macedonia were statistically analysed and the non-fatal injury IR was calculated. The project was a part of the Pan-European Corridor X, realized by the main contractor and subcontractors, from 2012 to 2017.

A branch of AKTOR SA – Greece was the main contractor constructing the rest of the highway A-1 (E-75) from Demir Kapija to Smokvica, with a length of approximately 28 km, to the level of highway with permitted speed of vehicles of 120 km/h.

Figure 1. *Structures on the Demir Kapija – Smokvica highway (construction phase)*

Among other things, construction of the highway included construction/drilling of 2 twin tunnels (4 tunnel tubes) with a total length of over 2.5 km, and 6 bridges with a total length of 2.4 km, with 3 overpasses, 7 underpasses and 2 interchanges. Construction of the tunnels by drilling and blasting as well as construction of the bridges using the cantilever method were the riskiest operations in terms of OSH during the construction phase.

INCIDENCE RATE

Incidence Rate (IR) is only one of many tools that can be used for measuring performance. It is a metric used to compare a company's safety performance against a national average, and also a safety benchmark to gauge performance against other companies in the same business sector (Rochester Institute of Technology, 2012).

Because there were no fatal incidents during the entire construction period of the highway (September 2012-December 2017), the fatal IR indicator has not been calculated.

The published Health and Safety executive IR (Health and Safety Executive (HSE), 2013) gives the number of full-time workers in a group of 100,000 employees injured over a year, and the formula for calculating the non-fatal injury IR makes no allowances for variations in part-time or overtime employment (Health and Safety Executive (HSE), 2015). The following equation considers recommendations regarding indicators and methods of standardization of data published by Eurostat (statistical office of the European Union), based on the European Statistics on Accidents at Work (ESAW) project, (corporate-body.ESTAT:Eurostat, 2013):

$$Non-fatal\ injury\ IR = \frac{Number\ of\ accidents}{Number\ of\ employees} \times 100000$$

The figures from the annual calculation need to be adjusted pro rata if they cover a shorter period (Health and Safety Executive (HSE), 2013).

Non-fatal accidents at work in the EU

Given that the workforces performing risky activities greatly vary in size, the non-fatal injury IR (number of non-fatal accidents at work for every 100,000 persons employed) gives a clearer impression of where workers are more likely to have non-fatal accidents. The total number of these accidents, between 2012 and 2019, rose by about 203,000 (equivalent of an overall increase of 6.9%). This increase may reflect to some extent the data collection methodological changes in some of the EU Member States (Accidents at Work - Statistics by Economic Activity, n.d.).

NACE (Section)	(thousands)									(incidence rate)							
	2012	2013	2014	2015	2016	2017	2018	2019	2020 (1)	2012	2013	2014	2015	2016	2017	2018	2019	2020 (1)
Total (all activities)	2,938	2,937	3,032	3,030	3,113	3,117	3,125	3,141	2,736	1,673	1,654	1,706	1,668	1,718	1,704	1,659	1,603	1,444
Agriculture, forestry and fishing (A)	144	152	170	163	162	148	144	139	109	1,627	1,629	1,871	1,857	1,915	2,100	1,964	1,447	1,493
Mining and quarrying (B)	12	11	10	9	9	9	8	8	7	1,947	1,878	1,743	1,456	1,717	1,628	1,508	1,725	1,535
Manufacturing (C)	638	613	592	592	601	592	597	586	497	2,147	2,077	2,009	1,939	2,001	1,907	1,990	1,859	1,623
Construction (F)	396	354	352	347	347	353	363	372	340	3,457	3,209	3,281	3,201	3,247	3,279	3,319	3,211	2,987
Wholesale and retail trade (G)	388	392	378	380	386	384	377	388	329	1,483	1,509	1,465	1,489	1,489	1,496	1,431	1,415	1,205
Transportation and storage (H)	251	255	242	245	243	273	280	282	231	2,749	2,768	2,613	2,568	2,543	2,766	2,759	2,673	2,212
Accommodation and food service activities (I)	146	150	144	151	159	159	163	166	103	1,888	1,911	1,786	1,814	1,863	1,789	1,763	1,757	1,226
Administrative and support service activities (N)	238	237	232	238	256	280	290	287	222	2,601	2,607	2,388	2,553	2,420	2,621	2,570	2,477	2,030
Public administration and defence (O) (2)	113	156	222	217	212	186	195	190	162	1,015	1,334	1,775	1,721	1,687	1,434	1,448	1,347	1,202
Human health and social work activities (Q) (1)	264	280	327	329	339	336	339	345	402	1,462	1,493	1,754	1,655	1,753	1,695	1,664	1,643	1,934

Note: non-fatal accidents reported in the framework of ESAW are accidents that imply at least four full calendar days of absence from work (serious accidents).
(1) Break in series.
(2) 2017: low reliability.
(3) 2017: estimates.
Source: Eurostat (online data code: hsw_n2_01)

Figure 2. *Non-fatal accidents at work by economic activity, EU, 2012-2020*

There was a decrease in the EU's non-fatal injury IR between 2012 and 2019 for all economic activities (down 4.2 %), reflecting growth in the number of persons employed. The average annual value of 3,245 for non-fatal injury IR in construction in the EU was calculated for 2013 and 2014.

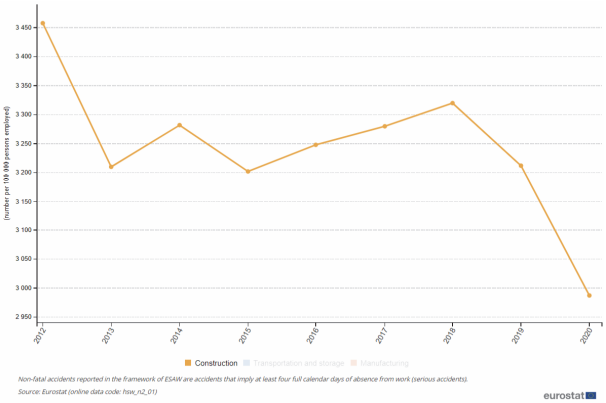


Figure 3. *Incidence rate of non-fatal accidents at work, EU, 2012-2020*

Likewise, in 2020, according to the Eurostat statistics by economic activity, the highest non-fatal injury IR in the EU was observed in construction, with 2,987 such accidents per 100,000 persons employed.

Non-fatal accidents at work in North Macedonia

According to the official data on accidents at work published in annual reports for fatalities, injuries and accidents at work by the Macedonian Occupational Safety and Health Association (Macedonian Occupational Safety and Health Association (MOSHA), 2022), a total of 1,293 non-fatal accidents

in Macedonia were registered in the past decade 2012-2022 (Table 1).

Table 1. *Non-fatal accidents at work and injury IR in North Macedonia (2012-2022)*

Year	All sectors in North Macedonia		
	Total number of non-fatal accidents	Total number of employees	Non-fatal injury IR
2012	116	674,418	17.20
2013	70	685,479	10.21
2014	88	696,046	12.64
2015	105	715,758	14.69
2016	94	723,550	13.00
2017	134	745,206	17.98
2018	124	759,054	16.33
2019	153	797,651	19.18
2020	127	794,909	15.97
2021	135	795,087	16.97
2022	147	693,062	21.21

The highest value for non-fatal injury IR of 21.21 was calculated for 2022 (Table 1). In construction, the total number of officially registered non-fatal accidents for the entire decade is 227, while 20 of them, or 8.8%, occurred in the analysed 2013-2014 period.

These results are highly inaccurate and misleading primarily because of the common 'culture' of not-reporting non-fatal injuries for fewer than 3 lost days to the authorities for many different reasons (Mitrevski et al., 2015). Also, the different source of information used for the reporting and evidencing of the injuries is another reason for number misrepresentation (Fotev, 2013).

RESULTS AND DISCUSSION

Considering the unrealistic number of non-fatal accidents reported in North Macedonia, it is not possible to compare the calculated non-fatal injury IR from AKTOR's activities with the corresponding official data. Therefore, the comparison in this paper is made between the non-fatal injury IR data obtained from the actual activities in AKTOR for 2013 and 2014 and the IR values in the EU published by Eurostat for construction over the same period.

Table 2. *Obtained and calculated OSH statistics within the AKTOR project for the 2013-2014 period*

Month	Total No. of employees	No. of accidents with days lost < 3 days	No. of accidents with days lost >3 days	Monthly non-fatal injury IR	Annual non-fatal injury IR
Jan 2013	162	1	0	617.28	620.85
Feb 2013	220	1	0	454.55	
Mar 2013	307	1	0	325.73	
Apr 2013	330	1	0	303.03	
May 2013	358	3	0	837.99	
Jun 2013	374	2	0	534.76	
Jul 2013	395	5	0	1,265.82	
Aug 2013	438	5	0	1,141.55	
Sep 2013	450	4	0	888.89	
Oct 2013	528	1	0	189.39	
Nov 2013	566	0	2	353.36	
Dec 2013	543	1	2	552.49	
Jan 2014	381	0	0	0.00	311.53
Feb 2014	419	1	1	477.33	
Mar 2014	629	1	2	476.95	
Apr 2014	610	0	0	0.00	
May 2014	611	2	0	327.33	
Jun 2014	625	1	1	320.00	
Jul 2014	636	0	3	471.70	
Aug 2014	622	1	2	482.32	
Sep 2014	603	0	1	165.84	

In the previous table (Table 2), the value for total number of employees (contractors + subcontractors) in each column is cumulative – the number of employees from the previous and the current month. Injuries and absences from work were analysed in relation to the number of employees and non-fatal injury IR was calculated on a monthly and annual basis. Considering that published data from Eurostat determined the average value of 3,245 for non-fatal injury IR in the construction sector in the EU during 2013 and 2014, the comparison shows that this value is more than 6 times higher than the obtained value of 518 for the same calculated parameter in AKTOR over the same period.

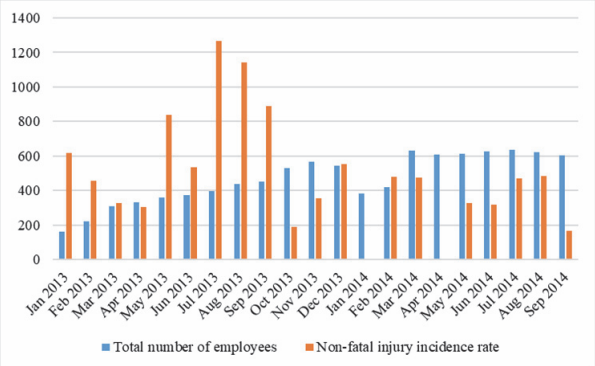


Figure 4. *Total number of employees in AKTOR and non-fatal injury IR per 100,000 employees by month*

ESAW methodology (corporate-body.ESTAT:Eurostat, 2013) is used to calculate the non-fatal injury IR of this project for the 2013-2014 period. The total number of employees and the non-fatal Injury IR per month are given in Figure 4.

These facts clearly show that occupational accidents and diseases are a major concern and must be properly managed (Mohammadfam et al., 2017). The improvements in OSH performance, as an interaction pattern that concerns safety and the varying trend of injury rates, can be interpreted as cultural change of the

learning process that led to a modification of the basic assumptions (Nielsen, 2014).

CONCLUSION

OSH management must be implemented with the same degree of expertise and to the same standards as other core business activities in order to effectively control risks and prevent harm to people, who are the most important investment (Injury Frequency Rates, 2015). Lack of commitment, knowledge, experience, or financial resources are some of the main factors responsible for the lack of functional systematic practices in OSH management.

Despite the fact that accident statistics in developing countries show a failure in the implementation of OSH laws and regulations, the calculated values for annual non-fatal injury IR in the analysed construction project reveal figures more than 6 times lower than the average annual values for the same parameters in the EU countries.

Unfortunately, it is impossible to make a comparison between the non-fatal injury IR that occurred in the 2013-2014 work period within the project and the national values for these indicators over the same period.

This shows that with good OSH management, modern work equipment, employee education, and investment in their safety at work, a much lower IR, and even zero deaths during the realization of the entire project can be achieved, even in a developing country.

REFERENCES

Accidents at work - Statistics by economic activity. (n.d.). Statistics Explained. Retrieved August 18, 2023, from https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Accidents_at_work_-_statistics_by_economic_activity

BiLİr, S., & Gürcanli, G. E. (2018). A method for determination of accident probability in construction industry. *Teknik Dergi*, *29*(4), 8537–8561. https://doi.org/10.18400/tekderg.363613

corporate-body.ESTAT:Eurostat. (2013, February 19). *European statistics on accidents at work (ESAW), Summary Methodology*. Publications Office of the EU. https://op.europa.eu/publication/doi/10.2785/40882

Fotev, N. (2013). *Safety and health at work in the function of companies' profitability* [MSc. Thesis]. Faculty of Economics – Prilep, University "St. Kliment Ohridski."

Health and Safety Executive (HSE). (2013). *Managing for health and safety*. HSE Books.

Injury frequency rates. (2015). Health and Safety Executive (HSE). http://www.hse.gov.uk/statistics/adhoc-analysis/injury-frequency-rates.pdf

Macedonian Occupational Safety and Health Association (MOSHA). (2022). *Annual Reports for fatalities, injuries and accidents at work 2010-2022*. MOSHA.

Mitrevski, V., Geramitcioski, T., Mijakovski, V., Lutovska, M., & Mitrevska, C. (2015). Situation Regarding Accidents at Work in the European Union and in the Republic of Macedonia. *International Journal of Engineering, ANNALS of Faculty Engineering Hunedoara, University Politehnica Timisoara, Romania*, *tome XIII*, 1584–2665.

Mohammadfam, I., Kamalinia, M., Momeni, M., Golmohammadi, R., Hamidi, Y., & Soltanian, A. (2017). Evaluation of the Quality of Occupational Health and Safety Management Systems Based on Key Performance Indicators in Certified Organizations. *Safety and Health at Work*, *8*(2), 156–161. https://doi.org/10.1016/j.shaw.2016.09.001

Nielsen, K. J. (2014). Improving safety culture through the health and safety organization: A case study. *Journal of Safety Research*, *48*, 7–17. https://doi.org/10.1016/j.jsr.2013.10.003

Rochester Institute of Technology. (2012). *OSHA Training Institute Education Centre, Module M5 – Incidence Rate*. https://www.rit.edu/academicaffairs/outreach/OSHA/documents/Module5/M5_IncidentRates.pdf

20th International Conference Man and Working Environment
SEMSIE
Safety Engineering & Management – Science, Industry, Education
www.znrfak.ni.ac.rs/semsie

MOMČILO MATIJAŠEVIĆ[1]
SINIŠA SREMAC[2]

[1]NIS JSC
[2]Faculty of Technical Sciences,
University of Novi Sad

[1]*matijasevic04@hotmail.com*
[2]*sremacs@uns.ac.rs*

RISK MANAGEMENT DURING UNCONTROLLED RELEASE OF VOCs DURING UNDERGROUND RESERVOIR AND VEHICLE REFUELLING

Abstract: *The biggest problem of air pollution, as well as the danger of electrostatic discharge, is associated with handling during the unloading of petroleum derivatives (PD) or refuelling of vehicle fuel tanks, especially significant when petrol (UN 1203) is involved, due to petrol evaporation, which consists of volatile organic compounds (VOCs). In the presence of sunlight, the VOCs react with nitrogen oxides and form ground-level ozone, a pollutant that can cause lung damage and respiratory difficulties, affecting both plant and animal life. Furthermore, petrol contains numerous toxic compounds, including benzene, which is likely a cause of lung cancer in individuals consistently exposed to petrol fumes. These gas emissions can be reduced by approximately 85% through the implementation of petroleum vapour recovery systems, specifically Phase I and Phase II vapour recovery, thereby decreasing the risks of fire, unpleasant odours, and most importantly, health hazards. Due to the rapid expansion of urban municipalities, many petrol stations are surrounded by residential areas, car parks, and storage spaces, and are located alongside public roads. In order to maintain the supply chain, the number of underground reservoir refills from tank trucks has increased. In this scenario, the unloading of petroleum derivatives into underground pump reservoirs and the refuelling of vehicle fuel tanks result in the emission of gas vapours into the atmosphere, with various potential consequences. Various hazard zones at the gas station and its surroundings are analysed, and the probability of events leading to accidents is modelled using the ALOHA tool.*

Keywords: risk refuelling fuel tank

HEALTH AND SAFETY POLICY IN THE OIL AND GAS INDUSTRY

Safety management and the continuous development of a safety culture are the cornerstones of corporate responsibility in oil companies in particular. The protection of occupational health and safety of employees, as well as consumers at filling stations must be under the direct supervision of the company, which means preventing accidents at work and occupational diseases, assessing potential hazards, ensuring comprehensive risk management, and creating a healthy working environment. Because of working with hazardous materials, workplace safety is becoming increasingly important, and a collective mindset where workers choose the right behaviour when no one is watching can lead to a successful safety culture transformation. Although security risks cannot be completely eliminated, they can be significantly reduced through awareness of potential hazards and ways to avoid them. Also, the safety of consumers at filling stations is an integral part of safety management, where consumers should be informed about the rules of behaviour at gas stations when fuelling the fuel tanks of vehicles.

MAIN PROPERTIES OF HAZARDOUS MATERIALS

Petrol is a complex mixture of many chemicals, some of which are known to adversely affect human health. Of particular concern are volatile aromatic hydrocarbons, including benzene, toluene, ethylbenzene, and xylene (BTEX group), which can be released during the filling of the fuel tank of a vehicle or unloading of petroleum products from a tank truck into the underground tanks of a filling station (Hilpert et al., 2015; Hilpert et al., 2019). For example, benzene is a known human carcinogen and is associated with multiple health problems, including respiratory, nervous, and immune system conditions (ATSDR, 2007). In addition, studies evaluating non-cancer outcomes have found decreased red blood cell counts, haemoglobin levels, and haematocrit in filling station workers (Abou-ElWafa, 2015). Some studies have specifically assessed exposure to petrol from vehicle fuel tank refills (Vainiotalo, 1999; Backer, 1997; Egeghy, 2000). The detailed properties of dangerous substances are listed in the SDS (safety data sheet) that accompanies the product and with which the employee who handles dangerous goods must be familiar (Law on Safety and Health at Work, 2023). In this paper, we will use the vapour exposure control parameters – limit value of exposure in the workplace, according to the SDS list, as shown in Table 1.

Table 1. *Limit value of exposure in the workplace*

	Petrol	
Slovenia	OEL TWA (mg/m³)	260 mg/m³
Slovenia	OEL TWA (ppm)	200 ppm
Slovenia	OEL STEL (mg/m³)	1,040 mg/m³
Slovenia	*OEL STEL (ppm)*	800 ppm
Croatia	OEL TWA (ppm)	300 ppm
Croatia	OEL STEL (ppm)	500 ppm

- OEL = Occupational Exposure Limit
- TWA = Average concentration of samples per unit of time (Time Weighted Averages)
- STEL = Short Term Exposure Limit

IDENTIFICATION OF HAZARDS

Hazard, as a term, refers to the possibility that accidental situations may occur that will affect the health of employees, persons on the premises, property, and, ultimately, the environment.

The process of hazard identification begins with the identification of hazards that systematically arise from the regular and non-regular operation of the facility (operation due to disturbances (breakdown), floods, high temperatures, shutdown of an automatic pump, etc.).

The biggest hazard in the facilities of the oil industry is the occurrence of vapours, which increases the hazard of electrostatic discharge that can ignite the vapour.

Hazard identification consists of two steps.

1. The first step is hazard recognition and identification of dangerous goods, quantities, accident site – source, accidents, potential effects, critical equipment, and critical points.
2. The second step is the risk assessment, in which the risks related to the identified hazards are assessed.

In this study, hazard identification and risk assessment are performed according to the Methodology for assessing the risk of chemical accidents in industry in relation to the SEVESO II Directive (ARAMIS D.1.C – Accidental risk assessment methodology for industries in the context of the Seveso II directive).

Risk management

The words 'risk' and 'hazard' have a precise meaning. It is impossible to explain what the term 'risk' means without first understanding what 'hazard' is. A 'hazard' is anything that can cause harm.

Risk is the probability, high or low, that a person or persons may be harmed by a hazard. Activities involving petrol are potentially hazardous because the vapours emitted by the substance are highly flammable and harmful to human health.

Filling station employees spend the most time on site (approximately 40 hours per week, for years) and occasionally spend time where pump fumes are at their highest concentration, with benzene concentrations measured between 30 and 230 ppm in the breathing zone (Van Wijngaarden, 2003; Hartle, 1993; Periago, 1997). Filling station users may also be exposed to fumes when refuelling. Compared to gas station employees, their exposure is short and fleeting.

Risk of chemical accident

The risk of a chemical accident is expressed as negligible, small, medium, large, and very large, according to the criteria shown in the table *Risk criteria based on the probability of the occurrence of an accident and possible consequences* from Annex 1 of the Rulebook on the Content of the Accident Prevention Policy and the Content of the Methodology for the Preparation of the Report on Safety and the Accident Protection Plan (Official Gazette of RS, No. 41/10).

The risk is acceptable if it is assessed as very low and low (occurs once every ten years in our case), which is clearly defined through the RAM Matrix.

MODERN TECHNICAL SOLUTIONS AS AN ADDITION TO TRADITIONAL EVAPORATION CONTROL METHODS

Public health may be affected by the ability of the vapour recovery system – VRU (Vapour Recovery Unit) phase I (reception of oil derivatives from the tank truck into the underground tank of the filling station) and phase II (replenishment of vehicle fuel tanks at the filling station) – to reduce exposure to petrol fumes to a safe level and to function properly throughout its working life. This is important for two reasons. First, volatile organic compounds (VOCs) released during refuelling of vehicle fuel tanks can chemically react in the atmosphere, contributing to the formation of ozone and other secondary pollutants, which can directly harm human health via cardiovascular pathways (Zhao, 2017). Second, exposure to primary VOCs, such as those in petrol, can also adversely affect health directly through exposure during refuelling.

Phase I – reception of oil derivatives from the tank truck into the underground tank of the station – is the return (recovery) of vapours that would have gone into the atmosphere at the filling station, as shown in Figure 1 (U.S. Environmental Protection Agency, 1975). Without phase I vapour recovery, about 80 kg of petrol vapours would be released from the 40 m^3 located in the tank of the filling station, if it is assumed that the density of the saturated vapour is 4 kg/m^3 (International Chemical Safety Cards, 2015) and that the vapours are in the upper portion of the tank space of the filling station, at half saturation.

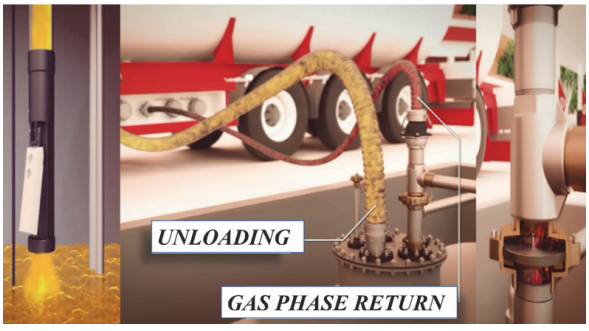


Figure 1. *Phase I – reception of oil derivatives from the tank truck into the station's underground tank*

Phase I is achieved by establishing a closed circuit between the underground tank of the filling station and the measuring equipment of the tank truck, as shown in Figure 1.

Phase II vapour recovery technology, Figure 2, can effectively collect vapours released from the vehicle's fuel tank during refuelling, thereby minimizing personal exposure of customers and workers to fuel vapours during outgassing (U.S. Environmental Protection Agency, 1991). The regenerated vapours are directed into the gas station tank. Two Phase II vapour recovery technologies have been developed, the vacuum assisted method and the equilibrium method.

Evidence from occupational studies has shown that individuals who are chronically exposed to lower levels of petrol vapours, such as gas station workers, are at increased risk of certain cancers (Morton, 1984). Despite this evidence, it is unclear what the risk is to consumers during a typical refuelling session, or the cumulative impact of such exposure over an individual's lifetime, particularly in today's regulatory environment. Our findings highlight, in a visually compelling way, that individuals can be exposed to significant amounts of petrol vapours during refuelling, even in fleets that contain Onboard Refuelling Vapour Recovery (ORVR) systems in the vehicle.

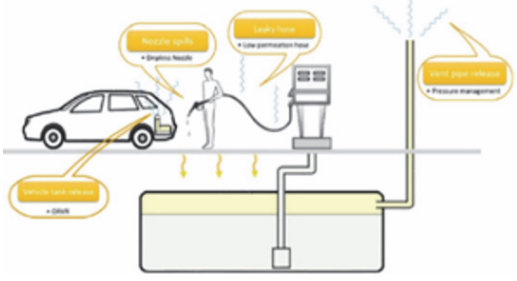


Figure 2. *Phase II – refuelling of fuel tanks of vehicles at the filling station*

CASE STUDY

This paper emphasizes the value of using modern techniques in addition to traditional methods of controlling fumes, which can cause potential health risks for employees and consumers, when delivering petrol from a tank truck to the underground tanks of a gas station or when refilling the fuel tanks of vehicles (even in vehicles with an ORVR system).

Figure 3. *Vapour source identification and gas detection*

The infrared camera allowed us to identify the source of the fumes, and the ALTAIR 5X IR Multigas Detector, which detects CO_2 and specific flammable gases up to 100% volume (Figure 3), allowed us to see fumes coming out of the pump nozzle, the vehicle tank, or both. The average time of filling the fuel tanks of the vehicle was 1.20 minutes, and was realized at the filling station with vapour recovery phases I and II.

A limitation of this paper may be that a newer generation vehicle was used, and therefore may not be representative of the actual vehicle fleet in Serbia. Furthermore, measurements at only one filling station do not provide enough data for statistical tests.

In addition, the evaluation of the video recordings made it possible to identify the sources of vapour and determine the time of vapour release as well as the movement of vapour during evaporation.

Information on the timing of vapour release is particularly useful as it can help HSE (Health-Safety-Environment) or technical personnel determine why vapours are released. However, the release of vapours that occurs in the middle of the process of filling the fuel tank with fuel or during the entire manipulative process (Figure 4) in vehicles with an installed ORVR system may indicate a malfunction of the ORVR system. In older generations of vehicles (without an ORVR system), it indicates a malfunction of the pump automatic nozzle itself or a malfunction of the entire built-in phase II vapour recovery.

Figure 4. *Near continuous vapour release*

The intense release of vapours from the fuel tanks of the vehicle was recorded at the end of filling the fuel tank of the vehicle, Figure 5.

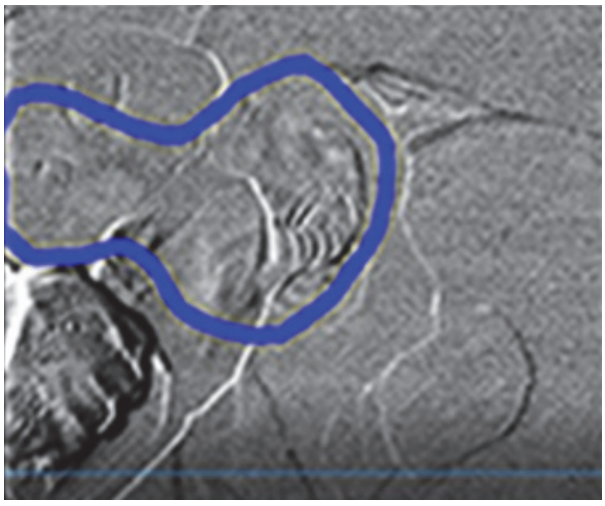


Figure 5. *Release towards the end and after nozzle withdrawn*

The results of measurements using the ALTAIR 5X IR Multigas Detector are presented in Table 2, for the entire process of vapour release during the filling of the fuel tank of the vehicle and with the value at the very end of the filling.

Table 2. *Results of measurement*

VOC (ppm)	Place of release
103.7 – 109.4 – 171.4	Continuous release of vapour during refuelling
510.3	End of filling and returning of the nozzle

If we compare the obtained values of VOCs with benzene concentrations measured between 30 and 230 ppm in the breathing zone according to Van Wijngaarden (2003), Hartle (1993), and Periago (1997), we observe a serious problem. Also, if we compare the obtained results with the data on the limits of exposure to fumes in the workplace (the SDS), shown in Table 1, we also observe very high values.

Possible outcome

A possible outcome is that the flammable chemical burns as it exits the tank through the inlet tube. The diameter of the circular opening is 60 mm.

Parameters of simulation:

- Tank diameter– 2.1 m
- Tank length – 5.77 m
- Tank volume – 20,000 l
- Fuel mass in tank – 10,500 kg / 83% fill

By entering the necessary data (location, movement of air masses, type of dangerous goods) into the ALOHA software, we obtain the necessary data about the dangerous substance.

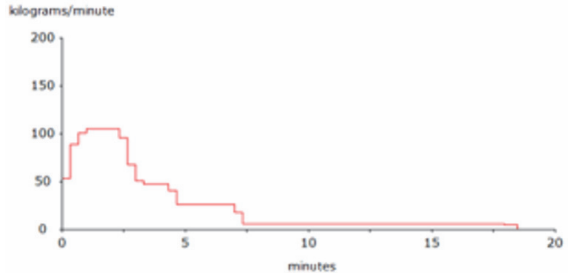


Figure 6. *ALOHA software results*

The scenario describes the conditions that can lead to a major accident and the potential consequences, which in most cases involve the loss of a hazardous substance also known as a critical event, which ultimately leads to a fire, explosion and/or spread of toxicity. Based on the entered and analysed data, the ALOHA software determines the danger zones as well as the amount of vapour released (kg/min) (Figure 6).

Table 3. *Hazard zones shown in Figure 6, i.e. modelled hazard: Thermal radiation from a fire in the zone of intense evaporation.*

Danger zones	Outcome
Red	12 meters (10.0 kW/(sq m))= (potentially lethal within 60 seconds)
Orange	19 meters (5.0 kW/(sq m)) = (2^{nd} degree burns within 60 seconds)
Yellow	32 meters (2.0 KW/(sq m)) = (pain within 60 seconds)

Based on the obtained data (hazard zone), the ALOHA software enables the entry of that data into the Google map (Figure 7), so that the potential hazard can be visualised and preventive measures taken against unwanted consequences.

Figure 7. *ALOHA software results on a Google maps image*

JUSTIFICATION OF APPLICATION OF THE SO-CALLED PETROLEUM DIRECTIVE

Since saturated petrol vapours have a density that is three to four times higher than the density of air, i.e. 4 kg/m^3, and the density of liquid petrol is about 720 kg/m^3 (International Chemical Safety Cards, 2015), about 0.5% of liquid petrol is released into the atmosphere.

Analysis of vapour losses at filling stations shows that they can range from 0.25 to 0.35% of the total volume of sales. For example, at a filling station with a flow of 16,000,000 litres, the loss will be 0.30%, which is equal to 16,000,000 x 0.30/100 = 48,000 per year.

CONCLUSION

If there is high turnover of fuel at a filling station cumulatively over a long period of time, loss of fuel through fumes or spills, even in small amounts, can constitute a serious amount that directly endangers employees and the environment. For example, about 0.01% of fuel can be lost during the filling process and even up to 0.5% of petrol can be lost in the form of vapours (worst case scenario).

Finally, it is of particular importance for public health and policy to install a vapour recovery unit (VRU), phase I and phase II. Not only is it legally required, but using efficient technology for pollution prevention can also be economically beneficial.

The degree of vapour retention efficiency must be a minimum of 85% according to the regulation, but to achieve higher efficiency, additional equipment is needed that is not currently installed in Serbian filling stations.

Problems: There is no accredited institution to check whether the equipment is correctly installed and maintained, what the vapour-liquid range is and whether the control system works and signals errors and cuts off the fuel supply in case of an error that occurs for more than 72 hours.

ACKNOWLEDGEMENT

This research paper is supported by the Ministry of Science, Technological Development and Innovation through project no. 451-03-47/2023-01/200156 “Innovative scientific and artistic research from the FTS (activity) domain”.

REFERENCES

Hilpert M, Mora BA, Ni J, Rule AM, Nachman KE. Hydrocarbon release during fuel storage and transfer at gas stations: environmental and health effects. J Curr Environ Health Rep. (2015) 2:412–22. doi: 10.1007/s40572-015-0074-8

Hilpert M, Rule AM, Adria-Mora B, Tiberi T. Vent pipe emissions from storage tanks at gas stations: implications for setback distances. Sci Total Environ. (2019) 650:2239–50. doi: 10.1016/j.scitotenv.2018.09.303

ATSDR. Toxicological Profile for Benzene. Agency for Toxic Substances and Disease Registry. Atlanta, GA: US Department of Health and Human Services (2007).

Abou-ElWafa HS, Albadry AA, El-Gilany AH, Bazeed FB. Some biochemical and hematological parameters among petrol station attendants: a comparative study. Biomed Res Int. (2015) 2015:418724. doi: 10.1155/2015/418724

Vainiotalo S, Peltonen Y, Ruonakangas A, Pfäffli P. Customer exposure to MTBE, TAME, C6 alkyl methyl ethers, and benzene during gasoline refueling. Environ Health Perspect. (1999) 107:133–40. doi: 10.1289/ehp.99107133

Backer LC, Egeland GM, Ashley DL, Lawryk NJ, Weisel CP, White MC, et al. Exposure to regular gasoline and ethanol oxyfuel during refueling in Alaska. Environ Health Perspect. (1997) 105:850–5. doi: 10.1289/ehp.97105850

Egeghy PP, Tornero-Velez R, Rappaport SM. Environmental and biological monitoring of benzene during self-service automobile refueling. Environ Health Perspect. (2000) 108:1195–202. doi: 10.1289/ehp.001081195

Law on Safety and Health at Work, 2023, Article 30, Rulebook on Preventive Measures for Safe and Healthy Work when exposed to chemical substances, Article 9

Van Wijngaarden E, Stewart PA. Critical literature review of determinants and levels of occupational benzene exposure for United States community-based case–control studies. Applied Occupational and Environmental Hygiene. 2003;18(9):678–93.

Hartle R. Exposure to methyl tert-butyl ether and benzene among service station attendants and operators. Environmental Health Perspectives. 1993;101 Suppl 6:23–6.

Periago JF, Zambudio A, Prado C. Evaluation of environmental levels of aromatic hydrocarbons in gasoline service stations by gas chromatography. Journal of Chromatography A. 1997;778(1– 2):263–8

Zhao R, Chen S, Wang W, Huang J, Wang K, Liu L, et al. The impact of short-term exposure to air pollutants on the onset of out-of-hospital cardiac arrest: a systematic review and meta-analysis. Int J Cardiol. (2017) 226:110–7. doi: 10.1016/j.ijcard.2016.10.053

U.S. Environmental Protection Agency, Design criteria for Stage 1 vapor control systems—gasoline service stations.1975.

International Chemical Safety Cards (ICSC). ICSC #: 1400. 2015 Available from: http://www.cdc.gov/niosh/ipcsneng/neng1400.

U.S. Environmental Protection Agency, Technical guidance —stage II vapor recovery systems for control of vehicle refueling emissions at gasoline dispensing facilities, Volume I: Chapters, 1991

Morton W, Marjanovic D. Leukemia incidence by occupation in the Portland-Vancouver metropolitan area. Am J Ind Med. (1984) 6:185–205. doi: 10.1002/ajim.4700060304

20th International Conference Man and Working Environment
SEMSIE
Safety Engineering & Management – Science, Industry, Education

www.znrfak.ni.ac.rs/semsie

MILICA JOVANOVIĆ[1]
JOVICA JOVANOVIĆ[1,2]

[1] Institute of Occupational Health Niš
[2] Faculty of Medicine,
Faculty of Occupational Safety,
University of Niš

[1]*joca@medfak.ni.ac.rs*
[2]*m.jovano1995@gmail.com*

OCCUPATIONAL SAFETY ENGINEERING FOR COMPUTER OPERATORS

Abstract: *All systems are exposed to the harmful effects of computer equipment components, and since professional work at a computer has the character of passive work, which is extremely tiring for the eyes, disturbances in the functioning of the locomotor system and vision disorders occur most often. Symptoms that occur primarily in the locomotor system are grouped under the term computer related injuries. These include damage to muscles, tendons, and neurovascular structures that most often affect the hands, the neck, and the spine. It is estimated that between 20% and 25% of computer users worldwide suffer from some form of computer related injuries. The two most common disorders from this group are carpal tunnel syndrome and tendon injuries. Computer vision syndrome includes eyestrain, dry eyes or excessive tearing, redness and burning sensation in the eyes, sensitivity to bright light, blurred near and far vision, slow focus, hypersensitivity to contact lenses, feeling of pain in the eyes, blurry letters on the monitor, inability to look in one direction for a long time, headaches, and colour perception disorders.*

Keywords: computer related injuries, occupational safety engineering, computer work, computer vision syndrome

INTRODUCTION

The use of computers and digital electronic devices, video display terminals, including e-mail, internet access, and entertainment is almost universal in modern society.

Computers have become key tools in virtually every aspect of work and learning, from managerial activities to document preparation and electronic communication. The applications of computer technology are revolutionizing the workplaces worldwide, and their use will continue to grow in the future. Computer users are constantly exposed to various occupational risks, such as awkward and unsafe postures, longer hours in front of a computer without minding one's own health, high levels of job strain, repetitive finger movements, utilization of software with poor usability, work related stress, repetitive tasks, boredom, interpersonal factors, and poor workstation design. The development of technology and unsafe use of computers can contribute to health damage such as insomnia, cumulative trauma disorders of extremities, back pain and musculoskeletal disorders, computer vision syndrome, asthenopia, consequences of stress, and psychological disorders, which negatively affects operators' task efficiency, performance, and productivity. It is estimated that 25% of computer users worldwide are already suffering from computer related injuries. Every country has to allocate a lot of funds annually for having ignored these computer related problems.

INFLUENCE OF COMPUTERS ON THE LOCOMOTIVE APPARATUS

Symptoms that occur primarily in computer users are grouped under the term computer related injuries, i.e. injuries caused by working on a computer. These include damage to muscles, tendons, and neurovascular structures that most often affect the hands, the neck, and the spine. Due to long-term static loading of the spinal column, non-physiological position, and repetition of unnatural movements of the extremities (especially the hands), the following symptoms occur: pain and stiffness in the neck, shoulders, back, arms and legs; swelling of muscles and joints; pressure in the head and neck; fatigue; exhaustion; lethargy; irritability; depression; and reduced working capacity. The most common disorders from this group are the carpal tunnel syndrome and tendon injuries. The carpal tunnel is an inextensible bone-connective channel, through which the tendons of nine muscles and the medial nerve pass and completely fill it. As a result of repeated bending of the hand and holding of the mouse, there is an increase in pressure, swelling of the tissue, and penetration of the connective tissue, which causes compression and ischemia of the medial nerve. It is manifested by friction and burning pain in the hand during the night. The treatment is surgical. The thoracic outlet syndrome is caused by pressure on the neurovascular pedicle of the shoulder, which consists of the subclavian artery and vein and the brachial plexus. The symptoms are tingling, painful swelling of the whole arm, pain and weakness of the hand muscles, and pressure on the plexus of the nerves at the junction of the neck and chest and/or the blood vessels located next to it. It is a consequence of sitting hunched over while working or sleeping with your hand under your head. The symptoms become worse when performing activities with the arm raised above the head. Other damage to the locomotive apparatus due to excessively long work on a computer includes epicondylitis, neuropathies n. ulnaris, myalgia m. trapezius, and

changes in the spinal column. The most common consequences are degenerative changes in the muscles of the neck and cervical spine, neck bending, kyphoscoliosis, which can compromise respiratory and cardiac function, and lower back pain (lumbalgia) due to prolonged sitting in chairs whose backrests do not follow the normal anatomy of the spinal column.

INFLUENCE OF COMPUTER ON VISION

Man has adapted his eyes to distance during the evolution. For the past fifty years, while working on a computer, the eyes have been fixed for hours on a point that is less than a meter away. Over seventy per cent of the computer-using population has some kind of eye problem. The main cause of these disturbances is the glare from the screen, which can also come from the reflection of shiny surfaces from the environment or due to sunlight. Computer vision syndrome includes eyestrain, dry eyes or excessive tearing, redness and burning sensation in the eyes, sensitivity to bright light, blurred near and far vision, slow focus, hypersensitivity to contact lenses, and colour perception disorders. Other symptoms are feeling of pain in the eyes, double vision of letters on the monitor, inability to look in one direction for a long time, and headaches. The symptoms are a consequence of insufficient tear flow due to reduced blinking, which results in greater exposure to light from the monitor, the need for frequent accommodation, and increased eye strain.

OTHER DAMAGE CAUSED BY WORKING ON A COMPUTER

For people suffering from epilepsy, it was found that using a computer carries a huge risk of seizures, due to the flickering of the image on the screen.

Allergic changes on the skin of the face (redness of the skin and acne-like changes) are the consequences of electrostatic field between the screen and the skin that attracts dust particles. Various soft pads may contain latex or silicone and are the most common cause of allergies. Allergens can be found in various plastics due to the chemicals they are treated with during production. The plastic used to produce the monitors contains substances that reduce its flammability. They evaporate from the monitor, irritate the mucous membrane and cause headaches. The **noise** produced by almost every computer thanks to fans and disks leads to a lack of concentration and nervousness. Older-generation printers were linked to hearing impairment in employees working directly with them. Computer keyboards can have more **dangerous bacteria** than the toilet seat of a public toilet. Some studies (Messina et al, 2011; Gerba et al, 2016; Das et al, 2018) have shown the presence of bacteria on computers that can cause diseases in humans. Bacteria found on keyboards can cause symptoms of food poisoning. The main cause of dirty keyboards is the fact that employees often have breakfast in the office, and leftover food is suitable for the development of millions of bacteria. **Psychosomatic disorders** caused by computer work include general fatigue, exhaustion, depression, concern, sluggishness, irritability, and reduced working capacity. Working in front of a monitor is not a direct cause of stress, but it is the content of the job, the need for numerous repetitions of actions, long-term increased concentration, and limited social. Physical stress due to poor ergonomic workplace solutions often leads to psychological stress. The results of previous studies (Weiss & Petersen, 1979; Franchini et al, 2018; Wongkasem, 2021; Juras et al, 2023) indicate that microwave electromagnetic radiation from the screen causes genetic and chromosomal changes and disrupts the metabolism of cells. It damages the epithelium of women's reproductive organs and leads to sterility, spontaneous abortions, or the birth of children with physical impairments. Research of computer addictions (Sussman et al, 2018; James et al, 2023) has shown that women who work in administration spend three times more time in front of the computer than in shopping or with their husbands or partners and that this makes them satisfied. They also often have sleep and eating disorders, a lack of physical activity, problems in spousal relationships, and a high degree of anxiety that occurs every time when an individual is separated from a computer for a long time. As a result of low-frequency **vibrations,** general weakness and indigestion occur. High frequency vibrations act on blood vessels (vasospasm and increased arterial tone), causing increased tension of the muscles and osteoarthritis.

DISCUSSION

The prevalence of computer vision syndrome has been found to be between 28-60% (Gadain, 2023; Jaiswal et al, 2019). A common symptom in computer operators is headache, followed by dry eyes and pain in and around the eyes. Headache was the most commonly reported symptom in computer users in several other similar studies (Lema & Anbesu, 2022; Xavier, 2015). Headaches are often accompanied by other symptoms of computer vision syndrome, although many patients do not consider it to be a directly vision-related problem. Human eyes need to adjust in order to see objects from different distances, e.g. by changing the size of the pupil, lengthening or shortening the lens to change eye focus, and contracting extra-ocular muscles to coordinate the two eyes. If a computer user needs to view the computer screen while looking at a paper on the table from time to time, the eyes have to adjust constantly. In addition, the words and images on a computer screen are difficult for the eyes to focus on due to their poor edge resolution. The eyes tend to change the focus to a resting point and then refocus on the screen. Therefore, constant focusing and refocusing is required. These constant changes take place thousands of times a day when a computer user stares at a computer screen for hours, which then stresses the eye muscles leading to eye fatigue and discomfort, which causes headaches. Studies have shown that a decreased spontaneous eye blink rate leads to increased evaporation of tears, which in turn leads to dry eyes syndrome (Zheng, 2022; Chester, 2023). Some authors (Kamøy, 2022; Zalat, 2022) argue that the use of a computer monitor in an ergonomic position – an arm's length distance or 40 inches away with a downward

gaze of 14° or more appears to help relieve the symptoms of computer vision syndrome. According to Occupational Safety and Health Administration (Rothstein, 2020), the preferred viewing distance is 20-40 inches and the letter size may be increased for smaller monitors. In the older guidelines for work with video display terminals, the safe distance from the computer screen was between 45 and 70 cm. The monitor should be kept directly in front of the user's chair so that the head, neck, and body face forward when viewing the screen. It should not be further than 35° to the left or right. It is recommended that while working from printed material, the monitor should be placed slightly to the side and the printed material kept directly in front. The printed material and the monitor should be kept as close as possible to each other. Viewing the computer screen from a distance (48.42 and 65.33 cm) causes more accommodation and convergence among people working with computers than those who do not work behind computer screens. The studies indicated a causal relationship between computer work and musculoskeletal disorders and complaints. The commonest risk factors for musculoskeletal disorders are awkward posture due to poorly designed seating devices that lack adjustable seat heights and back rests, and repetitive tasks. These results were presented by several authors (Lee et al, 2021; Emerson et al, 2021; Pattath & Webb, 2022), who point out the importance of preventive measures in musculoskeletal disorder reduction. However, the application of ergonomic principles to office workstations can reduce such health risks. For example, one of the goals of ergonomic processes is to design or modify people's work and other activities to match their capabilities and limitations. Other authors (Saiklang et al, 2022; Povlsen, 2012) investigated the effects of ergonomic intervention and physical exercise on musculoskeletal pain symptoms in all regions of the body, as well as on other musculoskeletal pain. These results show that ergonomic intervention, specific resistance training, and all-round physical exercise for office workers caused better effects than a reference intervention in relieving musculoskeletal pain symptoms in exposed regions of the body.

PREVENTION OF COMPUTER VISION SYNDROME

Prevention of computer vision syndrome involves the application of the following measures:

- **Positioning the viewable area of the screen a little below the line of sight.** Assuming good ergonomics at the desk and chair, the computer should be positioned for a slightly downward gaze. The slightly downward gaze is easier on the eye than looking straight across or viewing upwards. It helps bring the eyelid down and helps eliminate the chances of being affected by draughts, especially when an air conditioning unit is in the room. It helps protect against dryness. In addition, proper screen position promotes good posture with both feet flat on the floor.
- **Eliminating or reducing screen glare.** Light toxicity or discomfort can result from too much glare. It can impact one's ability to perform their job. A good test is to place a folder over your head as you look at your work terminal. If it becomes easier to read with the folder, then the user may have problems with discomfort and disability glare. Glare can be reduced by placing a screen on the computer terminal. Anti-glare coating on eyewear can also help.
- **Minimizing exposure to blue light.** As computers become more modern and sophisticated, so does exposure to blue light. This type of light has immediate consequences including impact on long term macular health, the part of the eye that processes 20-20 vision. Likewise, blue light can impair the sleep cycle. Filters and coatings can help reduce blue light exposure.
- **Allowing for workstations to enable peripheral vision.** Workstations should be built to permit ambient visual stimulation or eye activity going on in peripheral vision. Vision performs best when it is exposed to a full range of visual stimulation, not just one type while blocked from seeing others.
- **Taking breaks.** To best prevent computer related eye stress, users should remember to blink, position screens in the right spot, avoid multiple screens, and take breaks. Getting up, moving around, and perhaps mildly stretching or rotating the arms, wrists, neck, and back will help alleviate a high degree of eye stress and ensure a more productive work experience.
- **Using eye drops.** Lubricating eye drops are designed to keep the eyes moisturized.

PREVENTION OF MUSCULOSKELETAL DISEASES

Prevention of musculoskeletal diseases should be based on an integrative approach combining ergonomics and physical activity interventions.In ergonomics, no clear positive impact has been demonstrated by single intervention programmes, such as workstation adjustments (technical), rest breaks (organizational), or ergonomic training (behavioural) on work-related musculoskeletal diseases. Physical activity interventions in the workplace demonstrated benefits on computer worker musculoskeletal diseases, consisting of either 20-30 min training sessions two or three times a week or short daily active breaks, in addition to either stretching and joint mobilisation exercises or strength training and dynamic endurance training.The involvement of a trainer or a physical therapist especially motivated the participants (Moreira et al, 2021; İkiz&Ergin, 2023).Training sessions appear to have more pronounced long-term effects than short daily active breaks. The majority of strategies have focused on new workstation design, yet their effectiveness remains highly questionable. Strategies could be more effective if they were to implement changes in the temporal pattern of the work task, such as supplementary rest breaks allowing for periods of recovery from the monotonous load. The effect of exercise on musculoskeletal diseases symptoms has been demonstrated in workers (Marangoni, 2010). In

addition to exercise, rest breaks and especially frequent 'microbreaks' have been shown to reduce discomfort, eyestrain, fatigue, and mood disturbances, in addition to improving keystroke speed and accuracy. Some software programs were built to promote frequent breaks at work for computer users. These breaks can be active, with stretching exercises during working days. A taskforce was convened including physicians, nurses, prevention engineers, and a sports teacher, aiming to evaluate an online tool called I-Preventive software, which promotes active breaks with stretching exercises (Irmak et al, 2012).

CONCLUSION

Vision and musculoskeletal disorders, work-related symptoms and addiction to computers are more often statistically significant in computer users who work longer than four hours per day. Unsafe ergonomic solutions, longer exposure time, addiction to computers, work related vision, and musculoskeletal disorders significantly reduce work ability of computer users. These results indicate the need for application and the type of preventive measures and activities that must be applied in order to protect the health and working ability of computer users.

REFERENCES

Chester T, Garg S, Johnston J, Ayers B, Gupta P (2023). How Can We Best Diagnose Severity Levels of Dry Eye Disease: Current Perspectives. *Clin Ophthalmol*.17: 1587-1604. https://doi.org/10.2147/OPTH.S388289

Das A, Conti J, Hanrahan J, & Kaelber DC(2018). Comparison of keyboard colonization before and after use in an inpatient setting and the effect of keyboard covers. Am J Infect Control. 46(4): 474-476. doi: 10.1016/j.ajic.2017.09.012. Epub 2017 Nov 9. PMID: 29129271.

Emerson S, Emerson K, & Fedorczyk J (2021). Computer workstation ergonomics: Current evidence for evaluation, corrections, and recommendations for remote evaluation. J Hand Ther. 34(2):166-178. doi: 10.1016/j.jht.2021.04.002. Epub 2021 Apr 14. PMID: 34030954.

Franchini V, Regalbuto E, De Amicis A, De Sanctis S, Di Cristofaro S, Coluzzi E, Marinaccio J, Sgura A, Ceccuzzi S, Doria A, Gallerano GP, Giovenale E, Ravera GL, Bei R, Benvenuto M, Modesti A, Masuelli L, & Lista F (2018). Genotoxic Effects in Human Fibroblasts Exposed to Microwave Radiation. Health Phys. 115(1):126-139. doi: 10.1097/HP.0000000000000871. PMID: 29787439.

Gadain Hassan HA (2023). Computer Vision Syndrome Among Medical Students at the University of Khartoum, Sudan: Prevalence and Associated Factors. Cureus. 9;15(5):e38762. doi: 10.7759/cureus.38762. PMID: 37303411; PMCID: PMC10249515.

Gerba CP, Wuollet AL, Raisanen P, & Lopez GU (2016). Bacterial contamination of computer touch screens. Am J Infect Control.1;44(3):358-360. doi: 10.1016/j.ajic.2015.10.013. PMID: 26940596.

İkiz H & Ergin E (2023). Musculoskeletal system problems in office workers: relationship of physical activity levels and quality of life. Int J Occup Saf Ergon. 29(1): 321-328. doi: 10.1080/10803548.2022.2043625. Epub 2022 Mar 17. PMID: 35172693.

Irmak A, Bumin G, & Irmak R (2012). The effects of exercise reminder software program on office workers' perceived pain level, work performance and quality of life. Work. 41 Suppl 1:5692-5695. doi: 10.3233/WOR-2012-0922-5692. PMID: 22317655.

Jaiswal S, Asper L, Long J, Lee A, Harrison K, & Golebiowski B (2019). Ocular and visual discomfort associated with smartphones, tablets and computers: what we do and do not know. Clin Exp Optom. 102(5):463-477. doi: 10.1111/cxo.12851. Epub 2019 Jan 21. PMID: 30663136.

James RJE, Dixon G, Dragomir MG, Thirlwell E, & Hitcham L (2023). Understanding the construction of 'behavior' in smartphone addiction: A scoping review. Addict Behav.137:107503. doi: 10.1016/j.addbeh.2022.107503. Epub 2022 Sep 26. PMID: 36228362.

Juras JA, Webb MB, Young LEA, Markussen KH, Hawkinson TR, Buoncristiani MD, Bolton KE, Coburn PT, Williams MI, Sun LPY, Sanders WC, Bruntz RC, Conroy LR, Wang C, Gentry MS, Smith BN, & Sun RC (2023). *In situ* microwave fixation provides an instantaneous snapshot of the brain metabolome. Cell Rep Methods. 18;3(4):100455. doi: 10.1016/j.crmeth.2023.100455. PMID: 37159672; PMCID: PMC10163000.

Kamøy B, Magno M, Nøland ST, Moe MC, Petrovski G, Vehof J, & Utheim TP (2022). Video display terminal use and dry eye: preventive measures and future perspectives. Acta Ophthalmol. 100(7):723-739. doi: 10.1111/aos.15105. Epub 2022 Feb 4. PMID: 35122403; PMCID: PMC9790652.

Lee S, DE Barros FC, DE Castro CSM, & DE Oliveira Sato T (2021). Effect of an ergonomic intervention involving workstation adjustments on musculoskeletal pain in office workers-a randomized controlled clinical trial. Ind Health. 24;59(2):78-85. doi: 10.2486/indhealth.2020-0188. Epub 2020 Nov 28. PMID: 33250456; PMCID: PMC8010160.

Lema AK, & Anbesu EW (2022). Computer vision syndrome and its determinants: A systematic review and meta-analysis. SAGE Open Med.. 9;10:20503121221142402. doi: 10.1177/20503121221142402. PMID: 36518554; PMCID: PMC9743027.

Marangoni AH (2010). Effects of intermittent stretching exercises at work on musculoskeletal pain associated with the use of a personal computer and the influence of media on outcomes. Work. 36(1):27-37. doi: 10.3233/WOR-2010-1004. PMID: 20555173.

Messina G, Quercioli C, Burgassi S, Nisticò F, Lupoli A, & Nante N(2011). How many bacteria live on the keyboard of your computer? Am J Infect Control. 39(7): 616-618. doi: 10.1016/j.ajic.2010.12.023. Epub 2011 Jul 22. PMID: 21782282.

Moreira S, Ferreira MS, Criado MB, Machado J, Mesquita C, Lopes S, & Santos PC (2021). Occupational Health: Does Compliance with Physical Activity Recommendations Have a Preventive Effect on Musculoskeletal Symptoms in Computer Workers? A Cross-Sectional Study. Int J Environ Res Public Health. 6;18(14):7604. doi: 10.3390/ijerph18147604. PMID: 34300055; PMCID: PMC8307835.

Pattath P, & Webb L (2022). Computer-usage and associated musculoskeletal discomfort in college students. Work. 73(1): 327-334. doi: 10.3233/WOR-210523. PMID: 35912768.

Povlsen B (2012). Physical rehabilitation with ergonomic intervention of currently working keyboard operators with nonspecific/type II work-related upper limb disorder: a prospective study. Arch Phys Med Rehabil. 93(1):78-81. doi: 10.1016/j.apmr.2011.05.023. PMID: 22200385.

Rothstein MA (2020). The Occupational Safety and Health Act at 50: Introduction to the Special Section. Am J Public Health. 110(5):613-614. doi: 10.2105/AJPH.2020.305623. PMID: 32267740; PMCID: PMC7144434.

Saiklang P, Puntumetakul R, Selfe J, & Yeowell G (2022). An Evaluation of an Innovative Exercise to Relieve Chronic Low Back Pain in Sedentary Workers. Hum Factors. 64(5): 820-834. doi: 10.1177/0018720820966082. Epub 2020 Oct 28. PMID: 33111563.

Sussman CJ, Harper JM, Stahl JL, & Weigle P (2018). Internet and Video Game Addictions: Diagnosis, Epidemiology, and Neurobiology. Child Adolesc Psychiatr Clin N Am. 27(2):307-326. doi: 10.1016/j.chc.2017.11.015. Epub 2018 Feb 1. PMID: 29502753.

Weiss MM, & Petersen RC (1979). Electromagnetic radiation emitted from video computer terminals. Am Ind Hyg Assoc J. Apr;40(4):300-309. doi: 10.1080/15298667991429624. PMID: 474414.

Wongkasem N (2021). Electromagnetic pollution alert: Microwave radiation and absorption in human organs and tissues. Electromagn Biol Med. 3; 40(2):236-253. doi: 10.1080/15368378.2021.1874976. Epub 2021 Feb 10. PMID: 33566706.

Xavier MK, Pitangui AC, Silva GR, Oliveira VM, Beltrão NB, & Araújo RC (2015). Prevalence of headache in adolescents and association with use of computer and videogames. Cien Saude Colet. 20(11):3477-3486. English, Portuguese. doi: 10.1590/1413-812320152011.19272014. PMID: 26602725.

Zalat MM, Amer SM, Wassif GA, El Tarhouny SA, Mansour TM (2022). Computer vision syndrome, visual ergonomics and amelioration among staff members in a Saudi medical college. Int J Occup Saf Ergon. 28 (2): 1033-1041. doi: 10.1080/10803548.2021.1877928. Epub 2021 Feb 25. PMID: 33517862.

Zheng Q, Wang L, Wen H, Ren Y, Huang S, Bai F, Li N, Craig JP, Tong L, & Chen W (2022). Impact of Incomplete Blinking Analyzed Using a Deep Learning Model With the Keratograph 5M in Dry Eye Disease. Transl Vis Sci Technol. Mar 2;11(3):38. doi: 10.1167/tvst.11.3.38. PMID: 35357395; PMCID: PMC8976934.

20th International Conference Man and Working Environment
SEMSIE
Safety Engineering & Management – Science, Industry, Education

www.znrfak.ni.ac.rs/semsie

ANA LUKOVIĆ[1]
DESANKA DAŠIĆ[2]

[1,2]Elixir Prahovo Ltd

[1]*ana.lukovic@elixirprahovo.rs*
[2]*desanka.dasic@elixirprahovo.rs*

A CASE STUDY OF THE SOUTH-EAST SERBIA ECO-INDUSTRIAL SYMBIOSIS NETWORK

Abstract: *Industrial ecology is an approach to the industrial design of products and processes and the implementation of sustainable manufacturing strategies. It is a concept in which an industrial system is viewed not in isolation from its surrounding systems but in concert with them. Industrial ecology seeks to optimize the total materials cycle from virgin material to finished material, to component, to product, to waste product, and to ultimate disposal. Environmentally friendly symbiosis between diverse local or regional businesses should become a valuable component of modern industrial development. Industrial symbiosis is a form of circular economy where exchanges of waste, by-products, or other resources between enterprises generate competitive advantages.*

This paper reviews the efforts of developing industrial symbiosis networks. The paper introduces a case study on the production of phosphoric acid and the usage of derived by-products. This is the example of the implementation of the eco-industrial symbiosis model in practice, aimed at reducing the consumption of natural resources.

Keywords: industrial symbiosis, circular economy, production of phosphoric acid, by-products

INTRODUCTION

In industrial systems, there is a tendency to emphasize the interdependence between enterprises. A unified management system has become a widely recognized approach. Companies/enterprises become an integral part of chains or networks of suppliers and consumers, like the chains and networks encountered in autochthonous ecosystems. With the aim to ensure their productivity, industries depend upon the resources found in the environment, while individual enterprises and corporations become parts of a unique system and they depend upon one another and co-operate in order to remain on the market (Leigh & Li, 2015).

Successful industrial systems are based on the study of mass and energy trends, which contributes to the minimization of quantities of waste materials (Luković, 2016). An important feature of the technological system, which is considered as a part of the industrial system, is systematic integration, which represents a correlation of all significant aspects in order to achieve maximum efficiency and profit. In this respect, the question arises as to whether industrial ecosystems are a simple analogy of natural ecosystems, whether the metabolism of the systems of industrial production and consumption is an indispensable part of the biosphere, and whether the industrial ecosystems are just another form of ecosystems in which humans are the dominant species. Industrial ecology is a scientific discipline that thoroughly describes the comprehension of the environmental impact of industrial systems, as well as the interaction between the environmental and industrial systems (Luković, 2016).

Industrial symbiosis, as part of industrial ecology, demands meticulous attention to the flow of material and energy through local and regional economies.

This paper presents a brief overview of the concept of eco-industrial symbiosis and describes the interaction of industrial symbiosis and supply chains as well as the significance of collaboration between participants in the supply chain in order to facilitate the implementation and development of environmentally friendly initiatives. The paper describes one of the models of industrial collaboration in the observed region, where the result is the exchange of materials between organizational units, with the overall aim to reduce resource consumption and minimize environmental impact, and thereby reduce the amount of by-products in the industrial sector. This case study refers to the chemical sector – the production of phosphoric acid, which is an important raw material for producing mineral fertilizers, while the by-products derived from its production are further valued as raw materials for other production processes, in line with the postulates of eco-industrial symbiosis.

ECO-INDUSTRIAL SYMBIOSIS AS PART OF A CIRCULAR ECONOMY

Within the broader concept of industrial ecology, industrial symbiosis can be defined as a process that optimizes the flows of resources, energy, and economic profit through the synergy between the actors who create an eco-industrial network. One of the definitions of industrial symbiosis is as follows: "Industrial symbiosis engages traditionally separate industries in a collective approach in order to achieve competitive

advantage involving physical exchanges of materials, energy, water and/or by-products. The keys to industrial symbiosis are collaboration and the synergistic possibilities offered by geographic proximity" (Chertow, 2000).

Industrial symbiosis is a concept that is not primarily designed for supply chains, but it can also be seen as a specific form of supply chain. In order to develop a completely closed circle where resource circulation takes place, the supply chain parties need to cooperate, which is the foundation of the concept of industrial symbiosis (Bansal & McKnight, 2009).

Industrial symbiosis supports a collective approach to the application of industrial ecology principles by enterprises in the expanded system (Chertow, 2000; Costa & Ferrao, 2010; Lombardi & Laybourn, 2012). However, the principle of industrial symbiosis encourages better links between organizations and helps strengthen networks in the supply chain by improving the relationships between all partners towards environmentally friendly activities (Bansal & McKnight, 2009). Industrial symbiosis implies the existence of at least three different entities exchanging at least two different resources (Chertow, 2007). Some authors have developed various models of industrial symbiosis that differ in terms of the amount of resources exchanged and the level of environmental impact (Chertow & Ehrenfeld, 2012).

According to these authors, models of industrial symbiosis include: "a model of the planned eco-industrial park", "a model of self-organized symbiosis", "a model of reconstructed industrial park", and "a model of eco-industrial park with the concept of circular economy". The goal of each of these models is to strengthen cooperation and ecological acceptability. The principle of industrial symbiosis stimulates the supply chain participants to a high level of collaboration in order to facilitate the implementation and development of environmentally friendly initiatives. The possibility of applying the principles of industrial symbiosis is not geographically limited to organizations of proximity that participate in the collaboration (Lombardi & Laybourn, 2012). A common geographic location is an advantage in terms of cooperation for more efficient waste management (Chertow & Ehrenfeld, 2012); however, the most important factor for the development of the relationship of industrial symbiosis is the cooperation among the organizations, because enterprises cannot implement the principles of industrial symbiosis alone (Bansal & McKnight, 2009). The industrial symbiosis emphasizes the need for community, co-operation, and connection towards an ecologically determined extended system. Social initiatives trigger symbiotic relationships and multiple mechanisms through which the partners connect and develop mutually beneficial relationships. Viewed through the perspective of supply chains, the concept of industrial symbiosis requires supply chain participants to improve their coordination mechanisms, which results in exceptional environmental benefits. Industrial symbiosis effectively improves the competitiveness of an enterprise and its supply chain in terms of cost reduction and improved environmental performance through promoting, creating, and exchanging knowledge among the participants in the supply chain network, as well as through improved supply chain configurations due to the application of the industrial symbiosis principles.

In the case of industrial symbiosis, the interaction between the supply chain participants largely depends on social, information, technological, economic and political factors (Costa &Ferrao, 2010).

The circular economy can be defined as a production and consumption model involving sharing, leasing, reusing, repairing, refurbishing, and recycling materials and products, thereby minimizing waste. Industrial symbiosis is a form of circular economy where exchanges of waste, by-products, or other resources between enterprises generate competitive advantages (International Labour Organization, 2022).

In December 2019, the European administration has presented the Green Agenda – a new developmental strategy with the goal of transforming the European Union into a fair and prosperous society, with a modern, resource-efficient and competitive economy, which will contribute to the complete reduction of greenhouse gas emissions until 2050 and in which economic growth is not linked to the exploitation of resources. Accordingly, concrete measures related to the areas of climate, energy, circular economy, construction, mobility, agriculture, sustainable food chains, biodiversity, and naturalization of pollution were proposed.

Cleaner technologies, innovations and research on GHG reductions are the top priorities of the European Commission, along with the ambition to turn Europe into the global leader in circular economy. In March 2020, the European Green Deal offered a new Circular Economy Action Plan focusing on the sustainable use of resources in the textile industry and construction (Ministry of Environmental Protection, 2020).

The following are the key relevant policies of the EU (Ministry of Environmental Protection, 2020).

- Towards a circular economy: A zero waste programme for Europe (2014) – The document sets up a joint coherent framework for the EU to promote circular economy, which includes: establishing a framework for policy creation; changing the waste management policies, increasing recycling, and preventing the loss of valuable materials; creating business opportunities, investments, and economic conditions for the implementation of circular economy; new business models, design, and industrial symbiosis to achieve zero waste (European Commission, 2014).
- Closing the loop – An EU action plan for the Circular Economy (2015) – Contains 54 measures for the sectors of manufacturing, consumption, waste management, and new markets (European Commission, 2015).
- A renewed EU Industrial Policy Strategy (2017) – The EU Industrial Policy aims to establish an enabling environment for industrial competitiveness. It is also integrated in many other

EU policies. The EU Industrial Policy particularly focuses on: faster industrial adaptation to the structural changes; creation of an enabling environment for initiatives and company development in the EU, with a special emphasis on SMEs; encouraging cooperation between companies; and improved use of the industrial potential offered by innovations, research, and technological development (European Commission, 2017).

- Monitoring Framework on progress towards a circular economy – The indicators established in this document refer to: production and consumption (resource independence, green public procurement, waste generation, food waste); waste management (overall recycling rate, recycling of special waste flows); use of secondary raw materials; competitiveness and inventiveness; and global sustainability and resilience (Eurostat database, n.d.).
- Clean Energy for All Europeans (2019) – This package of measures proposes a new framework to step up, transform, and consolidate the energy transition, which will result in energy independence. By ratifying the Paris Agreement, the EU aims to produce clean energy based on the new business models (European Commission. Directorate-General for Energy, 2019).
- Report on the implementation of the Circular Economy Action Plan – Contains detailed references to all activities implemented between 2015 and 2018. It is expected that by 2030 there will be visible results in the context of the new economic model (European Commission, 2019).

CASE STUDY IN SOUTH-EAST SERBIA

Description of the technological process of phosphoric acid production from the aspect of eco-industrial symbiosis network

Since its founding, the chemical industry in Prahovo has been conceived as a succession of the technological chain of copper production in the Mining and Smelting Basin Bor. By using sulphuric acid, which is generated as a by-product from the smelter in the Mining and Smelting Basin Bor, the cycle of industrial substances has been closed and the first step towards eco-industrial networking has been made. The entire quantity of sulphuric acid produced in the copper mining and smelting complex located in Bor can be used owing to the production capacity of the phosphoric acid production plant. This approach has reduced sulphur dioxide emissions in the air and enabled the use of sulphuric acid as a by-product in the technological process of smelting and refining copper in the production of phosphoric acid.

In the production sector of the Industry of Chemical Products (IHP) Elixir Prahovo, the technological chain starts with the production of phosphoric acid, which is the main component for producing mineral fertilizers, mineral nutrients, additives in the food industry, etc. The production capacity of the phosphoric acid factory is 180,000 t/year.

Phosphoric acid is an inorganic (mineral) acid with the chemical formula H_3PO_4. In practice, it is commonly expressed in the form of its anhydride P_2O_5. It belongs to the medium strong acids and is obtained in the reaction of phosphate ore and sulphuric acid.

Decomposition of crude phosphates with sulphuric acid by extraction yields phosphoric acid (with 27-28% of P_2O_5) and calcium salts in dihydrate form, which emerge as a by-product (insoluble calcium sulphate). It is an exothermic reaction which takes place in the reactor accompanied by powerful stirring and cooling.

By filtration, on a rotary drum vacuum filter, the phosphoric acid, which contains 27-28% of P_2O_5, is transported by the pipeline system to a phosphoric acid storage site. Calcium sulphate (phosphogypsum), a by-product in the technological process of phosphoric acid production, is separated on a rotary filter, and then deposited on a pre-prepared site using a hydro-mixture (suspension). Depending on the percentage of calcium in phosphate, the amount of obtained phosphogypsum per ton of P_2O_5 is 5 to 5.5 tonnes. It can be further used in the construction and cement industry, but the problem related to its usage pertains to its quantities, since the amounts produced far exceed the quantities that could be simultaneously used in industry. Compared to the current production of phosphoric acid of 120,000 t/year, the phosphoric acid production plant in IHP Elixir Prahovo produces 660,000 tonnes of phosphogypsum. A quarter of the annual production of this by-product is sold to cement factories in Serbia for the production of cement.

Due to a low percentage of active substance P_2O_5, which is only 27-28%, phosphoric acid is further evaporated to reach a concentration of about 50-54% of P_2O_5 after filtration. During the evaporation, gases that contain fluorine are released. The gas is absorbed in the devices known as absorbers, and it forms fluorosilicic acid (H_2SiF_6), which is also a by-product of the reaction, i.e. the evaporation process. The absorption of fluorine is carried out by counter current air-water flow. The gas consists of water vapour and fluorine, whereas the presence of other chemical elements is negligible. The water in the absorber is discharged through nozzles in order to maintain greater gas/liquid contacting surface, and therefore better absorption.

Fluorosilicic acid is a weak acid, corrosive to metals and very aggressive to silicon-containing substances (such as sand, concrete, glass, etc.). The amount of fluorosilicic acid obtained per ton of P_2O_5 depends on the percentage of fluorine in phosphate, its distribution and the efficiency of the absorber, but it usually ranges from 120 to 180 kg. The obtained H_2SiF_6 acid is in the form of a 18-24% solution and is stored in storage tanks, where it is further valorised to produce aluminium-fluoride, which is a new product. Aluminium-fluoride (AlF_3) is an inorganic compound used in the production of aluminium and as a means of reducing electricity consumption.

CONCLUSION

Due to the existing infrastructure, current business models, and technology, as well as due to the grounded behaviour, the economy becomes 'trapped' in the linear business model. Industrial symbiosis accelerates the development of the economy moving it from a linear to a circular model; however, business entities lack the information and the capacities to accept the solutions provided by circular economy (European Environment Agency, 2016). Instead of relying on solutions focused on the use value of products, circular economy eliminates waste at the design stage and fosters innovations throughout the life cycle of the product.

This paper explained the mechanisms for establishing a collaboration between industries and provided an overview of the diverse factors that could influence the synergy between the industries to a lesser or greater extent. In the example of phosphoric acid production, the partners have created mutual agreements for several reasons: lower prices of potential raw materials, minimization of storage costs of by-products, and greater environmental responsibility.

The provided example has given the following advantages:

- Emissions of polluting substances have been reduced; therefore, water pollution and emissions of harmful gases have also been reduced.
- The use of secondary materials has been increased; therefore, storage costs have been cut down and by-products have been used as material inputs, which reduced the need for natural resources.

Development of the described business model significantly contributes to the zero-waste concept, while the practical example of the collaboration of participants within the chain of eco-industrial symbiosis can promote the emergence of industrial clusters whose target would be the exchange and use of by-products as a valuable raw material for another production process.

REFERENCES

Bansal, P., & McKnight, B. (2009). Looking forward, pushing back and peering sideways: analyzing the sustainability of industrial symbiosis. *Journal of Supply Chain Management, 45*, 26-37. https://doi.org/10.1111/j.1745-493X.2009.03174.x

Chertow, M. (2000). Industrial symbiosis: literature and taxonomy. *Annual Review of Energy and Environment*, *25*, 313-337.

Chertow, M. R. (2007). "Uncovering" industrial symbiosis. *Journal of Industrial Ecology*, *11*, 11-30. https://doi.org/10.1162/jiec.2007.1110

Chertow, M., & Ehrenfeld, J. (2012). Organizing self-organizing systems. *Journal of Industrial Ecology*, *16*, 13-27. https://doi.org/10.1111/j.1530-9290.2011.00450.x

Costa, I., & Ferrao, P. (2010). A case study of industrial symbiosis development using a middle-out approach. *Journal of Cleaner Production*, *18*, 984-992. https://doi.org/10.1016/j.jclepro.2010.03.007

Despeisse M., Ball, P.D., Evans, S., & Levers, A. (2012). Industrial ecology at factory level – a conceptual model. *Journal of Cleaner Production*, *31*, 30–39.

European Environment Agency. (2016). *Circular economy in Europe Developing the knowledge base* (Report No. 2). https://www.eea.europa.eu/publications/circular-economy-in-europe

European Commission. (2014). *Communication from the commission to the European parliament, the council, the European economic and social committee and the committee of the regions - Towards a circular economy: A zero waste programme for Europe*.

https://eur-lex.europa.eu/resource.html?uri=cellar:50edd1fd-01ec-11e4-831f-01aa75ed71a1.0001.01/DOC_1&format=PDF

European Commission. (2015). *Communication from the commission to the European parliament, the council, the European economic and social committee and the committee of the regions – Closing the loop – An EU action plan for the Circular Economy*.

https://eur-lex.europa.eu/resource.html?uri=cellar:8a8ef5e8-99a0-11e5-b3b7-01aa75ed71a1.0012.02/DOC_1&format=PDF

European Commission. (2017). *Communication from the commission to the European parliament, the council, the European economic and social committee, the committee of the regions and the European investment bank - Investing in a smart, innovative and sustainable Industry A renewed EU Industrial Policy Strategy.*

https://eur-lex.europa.eu/resource.html?uri=cellar:c8b9aac5-9861-11e7-b92d-01aa75ed71a1.0001.02/DOC_1&format=PDF

European Commission. Directorate-General for Energy (2019). *Clean energy for all Europeans*. https://data.europa.eu/doi/10.2833/9937

Eurostat database. (n.d.). *Circular economy, EU monitoring framework*.

https://ec.europa.eu/eurostat/web/circular-economy/monitoring-framework

European Commission (2019). *Report from the commission to the European parliament, the council, the European economic and social committee and the committee of the regions on the implementation of the Circular Economy.* https://commission.europa.eu/system/files/2019-03/report_implementation_circular_economy_action_plan.pdf

International Labour Organization. (2022). *Industrial symbiosis networks as part of a circular economy: Employment effects in some industrializing countries*. https://www.ilo.org/wcmsp5/groups/public/---dgreports/---inst/documents/briefingnote/wcms_844753.pdf

Leigh, M., & Li, X. (2015). Industrial ecology, industrial symbiosis and supply chain environmental sustainability: a case study of a large UK distributor. *Journal of Cleaner Production*, *106*, 632-643.

Lombardi, D. R., & Laybourn, P. (2012). Redefining industrial symbiosis. *Journal of Industrial Ecology*, *16*, 28-37.

https://doi.org/10.1111/j.1530-9290.2011.00444.x

Luković, A. (2016). *Development of an eco-industrial network-based model for managing industrial waste flow*. [Doctoral dissertation]. University of Niš.

Ministry of Environmental Protection. (2020). *Roadmap for circular economy in Serbia.* https://circulareconomy.europa.eu/platform/sites/default/files/roadmap-for-circular-economy-in-serbia.pdf

20th International Conference Man and Working Environment
SEMSIE
Safety Engineering & Management – Science, Industry, Education

www.znrfak.ni.ac.rs/semsie

STANKO PAVLOVIĆ [1]
JUGOSLAV ILIĆ [2]
DEJAN IVANOVIĆ [3]
EVICA JOVANOVIĆ [4]

[1,2,3] NIS - Petroleum Industry of Serbia
[4]University of Niš,
Faculty of Occupational Safety

[1]stanko.pavlovic@nis.rs
[2]jugoslav.ilic@nis.rs
[3]dejan.ivanovic@nis.rs
[4]evica.jovanovic@znrfak.ni.ac.rs

HUMAN ERROR ANALYSIS IN A PERMIT-TO-WORK SYSTEM: A CASE STUDY OF PANČEVO OIL REFINERY

Abstract: *Human Error Analysis (HEA) is a significant part of the assessment of systemic risk, because if the error is omitted, it will not be considered, and the results can seriously underestimate the effect of human error on the observed system. Therefore, it is necessary to consider the following groups of errors at each step in the procedure of defining and analyzing activities or tasks: error of omission, error of commission, and error of incorrect execution. The aim of this paper is the practical application of the Absolute Probability Judgement (APJ) method for the analysis of human errors in the system of permits to work in Pančevo Oil Refinery which is managed by NIS (Petroleum Industry of Serbia). For the quantification of Human Error Probability (HEP), identified in the specific scenario, individual assessments of 6 experts were used. Experts are competent in the field of process safety and occupational health and safety and have over 20 years of work experience in NIS. Based on the results of the research, we came to the conclusion that the continuous improvement and updating of procedures, normative documents, and the implementation of training sessions will certainly reduce the likelihood of error and increase the reliability of operators and the awareness of employees about safety and protection at work in the process industry.*

Keywords: Human Error, Human Error Probability (HEP), Permit to Work (PTW), High-risk Work Activities, Absolute Probability Judgement (APJ).

INTRODUCTION

NIS GROUP is one of the largest vertically integrated energy systems in Southeast Europe, whose main activities are exploration, production, and refining of oil and natural gas, sales of a wide range of oil and gas products, as well as implementation of projects in the areas of energy and petrochemistry. Over the past 30 years, the 100 largest accidents in chemical and hydrocarbon processing plants have seriously injured or killed hundreds of people, polluted the environment, and caused more than USD 8 billion in property damage (API 770, 2001). Human errors have either directly caused or significantly contributed to many major accidents in the process industry. Therefore, more and more attention is paid to the identification of causes and possible consequences caused by human error, as well as to the quantification of Human Error Probability (HEP) by applying methods for human reliability assessment.

The common term "Human Error" has been defined by Swain (Swain, 1989) as "a member of a set of human actions that exceeds some limit of acceptability, i.e. an out-of-tolerance action (or failure to act) where the limits of performance are defined by the system". According to the traditional approach, human error is considered to be the cause of accidents and failure in the functioning of the system. In contrast, the modern approach indicates that human error reflects deeper issues within the system, mainly of relations between people, tools, tasks, and the work environment (Dekker, 2002; Dekker, et al., 2010). Therefore, most researchers dealing with the issue of human reliability assessment agree that human errors are a specific result of their actions or characteristics. Operator performance depends on many factors called Performance Shaping Factors (PSFs). Performance Shaping Factors are factors that influence human behaviour and decision-making. As human error is one of the manifestations of human behaviour, PSFs are also considered possible causes of errors. Therefore, PSFs can affect both the increase and the decrease of HEP, depending on the individual characteristics of the person, the environment, the organization at work, the complexity of the tasks, etc. Typical performance shaping factors used in the analysis of human errors are (Stojiljković, 2017): time load or stress level, quality of information, type/quality of procedure, consequences visible to the eye of the operator, level of complexity of the task, experience of the operator, teamwork, training, etc.

Human Reliability Assessment is one of the significant segments in the assessment of systemic risk and risk management. Therefore, it is necessary to consider the following groups of errors in the analysis of human reliability at each step, especially in the procedure of defining and analyzing activities or tasks (Stojiljković, 2020):

- *error of omission,* the action is not performed (non-implementation of an appropriate decision, e.g. omitted, non-performed action);
- *error of commission,* the action is performed inadequately (incomplete or inadequate execution of the decision, when the action was performed in the wrong sequence or too early or too late);
- *error of incorrect execution,* where activities are executed incorrectly (incorrect implementation of decisions).

This is a heuristic classification system of human error division, which has been developed through the experience and expertise of many researchers in the field of human reliability and systems. This division is not based on theoretical approaches, but it is derived from the study of various technological systems, i.e. from practical analyses.

However, in the literature we often encounter the following taxonomy of human errors (Stojiljković, 2020):

•*Meister's classification:*
- an error of omission;
- an error of commission;
- implementing the correct action in the wrong order or moment.

• *SRK (Skill-Rule-Knowledge)* – distinguishes errors according to the behaviour based on:
- skills: routine activities in known circumstances;
- rules: incorrect or inadequate application of problem-solving rules;
- knowledge: understanding the newly arising situation or making difficult decisions.

•*SLMV (Slips, Lapses, Mistakes, Violations):*
- slips: unintentionally and incorrectly performed actions;
- lapses: a consequence of a lack of concentration or an external factor;
- mistakes (misunderstandings): wrong actions performed correctly;
- violations: intentional implementation of the wrong action.

In the analysis of errors, in addition to the previously mentioned classifications, it is necessary to analyse organizational and socio-technical errors. Organisational and socio-technical errors make the following group of errors that are important for human reliability assessment (Stojiljković, 2020):
- increase in the tendency to avoid responding to emergencies;
- decline in the will to make decisions;
- formulation of a higher number of global hypotheses;
- difficulties in analyzing the exponential development of the accident, etc.

Socio-technical errors are very difficult to predict, but they can happen in reality. Currently, the best way to deal with socio-technical errors at the qualitative level is to develop a well-organized operational and security structure, while avoiding prejudices or patterned behaviour. In contrast, the best way to deal with them on a quantitative level is to introduce a certain level of caution in each diagnosis assessment. Errors that must also be properly classified are those that affect the organization, especially in high-risk systems.

The aim of this paper is the practical application of the Absolute Probability Judgement (APJ) method for the analysis of human errors in the scenario of "Issuance of a Permit to Work for High-Risk Work Activities" in NIS – Pančevo Oil Refinery.

METHODOLOGY

According to its concept, Absolute Probability Judgement is the simplest approach to quantifying human reliability, because it is based on the assumption that experts can directly assess the probability of human error. The procedure for APJ consists of the following steps (Stojiljković, 2020):

The selection of experts in the specific scenario is carried out in accordance with their competence in the field of process safety and occupational safety and health, and they should have 10 years of work experience in the company. During the expert group meeting, a coordinator is hired to organize and lead the meetings, but without the authority to make any quantitative assessments.

The definition of tasks is the first critical point in the implementation of the APJ procedure because if the tasks are vaguely defined, a larger space for individual interpretation by the experts performing the assessment is opened. In addition to the general methodological assumptions for a valid definition of tasks (level of detail, degree of clarity, valid assumptions about possible errors, etc.), it is necessary to pay attention to the adequate definition of performance design factors, clear separation of tasks that are similar to the tasks being assessed and defining the affiliation of the assessed task to the general group of tasks.

The development of the assessment tools – assessment scales should be sufficiently detailed to provide experts with the opportunity to adequately define the levels of probability in different sectors of human activity.

Obtaining the assessment is done on the basis of methods from individual to group *HEP* assessments. All expert assessments should be presented in tabular format and converted into logarithmic equivalents.

Checking the validity of the individual assessment is based on the use of the technique of Analysis of Variance – ANOVA and includes the following (Stojiljković, 2020):
- calculation of the sum of the columns (n),
- calculation of the sum of rows (m),
- calculation of the total sum (T),
- calculation of the permanent correction (C),
- calculation of the sum of squares (x^2),
- calculation of the total sum of squares (TSS),
- calculation of the sum of the squares of the

columns (t^2),
- calculation of the sum of the squares of the rows (r^2),
- calculation of the sum of the squares of the residues (OS),
- determination of the degree of freedom (df),
- assessment of variations,
- calculation of the F quotient,
- determination of the correlation coefficient (K).

Aggregation of the individual assessment is performed after the confirmation of the agreement in the expert opinion by statistically processing the arithmetic means of valid individual assessments.

Uncertainty-bound estimation is performed using the following expression (Stojiljković, 2020):

$$\log HEP \pm 2s.e \quad (1)$$

$$s.e = \left(\sqrt{\frac{V(\log HEP_i)}{m}} \right) \quad (2)$$

$$V(\log HEP_i) = \frac{\left[m \sum_{j=1}^{m} (\log HEP_{ij})^2 \right] - \left[\sum_{j=1}^{m} (\log HEP_{ij})^2 \right]}{m(n-1)} \quad (3)$$

where: $s.e$ - standard error, m - number of experts, n - number of errors/events/tasks.

RESULT AND DISCUSSION

Due to the frequent errors of the process staff and the employees of the contractors when performing high-risk activities, we recognized the need to apply the method for the quantification of human errors in order to manage them. The analysis of human errors, as well as their quantification, was carried out on the task of "Issuance of a Permit to Work for High-Risk Work Activities" in Pančevo Oil Refinery.

High-risk work activities pose a potential threat, i.e. the occurrence of hazards that can lead to immediate negative consequences for the health and safety of employees (multiple injuries at work, injuries at work with a fatal outcome, disability, damage to work equipment, environmental pollution, etc.). A permit to work (PTW) is an instrument for managing high-risk work activities and aims to ensure the existence of an appropriate system of control of recognized risks that occur when performing high-risk work activities and controlling recognized risks. In addition, the PTW is a means of communication between the responsible persons and the contractors, ensuring the control of the safe manner of performing high-risk activities and the creation of conditions for the contractor to clearly understand the measures to be applied in order to prevent adverse events before, during, and after performing high-risk work activities. The PTW is issued for one working day (one work shift/maximum 12 hours), with the possibility of extending its validity, provided that there has been no change in the conditions that existed at the time of issuance of the PTW, in accordance with the procedure for "Daily Conclusion and Extension of the PTW" (UP-09.01.14-010).

The human reliability assessment on a specific case in NIS – Pančevo Oil Refinery includes five basic tasks according to the "plan-do-check-act" (PDCA) principle (Figure 1):

1. Analysis of the activities and tasks during the issuance of the permit to work;
2. Investigation of Health, Safety and Environment Events – HSE Events and analysis of the basic, immediate, and systemic causes of the event;
3. Hierarchical Task Analysis – HTA and identification of possible human errors by type of activity;
4. Application of the APJ method for the quantification of human errors;
5. Mitigation of human errors (development of an action plan and definition of prevention measures and recommendations for the elimination of key identified errors).

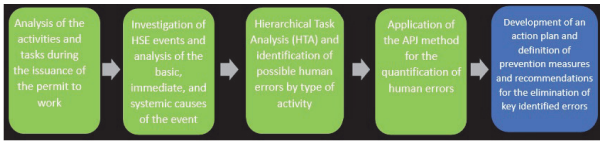


Figure 1. *The process of analyzing human errors in NIS (Pavlović, 2023).*

Analysis of activities and tasks performed by employees according to the Responsible, Accountable, Consulted, Informed – RACI matrix: Responsible (R) for the execution of the task, Accountable (A) for decision-making, Consulted (C), Informed (I), in order to perform the safe implementation of high-risk activities through the application of the PTW system, refers to:

1. Recognition of high-risk activities in the proposed works;
2. Initiation of the PTW;
3. Issuance of PTW;
4. Execution of works described in the Permit to Work;
5. Closing of the PTW.

The tasks, activities, and conditions to be fulfilled to ensure risk management, in the phase of recognizing high-risk activities in the proposed works when issuing the PTW, are as follows:

- Approval of the work order in the CMMS (Computerised Maintenance Management System);
- Risk analysis in the JSA (Job Safety Analysis) system.

The second step in the analysis and assessment of human errors refers to the reporting of all HSE Events and the creation of an event database regardless of the level of the event. HSE Events are classified in accordance with KT-09.01.16: HSE Event Classifier and investigated based on the Instructions for Investigating the Causes of an HSE Event (UP-09.01.15-001). The entire process of investigating HSE events is documented in the record of HSE event

investigation. The HSE event investigation identifies the immediate, underlying, and systemic causes of the event. Human actions and equipment failures/malfunctions that can result in an accident (adverse event) are analysed.

The next step in the human reliability assessment is HTA by workplace, as well as the identification and classification of errors in the activities performed by employees when issuing a permit to work for high-risk work activities.

With a detailed analysis, we identified human errors by type of activity:

- Sequence: Wrong order; Skipped step.
- Action: Skipped Action; Incomplete Action; Wrong Action on the Right Facility; Wrong Action on the Wrong Facility; Right Action on the Wrong Facility; Too Large or Too Small Action; Too Long or Too Short Action; Action at the Wrong Time; Action in the Wrong Direction.
- Communication: Information not Received; Incorrect Information Received; Incomplete Information Received.
- Monitoring: Monitoring is not Conducted (Skipped); Monitoring Incomplete; Correct Check on the Wrong Facility; Incorrect Check on the Correct Facility.
- Decision: Skipped Decision; Wrong decision.

The key human errors that have a direct impact on the HSE event in the case study presented in this paper are the following:

1. Non-recognition of risks based on defined types and scope of works,
2. Not all measures that are necessary to control the risk have been identified,
3. Not all prescribed measures have been checked (at the physical location),
4. Failure of the contractor to comply with the prescribed measures during the execution of works,
5. Prescribed personal protective equipment is not used in the right manner,

After the identification of human errors using the APJ, they were quantified. The quantification of key human errors was carried out by 6 experts on the basis of 3,000 permits to work issued over a period of 3 years in Pančevo Oil Refinery. Figure 2 shows the values of the probabilities of identified human errors for the investigated case.

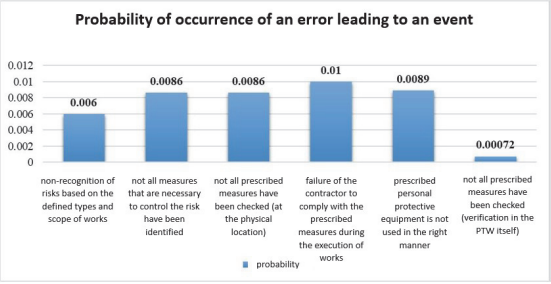


Figure 2. *The HEP values were obtained by applying the APJ method (Pavlović, 2023).*

As can be seen from the figure, human error in the system of performing high-risk work activities, which has the highest probability is "failure of the contractor to comply with the prescribed measures during the execution of works" (0.01), it is followed by: "prescribed personal protective equipment is not used in the right manner" (0.00089), "not all prescribed measures have been checked (at the physical location)", and "not all measures that are necessary to control the risk have been identified" (0.0086), "non-recognition of risks based on the defined types and scope of works" (0.006), while the error "not all prescribed measures have been checked (verification in the PTW itself)" (0.00072) has the lowest probability.

After the quantification of human errors, preventive and corrective measures are defined with the aim of minimizing errors or mitigating human error. The following table provides an example of control measures for different types of errors (API 770).

Table 1. *Example of control measures (API 770)*

	Eliminate	**Prevent**	**Reduce**	**Mitigate**
Error	Competence assurance	Communication of the Convention	Software interface logic and layout	Engineering controls
Action omission	Design for tactile differentiation	Urgently confirm action	Training for error management	Engineering controls
Memory lapse	Control checklists	Independent check	Warning / Alarm	Engineering controls

For the case study presented in this paper, the experts have formulated preventive, corrective measures and recommendations for activities that have a large and medium level of HEP. Recommendations for the reduction of high risks, based on the results of the conducted APJ analysis, are included in the action plan with the implementation period not exceeding five years. The Client, with the help of the coordinator, prepares an Action Plan, in which the responsible person, the deadline for implementation, and the level of priority are defined for each of the stated prevention measures and recommendations. The Client submits the Action Plan to the coordinator and the persons responsible for the implementation of the activities for providing their agreement and signing, and then for approval as well.

When drafting the Action Plan, it is possible to replace one of the initially proposed recommendations with another, if that recommendation has the same effect on the identified risks (i.e. has the same ALARP level).

Responsible persons implement individual measures from the action plan while their managers control the implementation of the proposed measures. The risk owner monitors the time schedule of the implementation of all measures from the Action Plan. In case of exceeding the deadline for a specific measure, the risk owner shall contact the manager of the person responsible for implementing the certain measure. Through the HSEnet application (software solution for keeping archives in the field of HSE), the record keeper enters the recommended measures as well as the responsible persons and the deadlines for

implementation. The person responsible for implementing the activities defined in the Action Plan shall submit to the risk owner, by e-mail, the proof of implementing the appropriate activities. In the case that the risk owner is satisfied with the submitted proofs of implementation, the activities shall be closed, while in the case that the risk owner is not satisfied with the submitted proofs of implementation, the activity shall continue.

In addition, metrics as performance indicators can be used to achieve the desired safety goal. Key metrics are a form of active monitoring of several critical risk control systems to ensure their continued effectiveness. They require a systematic check to ascertain whether key actions or activities are being carried out as prescribed.

CONCLUSION

The human reliability assessment is an important step in the management of human errors and the reduction of systemic risk to an acceptable level. We applied the APJ method for the quantification of human errors when performing high-risk activities by applying the permit-to-work system implemented in NIS – Pančevo Oil Refinery. The quantification of key human errors was carried out by six experts on the basis of 3,000 permits to work issued over a period of 3 years. Based on the key categories of errors that lead to the unsafe implementation of operator activities, the team of experts has defined the description of errors in order to facilitate the definition of preventive and corrective measures, with the aim of reducing risks and avoiding the repetition of the same errors and/or the same or similar HSE events in the future. Based on all points presented in this paper, we can conclude that the continuous improvement and updating of procedures, normative documents, and the implementation of training sessions will certainly reduce the likelihood of error, and also increase the employees' awareness of the safety of the process.

Hazard and risk analyses, safety examinations, and inspection programs help detect human errors in the design, construction, installation, modification, and maintenance of process equipment before such errors cause a process disruption or accident. Human factors engineering, analysis, and assessment of human reliability can greatly contribute to the safety and security of the process by identifying activities with a high probability of error that should be corrected. The inclusion of well-defined human factor engineering principles in equipment design and operating procedures will help reduce the frequency of errors and will help to detect and correct them in time – before the system suffers adverse consequences.

ACKNOWLEDGEMENTS

Part of the research presented in this paper was conducted within the OMS project 2022-OMS-REF-02-01, sponsored by NIS j.s.c. FHSE. This paper is supported by the Ministry of Science, Technological Development, and Innovations, contract no. 451-03-47/2023-01/ 200148.

REFERENCES

API 770. (2001). *Manager's Guide to Reducing Human Errors*.

Dekker, S. (2002). Reconstructing Human Contributions to Accidents: The New View on Error and Performance, *Journal of Safety Research*, 33, 371-385. https://doi.org/10.1016/s0022-4375(02)00032-4

Dekker, S., Cook, R. I., Johannesen, L., Sarter, N., & Woods, D. D. (2010). *Behind Human Error*. Farnham: Ashgate Publishing Ltd.

Pavlović, S. (2023). *Quantification of Human Errors in NIS – Pančevo Oil Refinery*. [Master Thesis, Faculty of Occupational Safety] (in Serbian: Kvantifikacija ljudskih grešaka u kompaniji NIS – Rafinerija nafte Pančevo).

Reason, J. (1990). *Human Error*. Cambridge: Cambridge University Press.

SA-09.01.14-030. *Permit to Work for Works in High-Voltage Plants, Works Near High-Voltage Transmission Lines, and Works on Live Installations and Equipment (High and Low Voltage) at NIS* (in Serbian).

SA-09.01.14-086. *Extension of the PTW in NIS* (in Serbian).

SA-09.01.14-087. *List of Persons Performing Works in NIS* (in Serbian).

SA-09.01.21-010. *HSE Activity Plan in NIS* (in Serbian).

SD-09.01.14. *HSE Risk Management* (in Serbian).

SD-09.01.21. *Contractors Management in NIS* (in Serbian).

UP-09.01.14-010. *Instructions for the System of Permits to Work for High-Risk Activities in NIS* (in Serbian).

UP-09.01.15-001. *Instructions for Investigating the Causes of HSE Events* (in Serbian).

Stojiljković, E. (2017). Knowledge Management for the Purpose of Human Error Reduction. Proceedings from M&S 2017 (CD1): *12th International Conference Management and Safety (Neum and Mostar, Bosnia and Herzegovina, 9-10. june 2017.)*, Čakovec, Croatia: The European Society of Safety Engineers, pp. 1-8 (Invited lecture paper).

Stojiljković, E. (2020). *Human Reliability Assessment*. Niš: University of Niš, Faculty of Occupational Safety (in Serbian).

Swain, A. D. (1989). *Comparative Evaluation of Methods for Human Reliability Analysis*. GRS-71, Gesellschaft fur Reaktor Sicherheit, GRSmbH, Koln, Germany.

20th International Conference Man and Working Environment
SEMSIE
Safety Engineering & Management – Science, Industry, Education
www.znrfak.ni.ac.rs/semsie

RADOMIR NIKOLIĆ[1]
PETAR RADONJIĆ[2]

[1,2]Fluoelektro d.o.o.

[1]*info@fluoelektro.com*
[2]*petar@fluoelektro.com*

THE IMPACT OF ARTIFICIAL LIGHTING ON RISK ASSESSMENT AND EMPLOYEE SAFETY AND HEALTH

Abstract: *Certain solutions presented in this paper can be applied in the process of risk assessment stemming from hazards in workplaces and work environments. Enhancing risk assessment and evaluating the risks associated with all factors arising from artificial lighting would contribute to the improvement of the risk assessment methodology, aiming for a more comprehensive assessment of the risks originating from all dimensions of artificial illumination, which can pose hazards and threats in the workplace and work environment. Improving the assessment of risks stemming from artificial lighting would enable employers to better manage the occupational health and safety system on one hand, and on the other, it would impact the occupational health and safety of employees, ultimately reflecting positively on the productivity and profit of employers.*

Keywords: Artificial lighting, workplace, work environment, risk assessment, safety.

INTRODUCTION

The risk assessment of artificial lighting is carried out through appropriate methods prescribed by domestic and international regulations. Previous experiences regarding the risk assessment process have shown certain shortcomings that, due to inadequate procedures during risk assessment, have led to a significant number of cases where all elements of illumination were not considered. The risk assessment of the five main illumination parameters, which, as physical hazards, are essential for achieving a safe work environment, was not conducted (Encyclopaedia of Occupational Health and Safety, 1972).

The five main parameters must be understood to comprehend illumination. These are luminous flux, luminous intensity, illuminance, brightness, and contrast.

Luminous intensity of the source is the mean value of the luminous flux per unit solid angle. The unit is candela (Cd), symbolized by I.

Illuminance is determined as the quotient of luminous flux and the area it falls upon, with the unit lux (Lx), equivalent to 1 lm/m^2, denoted as E.

Brightness is the luminous flux reflected from a surface. The unit is candela per square meter (Cd/m^2), denoted by L.

Contrast is the difference in brightness between an object and the surface it lies on. The symbol is C. Contrast is a dimensionless number with a value between 0 and 1. Example: When the surface on which an object lies has a brightness of L1 and the object has a brightness of L2, where (L1 > L2), it can be expressed as C = (L1 - L2)/L1. Encyclopedia of occupational health and safety. International labor office Geneva 1971-1972 CTP962.

Due to the aforementioned procedure used for risk assessment and inadequate data, it was not possible to implement adequate preventive measures to reduce the hazards and harmful effects stemming from artificial lighting. Illumination is one of the input elements in the technological system, which, together with other input elements comprising the technological system, due to its physical properties, plays a significant role in achieving occupational health and safety. Presenting certain solutions to improve the risk assessment process stemming from artificial lighting aims to encourage manufacturers of artificial lighting sources, lighting system designers, and employers to recognize their interests in their respective domains, to enhance occupational health and safety on one hand and raise productivity levels on the other. (EN 1264, Light and Lighting).

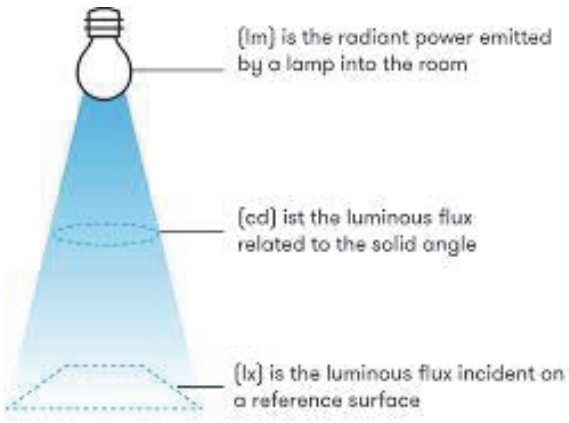


Figure 1. Lighting and parameters

LEGAL, REGULATORY, AND TECHNICAL PROVISIONS IN THE OHS SYSTEM

One of the main international legal sources that obligate employers to conduct risk assessment is

contained in the European Union Directive 89/391. The basis for conducting risk assessment in the process of risk assessment stemming from physical harm, the source of which is illumination in the workplace and work environment, is Standard SR EN 12464, International Standard EN 12464, Light, and lighting, as well as Standard SRPS BS OHSAS 18001:2008.

The basis for the development of the international standard is the British standard BS 8800, OHSAS 18001 (OHSAS 18001 - Occupational Health and Safety Assessment). The mentioned standard is built based on a large number of certified institutions and national standardization bodies from the United Kingdom, Ireland, South Africa, Spain, Malaysia, Singapore, Mexico, and others. The standard has been developed in such a way as to enable its compatibility with the standards of quality management systems ISO 9001:1994 and ISO 14001:1996 (environment). This standard does not contain specific criteria for risk assessment and does not provide detailed specifications for designing a workplace health and safety management system; instead, it is left to each country to regulate this through its legislation. It does not contain specific performance evaluation criteria, nor does it provide detailed specifications for designing health and safety management systems at work.

HAZARDS AND RISKS IN THE WORKPLACE

Determining the hazards and risks in the workplace and working environment is the most crucial phase of risk assessment and is a fundamental prerequisite for risk ranking. In specific cases where the determination of hazards and risks stemming from illumination is concerned, it is conducted based on the examination and measurement of the working environment conditions. These examinations and measurements are carried out by authorized legal entities. Subordinate regulations, such as the Regulation on the Method of Risk Assessment in the Workplace and Working Environment and the regulation on the maintenance of records on occupational health and safety, prioritize the hazards and risks in the workplace and working environment, serving as the basis for risk assessment in the workplace and working environment (Regulation on the Procedure for Examination and Verification of Work Equipment and Testing of Working Environment Conditions, 2023).

Risk assessment in the workplace and the working environment is based on identifying possible types of hazards and risks in the workplace and working environment. In the specific case of hazards and risks related to insufficient or excessive illumination as physical hazards or the harmful effects of lighting, all potential hazards from the impact of the mentioned light sources and their consideration, along with all dimensions and other sources of hazards originating from the work environment, need to be evaluated to provide a final risk assessment for the safety and health of employees in the working environment (Regulation on the Method and Procedure for Risk Assessment in the Workplace and Working Environment, 2015).

Various methods are used for risk assessment, including OHSAS, the Kinney method, the Singapore risk assessment model, the 5X5 matrix method, and the EMESA-Kinney method, especially for the assessment of risk arising from lighting hazards and risks. For risk assessment, the Kinney method's risk matrix is commonly used, where the risk is calculated using the formula R = V x P x U, where R is the risk of the occurrence of hazards and risks, V is the probability, P is the consequence that can be caused by the risk, and U is the frequency of the occurrence of hazards and risks. (Borjanovic, 20087)

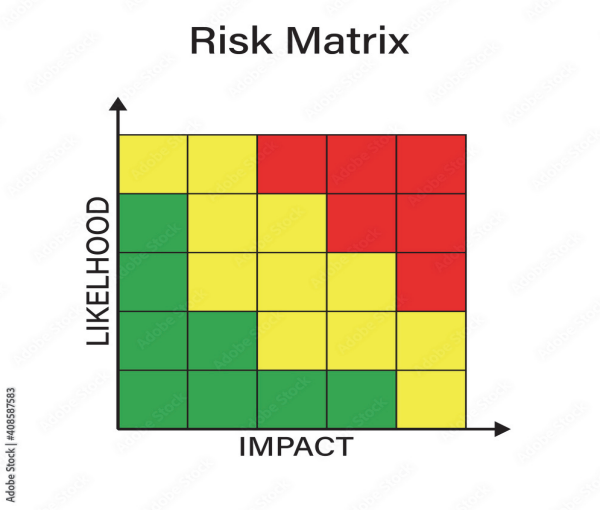


Figure 2. Risk Matric 5x5

All the mentioned risk assessment methods are insufficiently precise and possess certain elements of subjectivity since they are qualitative methods. In addition to these, assessments based on measured indicators and their comparison with the corresponding standards, Standard SRPS U.C9.100/62, International Standard EN 12464, Light and Lighting - Lighting of Workplaces provide a basis for determining the level of risk.

POOR LIGHTING AT WORKPLACE - ANALYSIS OF INDICATORS FOR RISK ASSESSMENT

The main requirement that an artificial lighting system must fulfill is to achieve good visual conditions necessary for the successful and safe execution of work tasks, ensuring a visual environment that contributes to the well-being and safety of employees within a complex work environment, preventing illness and injury.

The analysis of indicators for assessing the risk due to inadequate lighting is a key part of the EN 12464-1 standard, which focuses on the identification and assessment of potential risks that may arise from insufficient or inadequate lighting in the workplace. This analysis is crucial as it helps understand how inadequate lighting can affect work efficiency,

productivity, and, most importantly, the health and safety of employees.

The standard defines a set of indicators and methods for assessing risk, which include the following key points:

Assessment of lighting levels: Identification of minimum and optimal lighting levels required for various types of tasks and work environments, ensuring that lighting conditions are in line with standard recommendations.

Identification of risk areas: Analysis of work areas where a lack of adequate lighting may pose a risk to the safety or health of employees, including areas requiring high precision and good visibility to prevent accidents or injuries.

Determination of potential consequences: Evaluation of potential consequences of poor lighting on the health, safety, and comfort of workers, including effects on vision, possible eye strain, fatigue, headaches, and other health issues resulting from poor lighting conditions.

Recommendations for risk reduction: Based on identified risk areas and potential consequences, the standard provides recommendations and guidelines for reducing risk by adjusting lighting, including changes in the arrangement of luminaires, increasing lighting levels, or using appropriate types of luminaires.

Periodic assessment and monitoring: The standard recommends regular monitoring and assessment of lighting conditions to ensure that lighting standards are maintained over time and to adequately respond to any changes in the work environment that could affect lighting and risk to the health of employees.

This risk assessment allows companies and organizations to systematically approach the identification, evaluation, and management of risks arising from insufficient lighting in workplaces, creating safer, more productive, and healthier working environments.

The complexity of light, through the eye's visual center in the brain, not only provides information about the visual field but also affects other nervous centers, the autonomic nervous system, which, through its regulatory function, affects the overall exchange of matter in the body and the physical characteristics of humans. Optimal lighting is not only for viewing and perception but also contributes to increasing the level of work capacity and achieving an optimal visual sensation in the work environment. Good visibility prevents occasional fatigue, which affects the concentration of employees.

Inadequate lighting in the workplace and work environment can potentially be a source of illness. Additionally, the uneven lighting to which employees are exposed can cause the appearance of the stroboscopic effect, leading to a subjective optical illusion. Employees may perceive objects illuminated in such light as rotating faster or slower, or even stationary, even though they are moving. Previous research reliably demonstrates that inadequate lighting, evaluated through risk assessment, is a high-risk factor that also increases the mental and physical fatigue of employees, reduces their attention (caution), decreases work precision, and leads to the occurrence of errors at work, which, from an economic perspective, reduces the efficiency of using working time, affects the quality of performed work operations, and ultimately directly affects the productivity of employees and the profit of the employer.

The assessment of risk from the aspect of lighting quality as a result of natural and artificial lighting is carried out by the risk assessment methodology and the SRPS EN 12464-1:2021 standard, which involves determining the level of uniformity of lighting in the workplace and the work environment and qualifying the work level - risk assessment by comparing measured values with predetermined values depending on the visual requirement that requires the specificity of the technological procedure.

Based on the nature of artificial lighting, for a proper risk assessment stemming from artificial lighting, it is necessary to carry out five basic photometric quantities: average illuminance of general lighting, maximum illuminance, uniformity of illuminance, and contrast of illuminance.

Average illuminance of general lighting: This is the average value of light intensity spread over a given space. It is measured in lumens (lm) per square meter (m^2). Average illuminance is important because it affects the overall visual experience of the space. In work environments, appropriate average illuminance is essential to enable good visibility and comfort.

Maximum illuminance: This is the maximum light intensity measured in a specific part of the surface in a given space. It reflects more intense light zones and may be of importance in the context of specific tasks or activities that require additional visibility or focus.

Uniformity of illuminance: This measures how evenly the light is distributed over the surface. Achieving uniform illumination is important to avoid shadows and glare that can affect visibility and working conditions. Uniform illumination is of vital importance in environments where high visibility and precision standards are required.

Contrast of illuminance: This quantity measures the difference in light intensity between different objects or areas in space. A high contrast of illuminance can lead to visual discomfort and strain, while moderate contrast can help highlight different objects and details in the environment. The contrast of illuminance is significant in lighting design, especially when different areas of the space are used for different activities or tasks.

The evaluation of all measured quantities needs to be conducted by the aforementioned SRPS standard and EN12464 Light and lighting of work. In addition to this, for risk assessment, it is necessary to consider the light color, color rendering, color temperature, color rendering index, the appearance of the working environment (production halls), or other business premises where a technological process is conducted, as well as the distribution of glare.

Light color: Light color refers to the spectrum of light, which is measured in different wavelengths of light. Selecting the right light color is crucial in work environments as it can affect work efficiency, comfort, and the overall environment experience.

Color rendering: Color rendering refers to the ability of light to reproduce the colors of objects as closely as possible to natural sunlight. Good color rendering is important in environments where accuracy and precision in distinguishing colors are essential, such as in the graphic industry or precise work.

Color temperature: Color temperature describes the visual effect of lighting and refers to the warmth or coolness of the color emitted by the lighting. Measured in Kelvin (K), a higher color temperature indicates cooler, bluer light, while a lower color temperature indicates warmer, redder light.

Color rendering index: The color rendering index (CRI) measures how well the lighting reproduces the true colors of objects compared to sunlight. The higher the CRI value, the better the lighting reproduces the colors of objects. High CRI lights are essential in environments where distinguishing shades and color tones are crucial, such as in art studios or the fashion industry.

Appearance of the working environment: The appearance of the working environment includes all aspects of the environment that affect work efficiency, comfort, and the overall experience of the user. This concept encompasses lighting, lighting distribution, light quality, as well as other factors such as sound, temperature, and overall spatial design. A well-designed appearance of the working environment can enhance work efficiency, lead to greater comfort, and improve the overall experience of working conditions.

In the risk assessment, it is necessary to consider the impact of local lighting on the occurrence of glare, as well as the influence of luminaires where the light source is installed.

Glare, in the context of artificial light, refers to the effect of flickering or changes in light intensity in a given environment. This is often an unwanted phenomenon that can be caused by various factors such as unstable power supply, use of poor-quality lamps, or poor lighting design. Glare from artificial light can have harmful effects on human health and well-being, including eye fatigue, headaches, reduced visibility and concentration, and even long-term vision problems.

The EN 12464-1 standard is a European standard dealing with workspaces' lighting. Regarding glare, this standard provides guidelines and recommendations for reducing or preventing glare from artificial light to ensure that the lighting in the environment is stable and comfortable for workers. The standard addresses reducing lighting flicker and recommends the use of stable light sources to minimize the harmful effects of glare.

Additionally, the standard provides guidelines for the minimum requirements concerning the frequency of flicker to ensure that the light does not produce unwanted effects on people working in the environment. It also focuses on proper luminaire placement and proper maintenance of the lighting system to prevent or reduce glare.

Including guidelines for reducing glare in the EN 12464-1 standard aims to create a safer and more comfortable working environment that supports the good health and well-being of employees. Implementing the standard helps create a stable and quality lighting environment that minimizes the risks associated with glare from artificial light.

When assessing the risk, it is necessary to assess the relative spectral sensitivity of the human eye in daylight and nighttime lighting in line with the spectral luminous efficiency function of the human eye prescribed by the International Commission on Illumination (CIE). When it comes to risk assessment about relative light intensity, the visual ability of the employee should also be taken into account. This is reasonable because it is more challenging to provide ease of vision for older employees compared to younger employees. (Nikolić, Peurača, 20148)

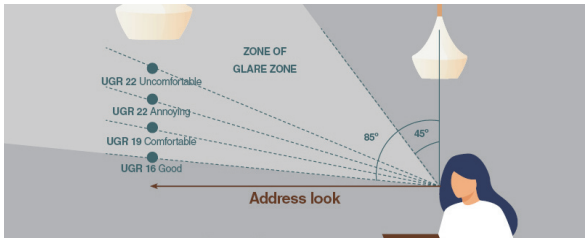


Figure 3. UGR of lighting

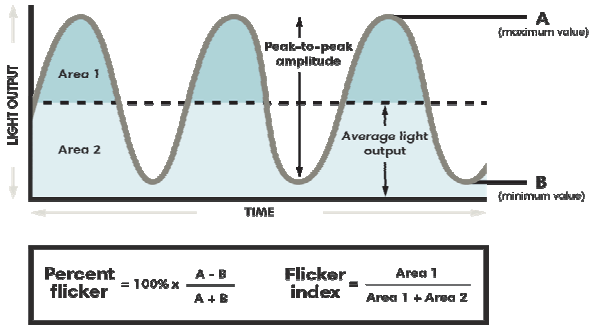


Figure 4. Flicker of lighting

THE IMPACT OF INADEQUATE LIGHTING ON PRODUCTIVITY

Inadequate lighting in the workplace and working environment can be a source of danger and harm that can have direct consequences for employees, reflecting on their lives and health, resulting in work injuries and occupational illnesses. The hazards and damages stemming from inadequate lighting have an economic nature as employees exposed to such hazards and harm lose work capacity over prolonged exposure, which, in economic terms, impacts productivity, manifested through reduced working hours, failure to meet production standards, and the production of goods of

diminished quality. The direct effect on productivity also involves the reduced number of workdays for employees due to absences from work caused by illnesses resulting from unsafe working conditions.

The above-mentioned facts contribute to economic losses, which, alongside the quality of finished products and lost profits, can directly affect an employer's competitiveness compared to other employers in the same industry. Inadequate lighting in the workplace can have significant consequences for the productivity and well-being of employees. Here is a more detailed explanation of the impact of inadequate lighting on productivity:

Reduced visibility and concentration: Insufficient lighting often results in reduced visibility in the workplace. This can hinder employees from clearly seeing details, leading to slower task performance. Additionally, reduced visibility can result in decreased concentration, as employees need to exert more effort to see what they are doing.

Eye strain and headaches: Working in conditions of poor lighting can cause eye strain, muscle tension around the eyes, and headaches. This often leads to decreased productivity as employees struggle to maintain a high level of comfort and focus throughout the workday.

Increased errors: Inadequate lighting can lead to more frequent work errors. This can be particularly problematic in situations where accuracy and precision are crucial, such as in laboratories, medical facilities, or the manufacturing industry.

Increased absenteeism and leave: Employees exposed to inadequate lighting often face health problems, including vision issues, headaches, and other symptoms. This can result in increased rates of absenteeism and leave, directly impacting productivity and the working capacity of the workforce.

Reduced product or service quality: In some industries such as manufacturing, design, photography, or medicine, color accuracy and details are critical. Poor lighting can significantly affect the quality of products or services, resulting in poor reviews, complaints, and market losses.

All of the above-mentioned factors lead to economic losses for the company. Productivity decreases due to slower work and a higher number of errors, while costs increase due to illnesses and absences from work. These economic losses can have serious consequences on the company's competitiveness in the market. Therefore, it is essential to ensure adequate lighting in the workplace to support productivity and employee well-being, as well as overall business success.

CONCLUSION

Risk assessment related to the spectrum of artificial lighting is of exceptional importance for ensuring workplace and environmental safety. The impact of lighting on the overall health and well-being of employees is often underestimated, but the reality is that it can have a significant effect on the quality of the work environment. Illumination represents a crucial parameter that directly influences the quality of the working environment and the quality of task execution in the workplace. As a result, every component of the technological system, including lighting, must meet specific quality standards to ensure the safety and well-being of employees.

Every type of lighting must be adequately assessed, including its impact on the health and safety of workers. This risk assessment plays a key role in managing workplace and environmental safety, as it enables manufacturers, designers, and users of electrical lighting to understand and identify their needs and interests in this context. By implementing best practices in this area, better technological solutions can be achieved, profits can be increased, and a safer and more comfortable working framework can be created. This not only affects the overall condition of working conditions but also contributes to increased productivity and efficiency in the workplace.

REFERENCES

Borjanovic, S. (2008). Method for Assessing Risks in the Workplace and Working Environment, Institute of Occupational Medicine Serbia "Dr. Dragomir Karajovic", Belgrade.

Directive 89/391/EEC - OSH "Framework Directive".

Encyclopaedia of Occupational Health and Safety, International Labour Office Geneve 1971-1972, p.962.

SRPS EN 12464-2:2014 Light and lighting - Lighting of workplaces.

Law on Occupational Health and Safety, Official Gazette of RS, No. 35/23.

Nikolić, R., Peurača D. (2014). Manual of Safety and Health at Work (in Serbian), Atlantis Niš.

Regulation on the Procedure for Examination and Verification of Work Equipment and Testing of Working Environment Conditions, Official Gazette of RS, No. 94/2006, 108/2006 - amended, 114/2014, 102/2015, 15/2023.

Regulation on the Method and Procedure for Risk Assessment in the Workplace and Working Environment, Official Gazette of RS, No. 72/2006, 84/2006 - amended, 30/2010, and 10/2015.

20th International Conference Man and Working Environment
SEMSIE
Safety Engineering & Management - Science, Industry, Education
20th International Conference Man and Working Environment
SEMSIE
Safety Engineering & Management - Science, Industry, Education

Sponsor Pages

Elixir Prahovo

Elixir Prahovo - 1 od 6 evropskih fabrika za proizvodnju fosforne kiseline.

Elixir Group je poslovni sistem koji se kontinuirano razvija u oblasti hemijske industrije i agrobiznisa, kroz brojne projekte posvećene održivom razvoju, primeni modela cirkularne ekonomije i unapređenju resursne efikasnosti.

Elixir Prahovo, kao 1 od 6 evropskih fabrika za proizvodnju fosforne kiseline, je najuspešnija i najbrže rastuća kompanija u regionu istočne Srbije sa više od 800 zaposlenih.

Investicije u proizvodnju fosforne kiseline i NPK đubriva, prečišćavanje fosforne kiseline, otvaranje novih pogona, ulaganje u tehnološki i infrastukturni razvoj, briga o bezbednosti, zdravlju i okruženju – su u fokusu strateškog razvoja.

Svi proizvodni procesi Elixir Prahova odvijaju se prema najvišim industrijskim standardima, sa potpuno novom opremom i u skladu sa BAT zahtevima EU u pogledu primenjenih tehnologija, zaštite životne sredine i kvaliteta proizvoda.

Planirane investicije u narednom periodu u funkciji su povećanja proizvodnih kapaciteta, viših faza prerade fosforne kiseline i primeni principa cirkularne ekonomije.

60+

Godina tradicije

300.000

Proizvodnja fosforne kiseline (t)

300.000

Proizvodnja NPK đubriva (t)

ASIP PREVENT
U bezbednom zagrljaju!

Mislimo PREVENTivno, živimo i radimo bezbedno.

ASIP Prevent

je kompanija sa sedištem u Novom Sadu,
koja pruža **širok spektar usluga u okviru 7 sektora**:

- bezbednost i zdravlje na radu,
- zaštita od požara,
- vanredne situacije,
- kontrolisanje, pregledi i ispitivanja,
- konsalting u građevinarstvu,
- koordinacija u fazi izvođenja radova i
- ASIP akademija.

Poslujemo u još 6 različitih gradova

i tako pokrivamo teritoriju cele Srbije, a zahvaljujući velikom broju službenih vozila, na upućene zahteve reagujemo brzo i efikasno.

Naš tim čini 100 iskusnih profesionalaca i mladih entuzijasta različitih profesionalnih opredeljenja, koji su okupljeni oko ideje zaštite i pružanja najkvalitetnijih usluga.

Naša vizija je
BEZBEDNO I ZDRAVO OKRUŽENJE ZA SVE ZAPOSLENE.

10
godina poslovanja

6
izdvojenih poslovnih jedinica

4000+
zadovoljnih klijenata

40+
usluga

Ivan Nikolić
063/574-159
ivan.nikolic@asip.rs

asipprevent.rs

RAZMIŠLJAJUĆI PREVENTIVNO,
POSVEĆENO BRINEMO O KVALITETU RADNOG OKRUŽENJA NAŠIH POSLOVNIH PARTNERA.

TEKSTKO NIŠ

KVALITET ISO 9001 ISO 14001

Proizvodnja i prodaja lične zaštitne opreme

SAFETY PANDA® Italian Style at work

ČERVA simply safety

COFRA® BORN TO WORK

SHOWA

eXena exclusive safety shoes

EO N

CATAMOUNT safety shoes

WELDAS®

DUNLOP PROTECTIVE FOOTWEAR

JSP® OXFORD, ENGLAND

DUPONT

3M

uvex

PROTEKT

PROFESSIONAL CLOTHING stenberg WORKING TOGETHER

PAYPER

Tekstko doo, ul. Stanoja Bunuševca 16, 18000 Niš, Srbija
office@tekstko.co.rs
Tel/fax: +38118 593 888; +381 18 593 040;

20th International Conference Man and Working Environment

SEMSIE

Safety Engineering & Management – Science, Industry, Education

20th International Conference Man and Working Environment

SEMSIE

Safety Engineering & Management – Science, Industry, Education

20th International Conference Man and Working Environment

SEMSIE

Safety Engineering & Management – Science, Industry, Education

9 788660 931155