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Maja Petrović

Ivana Mihajlović

Nevena Živančev

Bojana Zoraja

Tijana Adamov

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PREFACE

With great pleasure, I extend warm greetings on behalf of the Scientific and Organizing Committees. It is an honor to introduce the Proceedings of the 1st International EUROSA Conference held from September 12 – 15, 2023, in Brzeće, Kopaonik, Serbia.

This compilation represents the culmination of dedicated efforts and scholarly contributions from our esteemed participants. The papers contained herein encapsulate a wealth of knowledge and innovation in the field of sustainable management of occupational health and safety, environmental protection, fire protection and emergency situations. They reflect the collective efforts of researchers, academics, and professionals who have generously shared their insights during the conference.

Our sincere gratitude goes to all contributors for enriching the conference and ensuring its success. Special appreciation is extended to all participants of the Roundtable and Panel Discussions. Special thanks are also due to our esteemed keynote speakers, session chairs, and reviewers for their invaluable contributions.

As we reflect on the insights shared during the conference, we recognize the power in connecting the academic community and the business sector. This synergy provided a platform for exploring significant achievements, the latest trends, and the exchange of practical experiences and best practices in the mentioned fields.

I would like to express my sincere thanks to all members of Scientific and Organizing committees, whose planning and execution were instrumental in ensuring the Conference's success.

Confident that the solid foundation created by the 1st International EUROSA Conference will continue to build up and strengthen the unique international network of academics and professionals, we present these proceedings as a lasting resource. May the papers herein inspire continued dialogue and exploration in the field of sustainable management of occupational health and safety, environmental protection, fire protection and emergency situations.

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In Novi Sad, September 2023

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PARTICULATE MATTER IN THE INDOOR AIR OF A BAKERY

Adamović D.[1], Crnjak C.[1], Adamović S.[2]

[1]University of Novi Sad, Faculty of Technical Sciences, Department of Environmental Engineering and Occupational Safety and Health, Trg Dositeja Obradovića 6, Novi Sad, Serbia (e-mail: draganadamovic@uns.ac.rs)

[2]University of Novi Sad, Faculty of Technical Sciences, Department of Graphical Engineering and Design, Trg Dositeja Obradovića 6, Novi Sad, Serbia

Abstract: In Serbia, small- and medium-sized bakeries are typical and ubiquitous food production spaces. Considering this, the present study investigated pollution trends of the aerosol particles during bakery working activities and the indoor particulate matter. This paper presents the results of air quality measurement in a small bakery in Novi Sad at four locations within the production process, in the production premises, at the point of sale, warehouse of finished products, and outside. The measurements were performed with air quality sensor analyzers from 14.05.2020. to 31.05.2020, and the results were read every two minutes. The microclimate parameters measured were temperature, humidity, pressure, and particle matter from $PM_{2.5}$, and PM_{10} categories. The obtained results indicate very frequent exceeding of the recommended limit values, which requires improving the production process to minimize particulate matter emissions and using personal protective equipment to prevent the development of occupational inhalation diseases.

Keywords: *small bakery; indoor air quality; occupational exposure.*

INTRODUCTION

Indoor air pollution

Air pollution is the most essential global environmental threat to public health and accounts for an estimated 7 million premature deaths yearly (Chowdhury et al., 2023; WHO, 2019). Air pollution and climate change are closely linked as all primary pollutants impact the climate, and most share familiar sources with greenhouse gases (Zahedi et al., 2019). In recent years, there has been growing public awareness regarding health due to the risk associated with poor indoor air quality (IAQ) in homes and workplaces, as humans typically spend 80–90% of their time indoors (Seguel et al., 2017; Van Tran et al., 2020). In addition, those exposed to indoor air pollutants for extended periods are often the most susceptible, such as children, the older population, and chronically ill persons, especially those suffering from respiratory or cardiovascular disease (Lin et al., 2013). Indoor air pollution caused by the burning of conventional solid fuels such as woodfuel, agricultural residues, and dried animal dung in unvented cookstoves has been present since ancient times. Problems associated with indoor air pollution, however, today have developed a new dimension because of energy-efficient measures (increased insulation and reduced ventilation) implemented as an answer to the energetic crisis. Tightly constructed buildings, for example, decrease the quantity of fresh air for dilution and purging out contaminants, which, in turn, builds up high levels of toxic pollutants indoors. The fact that indoor air quality is not a precise reflection of ambient air quality was identified only recently. Scientific evidence has shown that the air inside homes and other public and office buildings can be remarkably contaminated than the outdoor air (Bhalekar and Sneha, 2018; El-Hougeiri and El

Fadel, 2004). Public concern about indoor air pollution's effects on health has therefore attracted expanded research on the topic.

Numerous sources emit air pollution indoors, including unvented cookstoves, space heaters, tobacco smoking, and building materials. Accumulating indoor air pollutants such as asbestos, formaldehyde (HCHO), radon, and so forth is increasingly recognized as causing many fatal diseases, including cancer. Toxic organic compounds such as formaldehyde, pesticides, and polycyclic aromatic hydrocarbons (PAHs) are often found indoors at levels much higher than outdoors. In the lack of indoor sources, the concentrations of NOx, CO, and respirable suspended particles indoors may be approximately the same as outdoors (Ballester et al., 2009; Bennett et al., 2019).

In the past, ambient air quality was the only basis for assessing human exposure to air pollution outside the workplace. Despite increasing awareness about indoor air pollution today, most air quality management measures still heavily address outdoor air issues, which may differ from indoor air quality. For example, most ambient air quality standards in the world do not include biological contaminants, an essential category of indoor air pollutants. Until recently, the definition of air pollution did not have the indoor air environment. Solving indoor air quality problems requires a continued coordination of engineering and public health methodologies. The synchronized efforts of engineers, architects, public health experts, and regulatory bodies are necessary to control and mitigate indoor air pollution. Principal categories of indoor air pollutants consist of combustion products, chemical products, radon, and biological agents (Madaniyazi et al., 2022; Yeatts et al., 2012). The main issues in indoor air pollution are related to the buildup of these pollutants at high concentrations resulting from the presence of emission sources and inadequate ventilation. Indoor air pollutants are emitted directly from numerous indoor sources such as cookstoves, heaters, tobacco smoking, building materials, and pest control chemicals. They may also originate outdoors during ambient air pollution episodes (Bennett et al., 2019).

Health problems of bakery workers

Professional asthma is a work-related respiratory disease frequently reported in many countries. Baker's asthma can be induced by immunologic sensitization to specific work-related allergens and following allergic reactions in the airways (Baur et al., 1998; Gordon et al., 1997; Yılmaz and Mungan, 2017). The inhalation of grain flour following exposure to flour dust is the major cause of the onset of this disease in bakery workers. In the publications, it is well known that exposure to grain flour dust can determine the occurrence of illnesses affecting the respiratory system. Many studies have documented that the exposure to flour dust and associated aeroallergen of bakers, pastry makers, and mill workers during the process of flour manipulation has resulted in numerous respiratory effects that have been described among bakers, including impairment of pulmonary function and chronic bronchitis (Fishwick and Curran, 2008; Pyana Kitenge et al., 2022). Less well-known are the different risk factors present in the baking industry. The bakeries have always been subjected to frequent food hygiene checks, but investigations to identify and assess the risk factors occurring during work activities inside bakeries are very rare.

In this work, we investigated the IAQ of a small pastry bakery in the Novi Sad province of Vojvodina, Serbia. In particular, a high-time-resolution study of aerosol particles (particle concentration, size distribution) in a small pastry bakery was carried out to provide information about concentration levels of aerosol particles in different premises of the bakery for a better understanding of indoor air quality.

MATERIAL AND METHODS

Sampling Site

The object of this study is a bakery located in Novi Sad, Serbia. Novi Sad is the administrative, economic, cultural, scientific, and tourist center of the Autonomous Province of Vojvodina, the second-largest city in Serbia. The climate in Novi Sad changes from moderate-continental to continental, so the city has all four seasons. The "košava" wind can blow during autumn and winter, usually lasting three to seven days. During the winter, košava can create snow drifts during blizzards. The average air temperature in the city is 10.9 °C, the average temperature in January is -1 °C, while in July it is 21.6 °C. An average of 578 mm of precipitation falls annually, and the number of days with rain is 122.

Here, we emphasize that the bakery has characteristics that are typical for Vojvodina bakeries—it is equipped with two electric ovens: an electric oven that is composed of five levels, with openings of 1.5 m^2 per level and a thermal power of 50,000 kcal/h.

In the bakery, working activities start early in the morning, at about 6:00. Generally, the first activity, a few minutes later than 4:00, followed by the ovens switching on around 6:10 until 7:00, for the heating phase. In parallel with the phase of heating the oven, the process of mixing small pastries and strudel runs. Most often, the daily production process ends around 14:00 with the cleaning of the premises by the employed workers.

PM Indoor Sampling

In the bakery, a monitoring campaign was performed from 14–31 May 2020 to collect $PM_{2.5}$ and PM_{10} indoor samples and particle concentration trends. In particular, indoor PM samples were collected by a sensor air sampler for eight working hours and in the period after work. Measurements were carried out using a sensor device to determine the concentration levels of particulate matter, with a response set to every two minutes at four bakery locations: point of sale, storage of finished products, production premise, and outside.

In parallel with the concentration levels of PM particles, microclimate parameters were also monitored: temperature and air humidity in the premises and outside.

RESULTS AND DISCUSSION

The results of monitoring microclimatic parameters indicate that the air temperature in the rooms during the sampling campaign was 21.35 ^oC to 25.09 ^oC. At the same time, the relative humidity values were in the range of 21 to 59%, following the recommendations prescribed by Serbian law ("Sl. glasnik RS", br. 21/2009 i 1/2019), given that the outside temperature was above 15^oC during the entire campaign.

Point of sale

The results of monitoring the concentration levels of $PM_{2.5}$ and PM_{10} at the measuring point "point of sale" are shown in Figure 1.

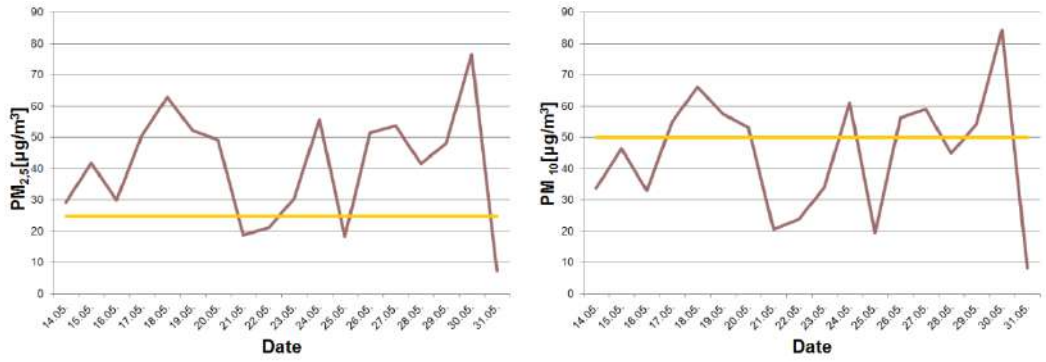

Figure 1. Concentrations of $PM_{2.5}$ and PM_{10} at the sampling point "point of sale"

The average daily values for $PM_{2.5}$ at the measuring point "point of sale" ranged from 8.26 µg/m³ (SD=15.45) to 76.51 µg/m³ (SD=151.48) and, in most cases, exceeded the recommended value of 25 µg/m³.

The average daily values for PM_{10} at the measuring point "point of sale" ranged from 7.38 µg/m³ (SD=14.34) to 84.24 µg/m³ (SD=165.24) and, in most cases, exceeded the recommended value of 50 µg/m³.

Storage of finished products

The results of monitoring the concentration levels of $PM_{2.5}$ and PM_{10} at the measuring point "storage of finished products" are shown in Figure 2.

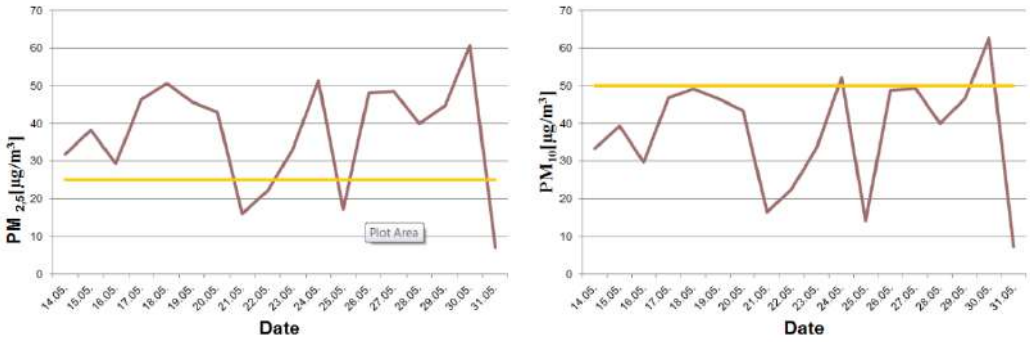

Figure 2. Concentrations of $PM_{2.5}$ and PM_{10} at the sampling point "storage of finished products"

The average daily values for $PM_{2.5}$ at the measuring point "storage of finished products" ranged from 6.98 µg/m³ (SD=12.96) to 60.82 µg/m³ (SD=118.31) and, in most cases, exceeded the recommended value of 25 µg/m³.

The average daily values for PM_{10} at the measuring point "storage of finished products" ranged from 7.38 µg/m³ (SD=14.34) to 84,24 µg/m³ (SD=165.24) and, in two cases, exceeded the recommended value of 50 µg/m³.

Production premise

The results of monitoring the concentration levels of $PM_{2.5}$ and PM_{10} at the measuring point "production premise" are shown in Figure 3.

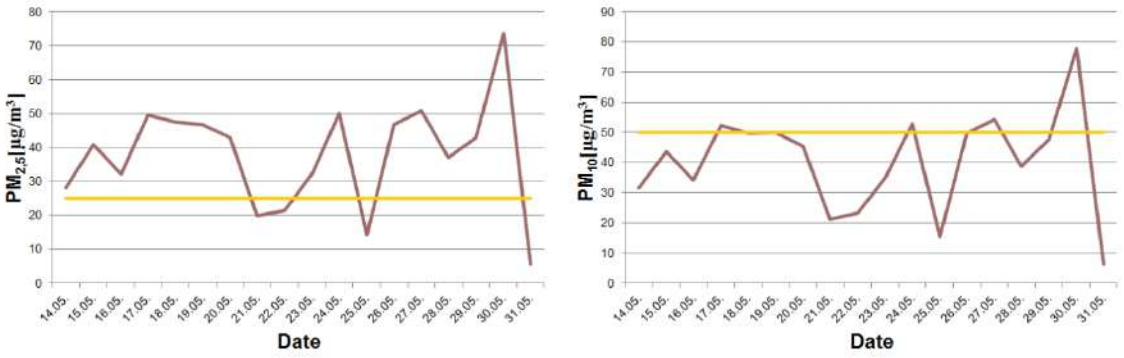

Figure 3. Concentrations of $PM_{2.5}$ and PM_{10} at the sampling point "production premise"

The average daily values for $PM_{2.5}$ at the measuring point "production premise" ranged from 5.47 µg/m³ (SD=11,39) to 73.61 µg/m³ (SD=145.27) and, in most cases, exceeded the recommended value of 25 µg/m³.

The average daily values for PM_{10} at the measuring point "production premise" ranged from 6.23 µg/m³ (SD=12,72) to 77.96 µg/m³ (SD=151.28) and, in most cases, exceeded the recommended value of 50 µg/m³.

Outside measurements

The results of monitoring the concentration levels of $PM_{2.5}$ and PM_{10} at the measuring point "outside" are shown in Figure 4.

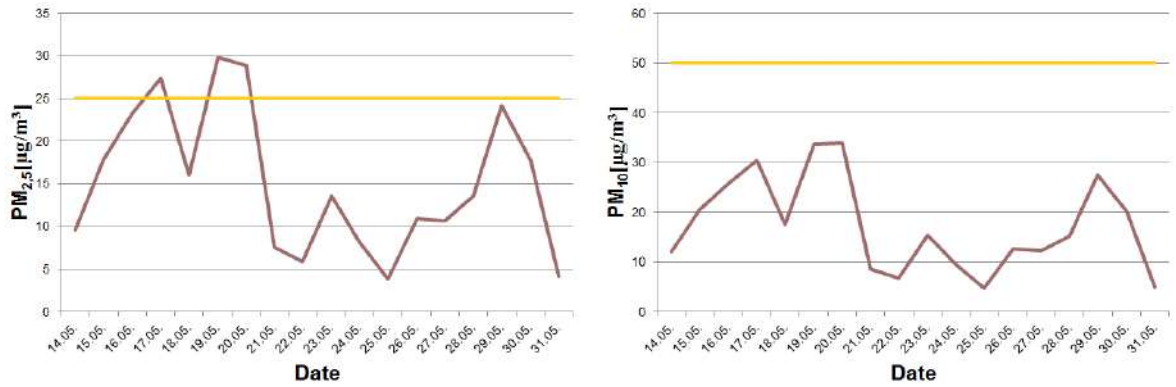

Figure 4. Concentrations of $PM_{2.5}$ and PM_{10} at the sampling point "outside"

The average daily values for $PM_{2.5}$ at the measuring point "outside" ranged from 3.88 µg/m³ (SD=7.16) to 29.87 µg/m³ (SD=14.32) and, in most cases, were under the recommended value of 25 µg/m³.

The average daily values for PM_{10} at the measuring point "production premise" ranged from 4.69 µg/m³ (SD=8.41) to 33.99 µg/m³ (SD=21.02) and, in all cases, were under the recommended value of 50 µg/m³.

CONCLUSION

Despite the reduced volume of bakery production during the period of the COVID-19 virus pandemic, significant deviations in the concentration levels of particulate matter from both categories were recorded in comparison with the recommended daily values at all measuring points within the production process, including the control point that was placed outside the bakery, as the possible impact of outdoor air contamination on the air quality inside the work area would be examined.

Concentration levels of particulate matter from the $PM_{2.5}$ category, in most cases, exceed the recommended daily value of 25 $\mu g/m^3$, with the highest average value detected of 76.51 $\mu g/m^3$ (SD=151.48) at the point of sale.

Compared to particulate matter from the $PM_{2.5}$ category, particles from the PM_{10} category, in a slightly smaller number of cases, exceed the recommended value of 50 $\mu g/m^3$. The highest average daily value of particles from the category PM_{10} is 84.24 $\mu g/m^3$ (SD=165.24), which was also recorded at the point of sale.

By monitoring the change in the concentration levels of PM particles of all categories, it was observed that the concentrations follow the dynamics of the production process.

During the monitoring period, microclimate parameters in the working area of the bakery were within the limits prescribed by law during the entire monitoring campaign.

Measurements carried out at the control point, located outside the production facility, to examine the possible impact of outdoor air contamination on the air quality of the workspace indicate that the sources of particulate matter in the workspace are dominant in comparison to external sources. Following this fact, any possibility of contaminating the air of the working space with outside air is excluded.

ACKNOWLEDGEMENT

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INCREASING WORK SAFETY IN THE CRUDE OIL INDUSTRY BY APPLYING LEARNING IN VR/AR

Babić A.[1], *Čepić Z.*[1], *Adamović D.*[1]

[1]University of Novi Sad, Faculty of Technical Sciences, Department of Environmental Engineering and Occupational Safety and Health, Trg D. Obradovića 6, Novi Sad, Serbia (e-mail: adrijana.capko@gmail.com)

Abstract: Safety training in the crude oil sector often lacks excitement and specificity, posing a significant challenge for an industry that has struggled with high fatality rates on its work sites for many years. Recent research has highlighted a significant deficiency in safety training programs, particularly in equipping the workforce with the skills needed for recognizing hazards and assessing risks. Additionally, the teaching methods employed in these programs do not effectively engage adult learners or facilitate the retention of the information provided. While immersive virtual environments have been employed for educational and training purposes for a considerable time (examples include flight and surgery simulators), the impact of utilizing virtual reality (VR) devices during simulation sessions remains an area requiring deeper investigation. To date, research in this realm has predominantly centered around the chemical and construction industries, particularly in relation to training for activities conducted at elevated heights and fire safety. As these investigations have yielded promising outcomes, this paper aims to outline the potential benefits that can be extended to the crude oil industry - a sector with one of the highest rates of workplace injuries.

Keywords: *chemical industry; AR/VR technology; work safety.*

INTRODUCTION

Historically, instructional methods for mastering the operation of industrial equipment have encompassed traditional classroom teaching alongside practical training in real-world settings. While hands-on experience is crucial for equipment operators with the necessary skills, it carries inherent drawbacks including the potential for personal injuries, equipment damage, fuel and site expenses, and the allocation of training personnel. To enhance cost-effectiveness, there is a need to explore alternative approaches that can substitute at least some part of the hands-on training conducted on actual equipment. The advent of virtual reality (VR)-based simulators specifically designed for construction equipment, categorized as Virtual Training Systems (VTS), presents a solution to this concern (Xing Su, 2013). Engaging in training through a simulator eliminates the need for expenditures related to fuel, equipment rental, site usage, and, most importantly, exposure to real operational hazards. These training simulators can replicate multiple scenarios within a virtual realm, encompassing situations such as fires, work at heights, confined spaces, and even simulated scenarios like rescuing injured personnel and delivering first aid. Trainees can repetitively practice these tasks without subjecting themselves, the equipment, or fellow personnel to any potential harm. Consequently, it's imperative that the training practice is designed to optimize the acquisition of skills from the virtual environment.

The crude oil industry in the United States contributes almost 8% to the total Gross Domestic Product (GDP) and employs around 11 million people. Despite its significant economic impact, this sector lags considerably in terms of safety performance compared to other industries. It has

the highest rate of injuries and fatalities among single-service industries, as reported by the Bureau of Labor Statistics (BLS) in 2020 (BLS, 2020). The injury rate in the oil and gas extraction field was 4.3 per 100 full-time equivalent workers, surpassing the overall injury rate of 3.3 across all industries in the USA. A similar scenario is observed in Canada, where the crude oil and natural gas industry contributes approximately 10% to the country's GDP and employs about 600,000 individuals. However, the injury rate in this industry is higher than that in most other sectors (Philippe Chan, 2023). In 2020, the lost-time claim rate (number of workers' compensation claims per 100 full-time equivalent workers) in oil and gas extraction was 2.9, exceeding the overall rate of 2.3 for all Canadian industries (Siddharth Bhandaria, 2019). In Serbia, the Ministry of Labour, Employment, Veterans and Social Affairs, Administration for Safety and Health at Work is responsible for tracking workplace injuries. The 2020 report indicates that the industrial sector accounts for 17.54% of total injuries, with 88 injuries reported within the oil industry (MINRZS, 2020).

These trends emphasize the need for a closer examination of how safety training and performance can be enhanced for workers in this critical industry. Recent studies have revealed shortcomings in current safety training methods, particularly in developing the necessary skills for hazard recognition and risk assessment among workers (Albert, 2013).

Recent investigations have revealed that conventional safety training methods lack effectiveness, as workers were found to identify and communicate fewer than half of all hazards present in their work environment during a given period (Albert, 2013; Carter, 2006). One of the key deficiencies in traditional safety training lies in its adherence to pedagogical principles typically designed for children, disregarding the extensive life experience that adult learners bring into the learning process (Albert, 2013). Remarkably, the same instructional principles applied to teach university students within the 18 to 24 age range (U.S. Dept. of Education, 2013) are also utilized in safety training, despite the fact that the median age of learners in this context is 43 years (BLS, 2017). Consequently, it's not surprising that Wilkins (Wilkins, 2011) discovered the majority of standard safety training programs struggle to effectively convey knowledge in a manner that resonates with the workforce, while Haslam et al. (Haslam, 2005) noted a prevalent negative attitude towards safety training among construction workers. The need is urgent for the development of safety training modules grounded in principles of adult learning (such as andragogy and self-directed learning), aiming to instill and maintain safety interests among construction/industrial workers (Compton, 2006). Present research indicates that incorporating Building Information Modeling (BIM), Internet of Things (IoT), and Virtual Reality/Augmented Reality (VR/AR) technologies could offer significant advantages in obtaining direct insights into building characteristics and indoor fire situations. This has the potential to enhance safety and operational efficiency in emergency fire rescue scenarios. Nevertheless, there exists limited investigation into the fusion of these technologies to create a comprehensive situational awareness system. The amalgamation of BIM, IoT, and VR/AR for fire safety management is still in its early phases of development.

APPLICATIONS OF AR/VR TECHNOLOGY

The improvement of perception can be facilitated through the utilization of Virtual Reality (VR) and Augmented Reality (AR) representations (Wang X., 2014; Hou L., 2015). Researchers have made efforts to combine AR and Building Information Modeling (BIM) for the visualization of 3D models and specific contextual information (Hou L., 2014). Chen, in his paper (Chen Y.-J., 2020),

devised a system based on BIM and AR for the inspection and maintenance of fire safety equipment. This system permits fire safety engineers to directly access inspection data visualized on a cloud database through mobile devices. As a result, the challenges arising from interpreting 2D paper-based data are overcome. Real-time AR visualization has also been applied to mitigate potential risks during fire incidents. VR technology has been extensively employed for workforce training purposes (Wang X., 2014), leading to a significant enhancement in on-site safety awareness. In the domain of fire safety training, a range of VR-based applications has made noteworthy progress in elevating on-site safety consciousness (Wang P., 2018). Syed (Syed Ali Fathima, 2019) introduced a VR extinguisher training system that guides trainees through operational steps to enhance their practical skills in using fire extinguishers. Narciso (Narciso D., 2019) developed a virtual environment for fire training and compared its effectiveness with real-life physical training, demonstrating that the developed system provides a high degree of spatial presence and immersion for trainees. Rüppel (Rüppel U., 2010) constructed a VR environment designed for fire rescue and evacuation training. However, this system exhibited limitations in terms of human-environment interaction. To address this limitation, the concept of gamification in training has emerged, leading to serious game-based training for developing fire safety skills in early childhood (Smith S., 2009), victim search, and evacuation (Backlund P., 2007).

Until now, only a limited number of research endeavors have focused on enhancing workplace safety and health through the application of AR/VR technologies. These studies have predominantly concentrated on sectors with elevated injury rates, particularly the chemical industry, which places considerable emphasis on enhancing safety measures. Similarly, the construction industry has employed VR/AR technologies for training in tasks performed at elevated locations. Since comprehensive examinations of the effects of VR/AR training on enhancing workplace safety and health within the crude oil industry have been lacking until now, our focus in the subsequent section has been on investigations encompassing tasks undoubtedly present in the oil industry's daily operations. Given that activities such as elevated work, confined space operations, fire hazards, operation of pressurized machinery, and handling of inflammable materials, are integral to tasks in crude oil refineries, we conducted assessments of these tasks using studies associated with sectors where they are also prevalent, notably construction and chemical industry. As a result of this rationale, we underscore research in this domain, as the utility of these VR/AR training methodologies directly extends to the oil industry and presents substantial opportunities for its integration.

CHEMICAL INDUSTRY

Personnel within laboratory settings encounter a diverse range of perilous substances, as well as various equipment and experimental configurations. If these aspects are not effectively managed, it can result in a significant potential for harm or even fatal accidents (Schröder, 2016). Consequently, the implementation of safety training becomes imperative, forming an integral component of any comprehensive safety management system. Historically, safety training has been delivered through methods such as traditional classroom lectures, video presentations, and printed safety manuals. These approaches involve a one-way flow of information, requiring trainees to be attentive and receptive to the instructor's guidance (Bhide, 2015). This methodology offers the advantage of delivering a substantial amount of theory within a condensed timeframe and to a large audience (Blair, 2007), However, it fosters a passive learning approach among trainees, potentially leading to disinterest and diminished attentiveness, consequently

diminishing the effectiveness of the training (Fivizzani, 2005). Other prevalent safety training methods encompass on-the-job instruction and hands-on training, in which trainees acquire essential safety protocols through practical engagement under the guidance of more experienced colleagues. This approach encourages trainees to be actively involved in the learning process, promoting the development of decision-making skills through experiential learning (Bhide, 2015). However, this methodology is restricted when it comes to training for highly hazardous scenarios, as it exposes both trainees and others to an elevated level of risk.

The study (Philippe Chan, 2023) encompassed a participant group of 37 individuals (comprising 14 males and 23 females) employed at a chemical company's research center, Arkema, located in France. These participants were selected randomly and displayed a voluntary willingness to take part. The process of recruitment involved the distribution of invitation notices to all site employees by the site director. While some participants engaged due to their inclinations, others were strongly recommended by their supervisors. The majority of these participants held positions as laboratory technicians or managers, demonstrating a background in chemical laboratory work. The participants' ages ranged from 20 to 60 years old. Notably, 14 participants (38%) indicated that they had utilized VR headsets at least once, and 11 participants (30%) confirmed that they had prior experience in playing video games.

The interviews conducted with employees from the chemical company revealed a prevalent trend of autonomous motivation when it comes to engaging in safety training programs. Participants conveyed that they perceive safety training as "essential for their well-being and the well-being of their colleagues" (P1 - a reference to a participant's statement) and expressed a desire to "acquire new knowledge and enhance their understanding of safety" (P8).

When inquired about the comparative effectiveness of safety training utilizing VR serious games versus traditional approaches, the majority of respondents (71%) exhibited a preference for VR serious games, primarily due to heightened engagement. They highlighted numerous advantages intrinsic to VR technology that conventional methods lack.

Initially, VR-based training offers prospects for contextual learning and diversity. Participants further outlined certain drawbacks associated with employing VR serious games for laboratory safety training. While novelty stands as a notable strength of VR safety training, it simultaneously poses a limitation for certain users. For instance, when questioned about their sustained interest following the initial exposure, participants noted that "the allure of discovery might wane" over time, Figure 1 (Philippe Chan, 2023).

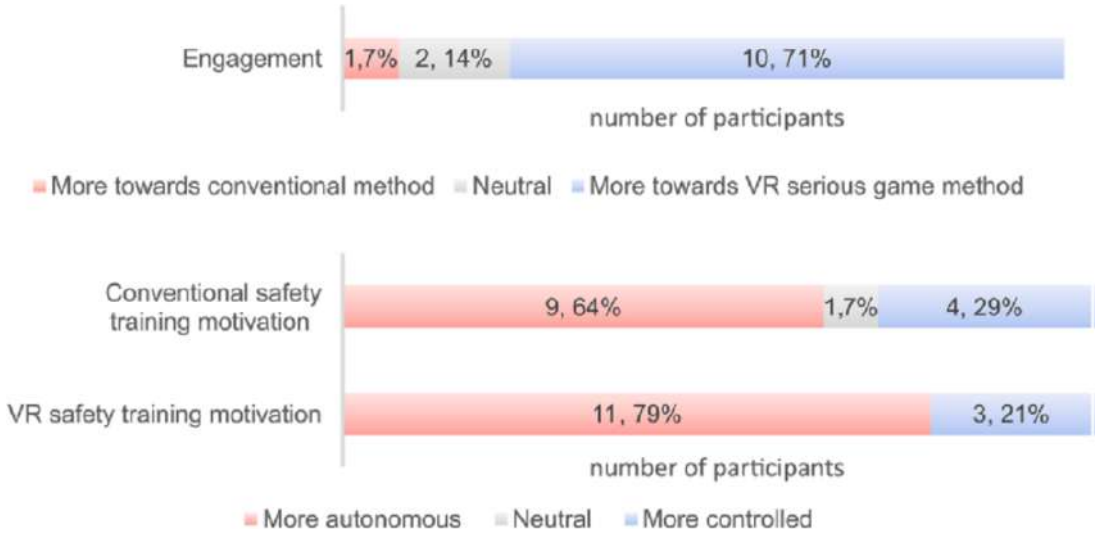

Figure 1. Participants' perception of the engagement and motivation of safety training with VR serious games compared to training with more conventional methods (Philippe Chan, 2023).

CONCLUSION

All the studies enumerated in this paper demonstrated a substantial enhancement in comprehension of training content (by more than 60%) when employing VR/AR equipment in comparison to conventional lecture-style training conducted by instructors and trainers. The degree of realism in the graphical environment positively correlated with participants' perception, deeming it more captivating and easier to grasp. Moreover, post VR/AR training, equipment manipulation exhibited a 30% increase in precision and safety compared to the group subjected solely to lecture-based training. Following VR/AR training, the ability to perceive workplace hazards improved by 18% relative to standard training methods. However, each study also reported certain limitations. Notably, participants aged 60 and above-encountered difficulties with VR/AR device usage due to perceived complexity. Furthermore, a subset of individuals experienced side effects like dizziness and headaches as a consequence of the training.

The potentials of Augmented Reality (AR) and Virtual Reality (VR) technologies have the capacity to reshape the landscape of education, introducing a more immersive and captivating learning encounter for students.

Several practical implications arise from their application:

- AR and VR technologies have the capability to deliver a richer and more interactive learning environment. By integrating these technologies, students/employees can delve into a plethora of engaging visuals and audio cues that foster heightened interest in the subject matter. Furthermore, these tools enable the creation of dynamic simulations and virtual realms, thereby enhancing the overall engagement and appeal of the learning process.
- The relevance of taught content can be significantly amplified through the use of AR and VR technologies. By enabling students/employees to explore diverse contexts and interact with content more authentically, these technologies facilitate a deeper comprehension of the subject matter. Additionally, they can introduce novel concepts and ideas in a manner

that is both compelling and captivating, elevating student engagement and enthusiasm.

- AR and VR technologies can lead to a more inclusive learning experience for students/employees with specific needs. By permitting students to navigate virtual environments at their own pace and in alignment with their personal preferences, these technologies pave the way for enhanced accessibility for individuals with physical or cognitive limitations.

The applications of augmented and virtual reality extend to education, enabling educators to recreate real-world scenarios, establish immersive learning environments, and offer students and employees practical, hands-on encounters that bridge theoretical learning and practical application. Continuous technological advancements suggest that these tools will substantially reshape pedagogical methods. In light of this, educational institutions as well as the industrial sector and in this case, crude oil refineries, are encouraged to invest resources, time, and training in integrating these technologies into their curricula. Augmented reality can animate textbook content with interactive diagrams, while virtual reality can create immersive simulations for students to engage with real-world situations within a controlled setting amid hazard reduction. These advancements aim to mitigate the constraints of traditional classroom setups while simultaneously enhancing student/employee engagement.

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METHODS FOR FIRE RISK ASSESSMENT IN WAREHOUSES - AN OVERVIEW

Bošković G.[1], Čepić Z.[2], Ubavin D.[2], Todorović M.[1], Bošković M.[1]

[1] University of Kragujevac, Faculty of Mechanical and Civil Engineering in Kraljevo, Dositejeva 19, Kraljevo, Serbia (e-mail: boskovic.g@mfkv.kg.ac.rs)

[2] University of Novi Sad, Faculty of Technical Sciences, Trg Dositeja Obradovića 6, Novi Sad, Serbia

Abstract: The paper discusses the problem of fire risk analysis in warehouses using different techniques for fire risk assessment. The application of different methods for assessing the risk of fire in different types of warehouses was analyzed from the aspect of the materials stored in them: batteries, textiles and chemical products. The aim of the paper is to provide an overview of recent research in the area of fire risk assessment in warehouses. The authors hope that this study can be used as an informative reference for future research in the field of fire protection and risk assessment and provide useful insight into the anatomy of fire risk assessment methods.

Keywords: *Fire Risk Assessment; Warehouse; Fire Protection*

INTRODUCTION

Increased construction and use of warehouses is the main strategy in terms of industrial logistics. Warehouses and storage systems often cover the needs of a wide geographical area and their size is determined accordingly. Due to increased industrial production and distribution, there is a need to build warehouses with increasingly large fire sectors and high-bay storage systems in order to make better use of the space inside the facility (Daganzo, 2005). Although this approach is considered useful in terms of reducing handling costs and better control of stored products, it also brings the problem of increased vulnerability in terms of warehouse hazards and security. In addition to earthquakes and floods, the biggest danger in warehouses is fire (Dinaburg, 2012). Regardless of whether it is a warehouse of smaller or larger capacity, in the event of a fire, which is the worst possible scenario, there is a possibility that the fire will engulf a large number of goods, cause a large amount of material damage, and that due to the combustion process, a large amount of smoke and heat will be produced, which is a large threat to human life and health.

Good and responsible management of fire safety in warehouses is crucial to ensure that fires do not occur or, if they do occur, are likely to be controlled and extinguished quickly, efficiently, and safely. Fire safety management in warehouses also implies that in case of uncontrolled fire growth and development, anyone who happens to be nearby can be safely and quickly evacuated from the fire to a safe location. A warehouse fire risk assessment ensures that all fire safety procedures, fire prevention measures, and fire safety measures in the form of plans, systems, and equipment are in place and functioning properly. (JIN Yu – Xiang, 2020). Fire risk assessment itself is a critical part of a fire prevention program. In this process, the fire risk associated with the possibility of occurrence and the severity of damage caused by fire is assessed and calculated.

REVIEW OF FIRE RISK ASSESSMENT METHODS

Fires in battery warehouses

Storage of lithium-ion batteries (LIB) has always been at increased risk of fire outbreaks due to instability and susceptibility to thermal breakdown. Many scientific papers and studies have analyzed the risk of fire outbreaks in battery warehouses and most of them have focused on the factors that affect fires due to battery heat losses, and very few papers have analyzed the papers on the causes that lead to heat losses. In order to solve this problem, the paper (Xie, 2023) proposed an approach that considers several influential factors for the risk assessment of fire in battery warehouses based on expert assessment and a Bayesian network (Figure 1). The proposed approach uses a Bayesian network model that contains three main groups of parameters: causes of fire, factors influencing the spread of fire, and consequences of fire in order to dynamically analyze the development and consequences of fires in battery warehouses. The results of the analysis showed that the proposed approach is reliable in assessing the risk of fire outbreaks in battery warehouses. In addition, it has been shown that the human factor usually causes open flame fires. It is recommended that in battery warehouses, a high degree of charging of the storage capacity is avoided, and if this is not possible, in addition to the timely response of firefighters, automatic fire extinguishing systems and mechanical ventilation should be installed in the buildings.

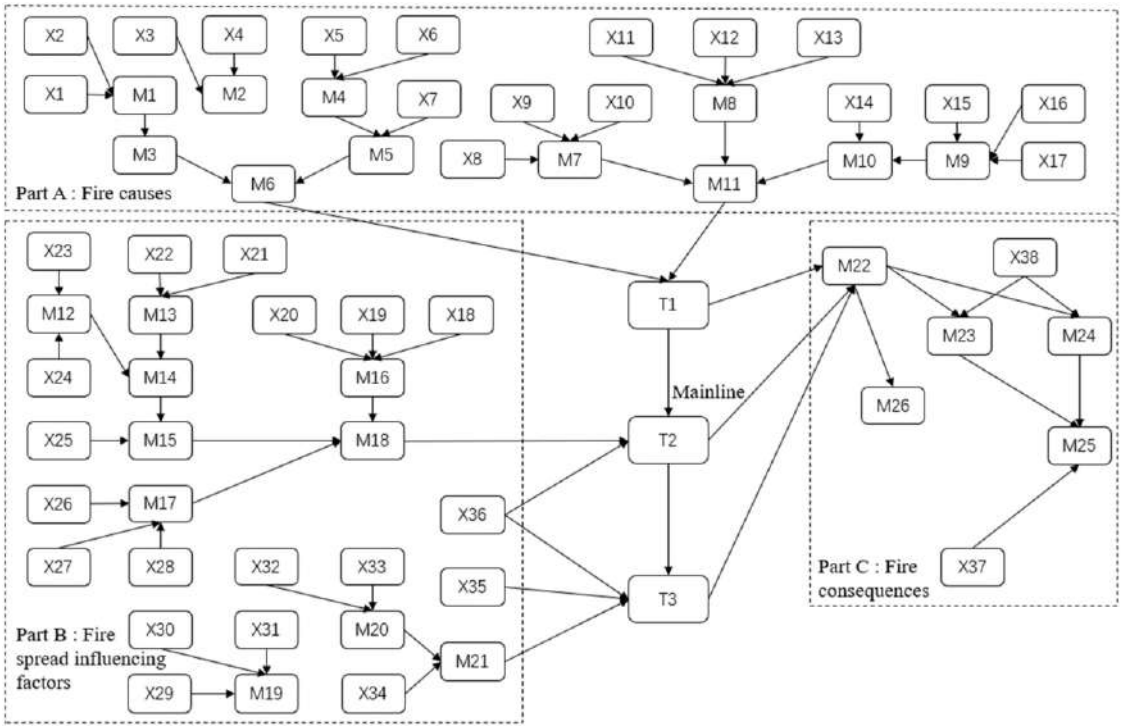

Figure 1. The block diagram of the BN model (Xie, 2023)

Proper transport and storage of batteries are important processes during the life of batteries. For this reason, it is important to create a procedure for assessing the risk of battery fires during transport and storage in order to prevent fires. The proposed procedure (Huang, 2022) presents an improved fire risk assessment method for lithium-ion batteries during transportation and storage by combining the event tree method (FTA) and the fuzzy logic method by performing 8 possible failure paths and 9 basic events. A case study of battery transportation by ship confirmed

that the proposed method can accurately assess fire risk and locate possible problems. By analyzing their importance structure to the largest event, the weights of each failure path are set to 0.128, which is used to calculate the HRN synthesis. In order to quantitatively assess the hazard risk of battery transportation and storage, probability, severity, and hazard control number are proposed as evaluation indices.

Fires in textile warehouses

It is known that cotton belongs to substances that are prone to self-heating and self-ignition during storage and that fires in buildings where cotton is stored are not rare. Research on fire risk assessment in cotton warehouses is limited. In the paper (Ding, 2019), the authors focus on fire risk assessment in a cotton warehouse and explore a strategy to control fire risk. Bow tie models (Figure 2) and Bayesian networks were established in order to investigate the relationship between the causes of accidents, safety barriers and possible consequences. The results obtained based on research showing that the first safety barrier (detecting and extinguishing a fire before the arrival of the fire brigade) is more controllable and more effective than the second safety barrier (extinguishing the fire after the arrival of the fire brigade). Based on the collected probability data, the probability and risk of a normal accident are greater than that of a major accident and a severe accident when safety barriers fail; when the first safety barrier fails, the probabilities and risks of major and severe accidents increase by more than 2000 times. Critical events for the occurrence of fire are open flames and sparks during cotton storage, and critical events for detection and extinguishing before the arrival of the fire brigade are supervision of the warehouse by an employee, regular inspection, and installation of automatic fire alarm and extinguishing systems.

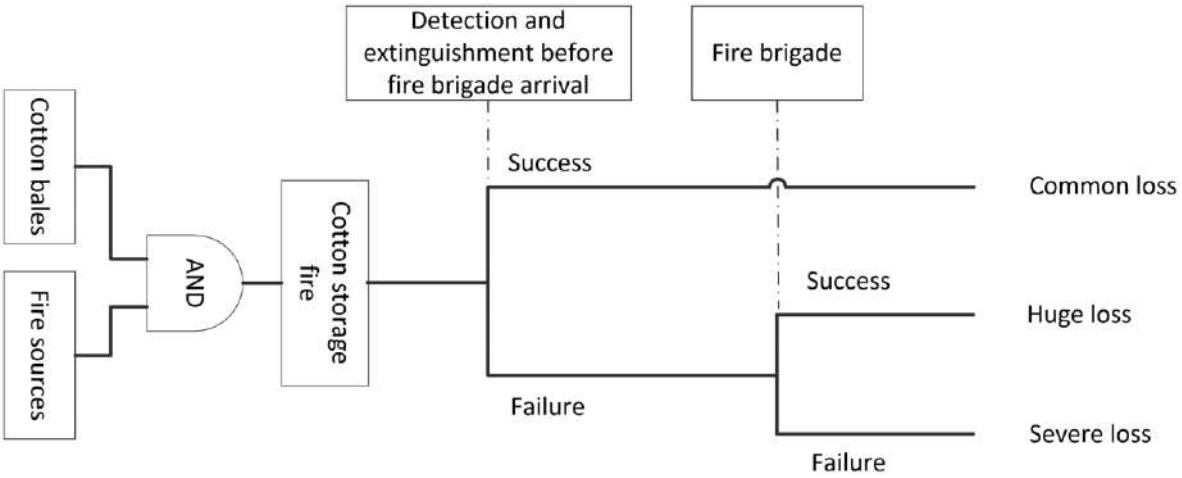

Figure 2. Generic Bow-tie model for cotton storage fire risk assessment (Ding, 2019)

Fires in industrial buildings

Fire safety is one of the main issues affecting the overall life cycle of industrial facilities. A better overview of the risk management of industrial facilities is realized through a risk management plan that reveals the relationships between all safety factors that are present during the exploitation of the facility itself. Due to the complexity of the industrial building system, the paper (Dârmon, 2020) discusses a probabilistic approach to assessing the risks and consequences associated with fire. The method of event trees was used to estimate the frequency of fires in an

industrial building and its consequences. In addition to requirements for the safety of employees' lives, criteria are set for the assessment of probability risks, taking into account the goals of property protection and business continuity. The above fire risk assessment approach can be considered as an optimization technique for sustainable production and better management of fire protection systems in industrial facilities.

Fires in chemical product warehouses

Fires at storage tanks for chemical products are very complex due to the difficulty of extinguishing them and the ease with which the fire spreads to nearby elements of the storage. The study (Ramezanifar, 2023) aimed to introduce a procedure based on Set of pairs analysis (SPA) based on Fault Tree Analysis (FTA), established through experts to identify and assess the fire risk of storage tanks. In a quantitative FTA system, sometimes only enough data is available to calculate the failure probability of the system to be studied. To illustrate the applicability of the proposed approach, a methanol storage tank fire fault tree was derived and Basic Events (BE) were analyzed. According to the obtained results, the fire accident was calculated at 48 BE, and the value of the probability of fire occurrence was calculated. In addition, this study lists the most important causes that led to the fire. The proposed approach established in this study can assist decision-makers in determining where to take preventive or appropriate measures on a storage tank system. Furthermore, parameter tuning can be performed for different systems with limited manipulation.

CONCLUSION

This paper presented a comprehensive review of the literature on fire risk assessment methodologies in warehouses based on selected references from the field of fire protection.

Based on the above references, the following conclusions can be drawn:

- Fire in warehouses represents a serious danger in both developing and developed countries and represents a significant threat to life, structure, property, and environmental safety.

- The fire protection measures currently in place lead to an unquantifiable level of fire protection in warehouses, providing minimal fire risk mitigation strategies and not taking into account contemporary fire risk issues.

- Implementing key measures that include improving fire safety features in warehouses, proper regulation and enforcement of building code provisions, increasing awareness and proper use of technology and resources are of great importance to reduce the risk of fire in warehouses.

- Research and training needs necessary to improve warehouse fire safety include implementation and development of cost-effective fire suppression systems, characterization of new materials, development of performance-based codes, and understanding of fire hazards.

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IMPROVING HEALTH AT WORK USING ERGONOMIC METHODS

Čolović G.[1,2], Maksimović N.[1,3]

[1]Academy of Technical and Art Applied Studies Belgrade

[2]SE-ERGO, Belgrade (e-mail: agencijaseergo@gmail.com)

[3] Clodynamic, Čajetina

Abstract: In order to reduce musculoskeletal disorders among employees, increase productivity, reduce operating costs, and optimize processes and procedures, it is necessary to use adequate ergonomic methods. Changing the working method and working position requires training and control. The modern application of sensors in work clothes facilitates and reduces ergonomic risk.

Keywords: *ergonomics; methods; smart work cloth; health.*

INTRODUCTION

Today, ergonomics is a discipline that is developing in a new direction, because it cannot ignore that a person's psychological and social limitations, needs, and requirements can also limit the use of a tool and that they should also be taken into account when designing a technical tool or a technical system. According to Hal and Kleiner, ergonomics aims to study and adapt working conditions, work tools, work processes, and products as a result of human work from psychological, physiological, and anatomical aspects. Ergonomic problems are present everywhere where it is possible to improve work tools, working conditions, work processes, and products in a way that is in accordance with human characteristics and limitations.

The basic goals of ergonomics are to achieve human and technical-technological efficiency and productivity through comprehensive organization, rationalization, and humanization of work. The goals of ergonomics are often divided into those that strive for betterment for individuals, users, and production systems (Čolović, 2014):

- The goals of a production system for employees are safety, comfort, health, and satisfaction, which leads to the humanization of work.
- For the user of a product, the most important thing is the reliability and safety of the product, i.e., a quality product.
- For the producer, on the other hand, the most important thing is labor productivity, which leads to the highest profit.

ERGONOMICS RISK

Ergonomic risk refers to physical stress factors and workplace conditions that carry the risk of damage to or disease of the musculoskeletal system of employees. According to the World Health Organisation, ergonomic disorders are the fastest-growing of all categories of occupational diseases. The ergonomics risk depends on:

1. worker - physical, psychological, and non-work-related activities may present unique risk

factors;

2. task - work procedures, equipment, and workstation design may introduce risk factors;
3. environment - physical and psychosocial "climate" may introduce risk factors.

Workers in many different industries can be exposed to risk factors at work, such as lifting heavy items, bending, reaching overhead, pushing and pulling heavy loads, working in awkward body postures, and performing the same or similar tasks repetitively (Figure 1). (Segar, Rahman 2019).

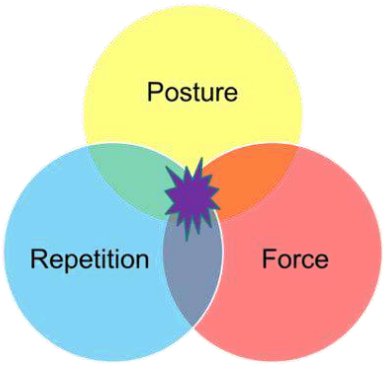

Figure 1. Primary ergonomics risk factors

According to Dul and Neumann, the ergonomic risk reduction process is a systemic process with clearly defined goals. The focus of the process is improving safety and health at work, i.e., identification of ergonomic risk factors and elimination or reduction of those risks, thereby reducing sick days and increasing efficiency and productivity.

The process of reducing ergonomic risk in the workplace

1. Steps to improve the workplace:

- Analysis of physical and mental demands in the workplace.
- Analysis of standard operating procedures.
- Job description (observation method, interview with employees).
- Division of work according to task activities or technological work operations.
- Connecting ergonomic risk factors with technological operations/activities of a specific work task: efforts, uncomfortable and static positions, repetitive movements, contact (stress) stress, and environmental influences (vibrations, temperatures, lighting).

2. Risk description and root causes

- Analysis of the workplace using appropriate ergonomic methods.
- Reviewing the possibilities for applying the principles of ergonomics to eliminate or reduce ergonomic risk (neutral positions, reduction of force, elimination of redundant grips and movements, carrying of objects, reduction of repetitive movements, avoidance of static positions, avoidance of pressure points, provision of adequate distance, reduction of vibrations, control of temperature and lighting).

3. Development of an implementation plan.

4. Analysis of implementation costs.

5. Training of employees for a new work method.

6. Getting feedback on the first and 30th days after implementation.

7. Audit (external control).

ERGONOMIC ANALYSIS

The design of the workplace is reflected in the recognition of the abilities and limitations of the employee. The main task is to adapt the working environment to the employee as much as possible. Each worker is an individual by himself with his characteristic features, whether physical, mental, or some other characteristic related to the type of work he performs. The position of the worker's body in the industry, the complexity of the structure of certain movements within the performance of the technological operation, and the degree of muscular and visual control of the worker depend on the type of technological operation, the type of machine, the technical equipment of the machine, and the installation system of workplaces (Colovic, 2014).

According to Berlin and Adams proper ergonomic design of each workplace, along with finding suitable methods of work with the appropriate time standards ensures better structure of technological operations with the increased efficiency of machines and tools. Working posture should allow the mobility of the limbs, ergonomically favorable arrangement of working and visible zones, and a stable balanced state when performing the work process.

Ergonomics uses biomechanical analysis of body movements and a study of time during the performance of tasks - to get the most comfortable positions of the body, which require at least psychomotor strain while ensuring the most successful performance of tasks (Figure 2).

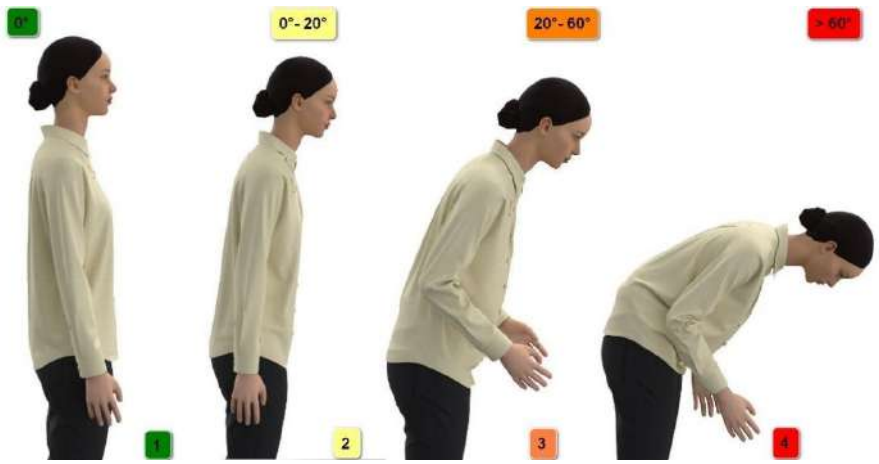

Figure 2. Biomechanical analysis

At Ramax Fashion Company we analyze workers between the ages 20 to 55. Ramax is a private, family-owned company whose main activity is the production of men's, women's, and children's clothing. We started the research with the conventional assessment method according to the RULA, NIOSH, MAC, HARM, and IS tools. The workers were monitored visually while photographs

and videos were taken at different periods of the shift for later analysis by the team, and based on them the recorded ergonomic risk condition was scored.

More than half (57%) of the workers have problems arising from the working environment and the equipment. The workers who have problems mostly complain of waist (52%), the back (30 %), the neck (25%) and the shoulder (13%) aches. These problems are followed by the foot, the leg, and the arm aches.

Also, for control and training, we use a workwear garment in which a motion-tracking sensor is embedded (Figure 3). The sensor is installed on the back piece of the workwear t-shirt and works on the stretch detection principle. Stretching occurs in situations where the wearer bends his back, the garment on which the sensor is located is stretchable enough to have the feature of following the curvature of the backbend and therefore increases the length of the rear piece of the garment. This new condition is detected by the microprocessor that reads the condition at the sensor, the received signal is processed, and based on it, a signal is sent in the form of sound and LED lights. The sensor, microprocessor, and battery are embedded together in the clothing in such a way that they allow free movement and do not hinder the worker when performing the tasks.

Figure 3. Placement and function of the motion sensor

In Figure 4 the worker was signaled by the wearable every time his current pose was outside the acceptable range of ergonomic risks. He would then simultaneously and independently correct his body position. The worker was previously familiar with functions and had the opportunity to try the wearable sensor, so he did not have a period to get used to it. Although the requirements of the work task itself were such that the worker was put in situations where he produced an unfavorable body position, he consciously corrected his posture in most cases.

In situations where the work operation would require the worker to lean his body forward, which is generally accompanied by the person lowering his chin down towards the object of production, which causes an even greater level of curvature of the neck and back, after the sensor signal, the worker would raise his chin straighten his neck which was followed by the sound signal stopped. After the data was collected and during the analysis, it was noticed that the changes occurred in the posture ergonomics risk rank.

Figure 4. Worker's posture - before and after

CONCLUSION

Modern industry is increasingly demanding effective ergonomic solutions for its workers. It stems from humane as well as productive motives. It is a well-known fact that many workers are absent from work or work with difficulties due to illnesses or conditions caused by work activities. Ergonomic disorders are the fastest-growing of all categories of occupational diseases. 30% to 50% of workplace injuries are related to ergonomics in some way.

Proper ergonomic assessment with appropriate methods and tools and implementation of changes in the workplace reduces musculoskeletal diseases by 60%, absences due to illness by 70%, and increases productivity by about 50%.

Introducing a wearable sensor that monitors body movements as a preventive measure to reduce ergonomic risks has its benefits in reducing and detecting ergonomic risks in the work environment. This type of work clothes accelerates the training of workers in order to reduce musculoskeletal diseases.

ACKNOWLEDGMENT

The authors would like to thank RAMAX Company DOO, Pozega, Serbia for their outstanding support in enabling this research possible using their production facilities.

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WIND TURBINE MAINTENANCE ANALYSIS: ENSURING EFFICIENCY AND RELIABILITY

Cvetković M.[1], *Mijailović I.*[1],

[1]Faculty of Occupational Safety in Niš (e-mail: miljan.cvetkovic@znrfak.ni.ac.rs)

Abstract: Wind turbine maintenance analysis is a critical aspect of ensuring the reliability, efficiency, and safety of wind energy generation. By utilizing various maintenance strategies and harnessing the power of data analytics, the renewable energy sector can significantly enhance the operational lifespan of wind turbines while minimizing downtime and maintenance costs. As technology continues to evolve, the methods of maintenance analysis will become more sophisticated, ultimately contributing to the growth and sustainability of renewable energy sources.

Keywords: *wind turbine; reliable; maintenance.*

INTRODUCTION

Due to its dependability, sustainability, and efficiency, wind power is the renewable energy source with the fastest-rising market share in the world. Wind turbines, both onshore and offshore, are frequently utilized to turn wind energy into electricity. In addition to being a renewable energy source, wind energy is also an environmentally clean energy source (no emissions of CO_2 or SO_2). The cost of fossil fuels has always been correlated with interest in wind energy. Fuel costs declined following World War II. At that point, enthusiasm for wind energy starts to wane. The price of petroleum increased in the 1970s, and the Organization of the Petroleum Exporting Countries imposed an embargo, which increased interest. With this expansion comes the need to enhance wind turbine productivity and optimize the return on investment in wind farms. Appropriate maintenance strategies (technically feasible and economically profitable throughout the life cycle of wind turbines) will be required for successful future development, given that "the net income from a wind farm is the income generated from the sale of electricity less operation and maintenance.

According to data from the World Wind Energy Association (WWEA), wind energy will be capable of producing 744 GW of power by the end of 2020 (Figure 1). In 2020, up to 93 GW of electricity will be added. Wind energy electricity output has surged by 58% in the previous five years.

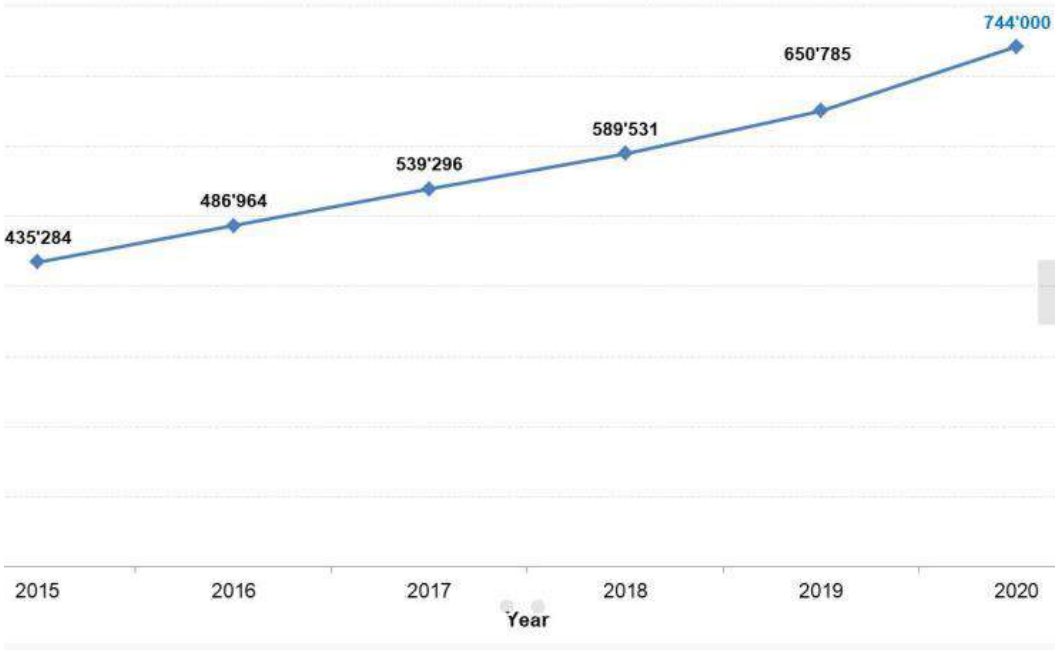

Figure 1. Total installed capacity

Wind turbines must be constantly inspected and serviced since they often operate in extreme environmental conditions; nevertheless, they are difficult to reach because they are typically placed in distant areas. As a result, one of the major difficulties impeding the growth of wind energy is maintenance expenses.

WIND GENERATOR COMPONENTS

The tower, rotor, and casing are the three main components of a wind turbine. The rotor is linked to the housing, which contains the transmission system, generator, control device, and brake. The casing also serves to protect the components contained within it. The transmission system, together with the generator, are critical components of a wind turbine (Figure 2).

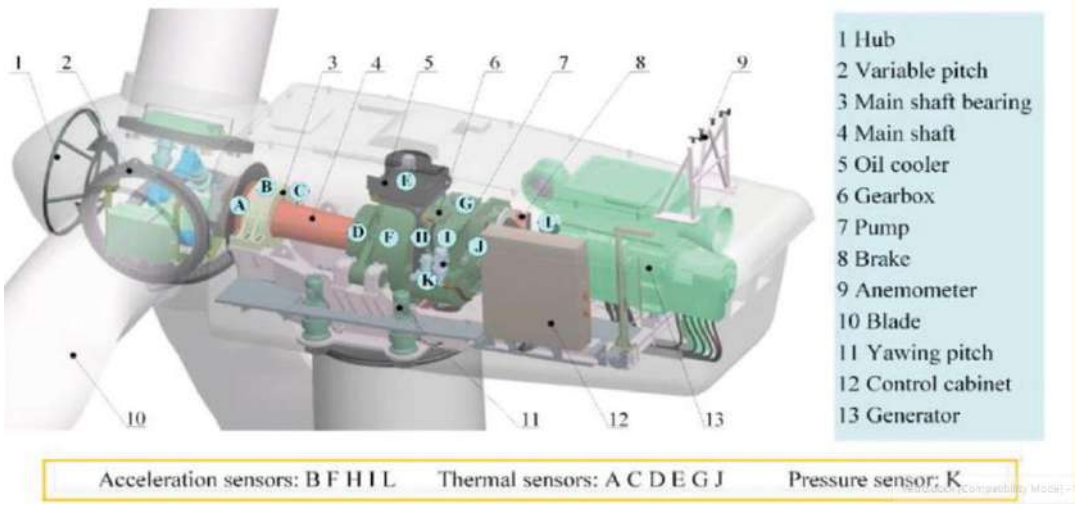

Figure 2. Wind turbines' primary components

The transmission system is made up of the following components: the hub, the main shaft (as shown), bearings, couplings, and gear transmission (as shown). The head is composed of gray cast iron due to its unique form. The primary shaft is typically forged from steel. The primary shaft rotates at a rate of 40-60 rpm. Spherical roller bearings are the most common type of bearing. The sealing is labyrinthine to prevent wear and tear as well as water and dirt intrusion into the bearing. The main shaft is linked to the gear transmission by a friction coupling and transmits torque to it. The gear transmission has to increase the rotation speed of the main shaft from 40-60 rpm to 1500-1800 rpm, which necessitates the use of massive gears. Transmission can be two-stage (150 MW), three-stage (300 MW), or planetary (beyond 450 MW) depending on output power. A stiff coupling connects the transmission's output shaft to the generator.

RELIABILITY AND MAINTENANCE OF THE SYSTEM

Existing criteria for high wind generating system dependability need the use of contemporary maintenance techniques. Wind turbine development nowadays is trending toward larger and heavier constructions, which increases the likelihood of breakdowns. In actuality, failure rates for onshore and offshore wind turbine systems of the same kind are substantially different. The failure rates of wind turbine systems and components are depicted in Figure 3.

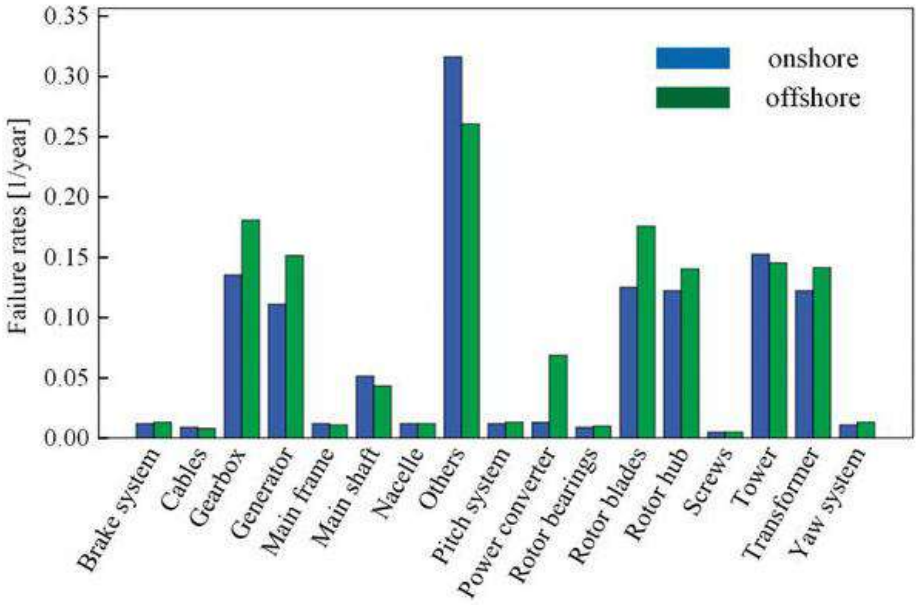

Figure 3. Failure rates for subassemblies of onshore and offshore wind turbines

Gear transmission

The fundamental issue with the bearings inside the gear is that they must withstand extremely high loads. Depending on the transmission location and operating load, the bearings will have to transmit heavy loads at low speeds and tiny loads at high speeds. High loads at low speeds, which occur when the wind speed is low, can cause the oil film to rupture and limit the bearing's life. An automated lubrication system lubricates the bearings in the gear transmission. The oil filter, which is separate from the oil cooling system, guarantees that the oil is of high quality. This approach is critical in deserts and arid places where flying dust can penetrate the equipment and cause abrasive damage. Moisture and salt are constantly present pollutants in wind turbines installed

on offshore sites. The purity of the oil is critical, and the most common impurities in the gear transmission are those introduced during installation, those formed inside the transmission itself, those introduced through vents and seals, and those introduced during maintenance negligence. Impurities introduced during installation are the result of poor assembly circumstances. Such contaminants are the most harmful when the engine is first started since the oil filter cannot remove them promptly. Impurities produced within the transmission are mostly the result of gear, bearing, and other component wear. Micro pitting, macro pitting, adhesion, abrasion, and fretting are all signs of wear. Dirt can enter the transmission via vents and seals. Maintenance, such as re-lubrication or re-lubrication, should also be performed to prevent contaminants from penetrating. A preventative maintenance program, which includes monitoring for oil pollution, acidity, viscosity, and the presence of water, can help minimize the frequency of failures. The chart shows the needed purity of the oil for the wind generator's gear transmission. For the time being, transmission oil is replaced every 8 to 12 months, however, work is being done to lengthen this period, which is projected to be extended to three years for wind turbines erected at sea.

The rotor blades

Wind energy drives wind turbine rotor blades, which convert wind energy into mechanical energy. Blades break often due to alternating stress and complicated conditions, with the primary failure mechanisms being fatigue, fracture, cracking, wear, freezing, and sensor failure. The rotor blades are difficult to replace and maintain due to their high placement, resulting in hefty expenditures. As a result, studying the link between failure mode, reliability, and internal/external stresses is necessary and useful in order to develop blades with high dependability.

MAINTENANCE STRATEGIES

Wind turbines are frequently offered with a 2–5-year contractual warranty that covers corrective and preventative (time-based) maintenance measures. These techniques are typically implemented after the contract time has expired to ensure the continuing maintenance of wind turbines. Fault-based maintenance entails running the wind turbine or any of its components until it breaks down. This technique is typically used when failure will not result in a loss of money, consumer displeasure, or an impact on health and safety. Critical component failures in wind turbines, on the other hand, can be disastrous, with major operational, health, safety, and environmental effects.

In most cases, solutions for continuing wind turbine maintenance are implemented after the contractual time has expired. Fault-based maintenance entails running the wind turbine or any of its components until it breaks down. This technique is typically used when failure will not result in a loss of money, consumer displeasure, or an impact on health and safety. Critical component failures in wind turbines, on the other hand, can be disastrous, with major operational, health, safety, and environmental effects.

Time-based maintenance entails executing maintenance chores at regular intervals. This method is frequently used to prevent voiding the OEM warranty and to keep sub-critical devices running if the failure pattern is well understood. However, selecting the optimum period is difficult since too frequent an interval raises operational expenses, loses production time, and necessitates the replacement of good-condition components, whereas unexpected breakdowns frequently occur

between too lengthy maintenance intervals. As a result, time and money are typically spent on maintenance with little awareness of the equipment's present health.

Condition-based maintenance is the most cost-effective method of maintaining important equipment. A condition-based maintenance plan is performing maintenance activities in response to deterioration in the condition or performance of an asset or component as detected by a condition monitoring technique. The extensive field of condition-based maintenance applied to wind turbines and other grid-connected infrastructure has received little attention. Although there is monitoring of turbine blade structural integrity utilizing thermal imaging and acoustic emission; usage of performance monitoring and temperature monitoring systems; and online analysis.

COMPARISON: CORRECTIVE MAINTENANCE VS. CONDITION-BASED MAINTENANCE

Maintenance expenses are incurred as a result of preventative maintenance, corrective maintenance, and lost production as a result of turbine stoppage. An ideal maintenance schedule decreases the likelihood of failures rather than eliminating them.

Maintenance and operation operations have been demonstrated to contribute between 25 and 30% of overall wind energy expenditures, prompting greater attempts to improve maintenance programs. This is a difficult process owing to the large number of parts in the turbine system, as well as a lack of understanding of their behavior, relationships, and degradation and failure causes. As a result, existing industrial practice is mostly focused on a corrective maintenance strategy, which results in considerable repair costs and lost income.

Corrective maintenance expenses (or lost benefits) occur from lost output, component repair, and damage escalation due to component failure. Monitoring and inspections will increase maintenance costs but decrease lost productivity and exacerbate the damage.

Simultaneously, contemporary wind farms are outfitted with condition-monitoring devices that provide a constant flow of data on many behavioral and environmental aspects. The data might be utilized to examine the present state of the turbine, allowing for extensive preventative maintenance planning.

The tub model in Figure 4 may be used to depict the development of the failure rate during the lifespan of multiple wind turbine components that are prone to deterioration/damage buildup.

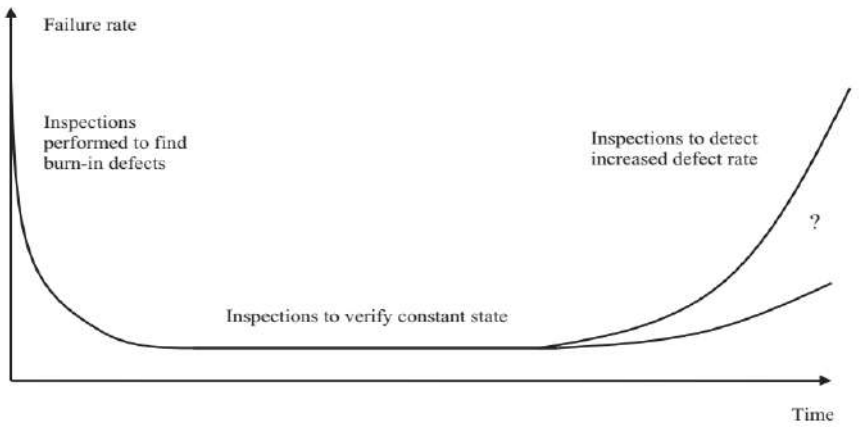

Figure 4. Life cycle failure rate tub model

Initially, a significant failure rate owing to workmanship faults might be anticipated. Following this is a period with a "normal" constant failure rate. During this time, corrective maintenance might be conducted. The failure rate of a component is predicted to rise as it nears the end of its useful life. If the failure rate rises significantly, preventative maintenance should be carried out. Pre-failure deterioration/damage can be noticed if the failure rate increases considerably.

The weather has a significant impact on various elements of wind turbine operation and maintenance, including damage accumulation, repair time windows, and (lost) production. Because of natural differences in execution, the parameters in the damage model for various components will vary, and the model is likewise unclear. There is a chance that no damage may be discovered during the examination. There is also the danger of incorrect detection of non-existent damage. When damage is recognized, a decision rule decides whether or not a repair is necessary. The ideal choice rule should be based on the component's end-of-life risk analysis, although a simpler rule with a damage threshold level may be easier to employ.

Depending on the weather, access to the wind turbine may be delayed for some time, and additional expenses should be incorporated into the projected costs of failure and loss of output. Repairing a component before it breaks is frequently less expensive. Of course, inspections will be beneficial only if the damage is not too abrupt to be recognized during the inspection.

CONCLUSION

Wind turbine maintenance analysis is the linchpin of efficient and reliable wind power generation. By embracing a holistic approach that incorporates condition monitoring, predictive maintenance, data analytics, and emerging technologies, operators can ensure their wind turbines function optimally, contributing to the growth of sustainable energy sources. As the renewable energy sector continues to expand, investing in robust maintenance practices will be paramount in realizing the full potential of wind power.

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STATISTICAL ANALYSIS OF MEASUREMENT RESULTS OF CO_2 EMISSION DURING COMBUSTION OF REFERENCE FUEL IN A PELLET BOILER

Cvetković M.[1], *Đorđević A.*[1], *Igić N.* [2]

[1] University of Niš, Faculty of Occupational Safety, Čarnojevića 10a, Niš, Serbia (e-mail: milos.cvetkovic@znrfak.ni.ac.rs)

[2] Kvalitet A.D, Bulevar Svetog cara Konstantina 82-86, Niš, Serbia

Abstract: Manufacturers of solid fuel heating boilers, when placing products on the market, are obliged to test the devices and provide a declaration of conformity with international and national regulations that are aligned with European eco-energy directives. In addition to energy efficiency, the testing is also based on the emission of combustion products. This paper presents the results of CO_2 emission measurements obtained by testing a device designed for heating the space it is located in, as well as heating the water circuit for additional heating units - commercially referred to as a pellet-based central heating stove.

Keywords: *emissions; CO_2; central heating stove; SRPS EN 14785:2011*.

INTRODUCTION

The energy sector, as a crucial element of global sustainable development, enables long-term economic and social progress by meeting the basic energy needs of the population and reducing risks related to energy supply security and environmental pollution (Petrović Bećirović, 2016). The use of pellets is currently relevant as an alternative to electric energy, which is currently being intensively used for heating residential and work spaces in the Republic of Serbia. Certain data indicate that almost 80% of global pellet production is used precisely in the European Union (Huang, 2015).

Considering that carbon, hydrogen, and oxygen are the main components of biomass as they form the cellulose, hemicellulose, and lignin components of the material, their combustion results in the formation of CO, CO_2, and H_2O. The content of volatile combustible matter in woody biomass varies in the range of 70-86% (Obernberger, 2010). Accordingly, fuel quality is an important parameter in the eco-energy analysis of small-scale pellet combustion stoves and boilers (Garcia-Maraver et al., 2014; Verma et al., 2012; Rabaçal et al., 2013; Sippula et al., 2007; Roy et al., 2013).

The standard SRPS EN 14785:2011 defines requirements related to the design, operation, and testing of characteristics for combustion appliances using wood pellets intended for household heating, with mechanical fuel loading and nominal heat output of up to 50 kWt. This standard specifies the required energy and environmental performance characteristics of these appliances, including prescribed minimum operating efficiency and maximum allowable combustion product emissions, which are also the subject of research in this paper.

ANALYSIS OF PELLET BOILER PERFORMANCE

Manufacturers of solid fuel space heating devices (boilers, stoves, ranges) are obligated to provide a declaration of conformity with European directives and domestic regulations when introducing

their products to the market. To ensure the validity of these declarations, testing is carried out in accordance with internationally recognized standards. When it comes to pellet stoves, one of the standards that these stoves must comply with is SRPS EN 14785:2011. This standard defines requirements related to materials, design and construction, safety, performance, instructions, labeling, and conformity assessment. The results subject to statistical analysis are obtained by testing devices that use pellets as fuel and are intended for heating the space in which they are located, as well as for heating a water circuit for additional heating units - commercially known as a pellet-based central heating stove.

Figure 1. Gas analyzer

The testing was conducted in a testing facility that continuously measures parameters over the designated period of approximately 3 hours, as required by the provisions of SRPS ISO 14785:2011 standard (Figures 1 and 2).

Figure 2. Test installation

STATISTICAL ANALYSIS OF TESTED PARAMETERS

The subject of this study is the analysis of CO_2 emissions data during 3 hours, which was taken as the reference period for data analysis. The measured CO_2 values are in parts per million (ppm), as shown in Table 1. The examined parameters were measured using appropriate instruments for

flow rate, temperature, pressure, mass, CO, NO, O_2, and CO_2. The values are recorded in digital format (Excel) every 10 seconds.

Table 1. CO_2 values for the reference pellet boiler

Red. no. classes	Class		Middle class x_i'	Freq. f_i	Rel. freq. f_i^*	Cumul. freq. Z_i	Cumul. rel. freq. Z_i^*
	Lower limit	Upper limit					
1.	9.25	9.80	9.525	6	0.0051	6	0.0051
2.	9.80	10.35	10.075	25	0.0210	31	0.0261
3.	10.35	10.90	10.625	58	0.0488	89	0.0749
4.	10.90	11.45	11.175	114	0.0960	203	0.1709
5.	11.45	12.00	11.725	214	0.1801	417	0.3510
6.	12.00	12.55	12.275	234	0.1970	651	0.5480
7.	12.55	13.10	12.825	230	0.1936	881	0.7416
8.	13.10	13.65	13.375	147	0.1237	1 028	0.8653
9.	13.65	14.20	13.925	97	0.0816	1 125	0.9470
10.	14.20	14.75	14.475	53	0.0446	1 178	0.9916
11.	14.75	15.30	15.025	10	0.0084	1 188	1
Σ	/	/	/	1 188	1	/	/

Based on the presented results, it can be concluded that the sample size is 1188 subjects. The mean CO_2 value is 12.43 ppm. The standard deviation is 1.05 ppm. The maximum measured value for CO_2 is 15.21 ppm, while the minimum is 9.26 ppm. Based on the difference between the maximum and minimum, a value of 5.95 ppm was obtained. There are 11 intervals, each with a size of 0.55 ppm. The results are graphically presented in Figures 3 and 4.

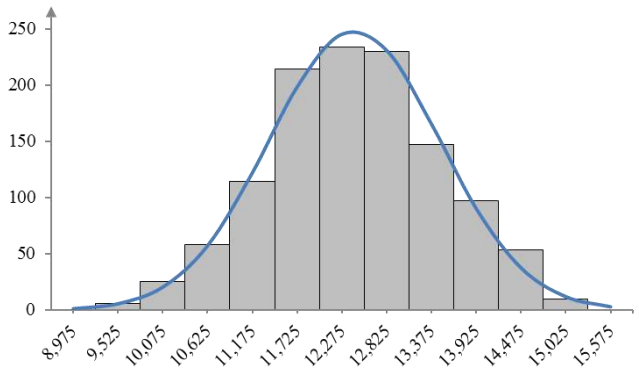

Figure 3. Polygon of CO_2 frequencies in ppm

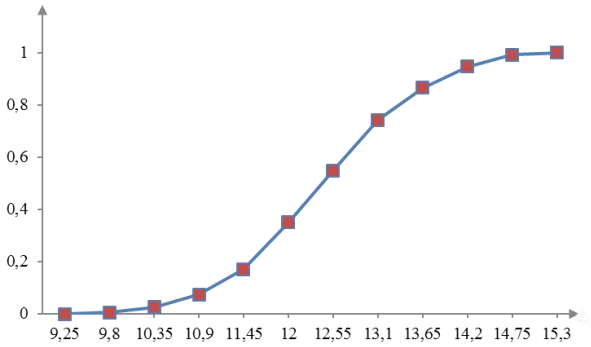

Figure 4. Polygon of cumulative relative CO_2 frequencies in ppm

The skewness is -0.03 and the kurtosis is -0.3, both close to 0, which means that the histogram aligns fairly well with the corresponding normal curve, as can be seen from the displayed graphs.

CONCLUSION

The significance of energy efficiency in heating boilers is reflected not only in its cost-effectiveness but also in environmental protection. By reducing energy losses in the heat production process, regardless of the current state of equipment, it is possible to significantly increase the efficiency of the boiler system. Through appropriate adjustments and operational optimization, significantly improved performance of pellet boilers can be achieved, resulting in reduced primary energy consumption and fewer emissions of pollutants. Consequently, the statistical analysis of combustion product parameters is of great importance in assessing the eco-energy efficiency of reference boilers.

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TECHNOLOGICAL RISK ASSESSMENT FOR SINCRO 950 AND RECO MILL 50 COPPER RECYCLING UNITS

Đorđević A.[1], Despotović Lj.[2], Ubavin D.[3], Krstić I.[1], Stojković A.[1]

[1] University of Niš, Faculty of Occupational Safety, Čarnojevića 10a, Niš, Serbia (e-mail: amelija.djordjevic@znrfak.ni.ac.rs)

[2] Jugoimpeks DOO, Dunavska 5, Niš, Vazduhoplovaca, Serbia

[3] University of Novi Sad, Faculty of Faculty of Technical Sciences, Trg Dositeja Obradovića 6, Novi Sad, Serbia

Abstract: Current global trends are focused on the analysis of possibilities for achieving primary goals and meeting the requirements of the circular economy. This paper discusses the end-of-waste status of electrical cables and the resulting granulated copper to be used as a raw material. On the one hand, this technological procedure and waste electrical cable treatment are strategically significant in terms of obtaining copper as a raw material used in numerous industry branches, and on the other hand, it allows the implementation of proper environmental protection procedures. Among others, SINCRO 950 and RECO MILL 50 units are used for electrical cable recycling and copper granulation. The paper provides a technogenic risk assessment for the two units conducted using the REHRA (Rapid Environmental and Health Risk Assessment) method. The qualitative and quantitative risk assessment was conducted based on the installation hazard index (IHI) and the accident risk index (ARI) for the units. The risk assessment revealed that the technogenic risk of the analyzed recycling units was acceptable.

Keywords: *technogenic risk; recycling, copper; end-of-waste status*.

INTRODUCTION

Material recycling and reuse is one of the basic requirements of a circular economy (Zeng, 2023). Copper is a strategic metal, used in all branches of industry. Yet, owing to rapid industrial development, copper ore supplies are decreasing, which leads to a global and regional undersupply of this resource (Nassar et al., 2020; Schipper et al., 2018). Considering that copper, with its unique electrical properties, has almost no alternative, this problem has become even more serious (Disna et al., 2019). In modern business operations, the demand for copper has escalated because of its wide applicability (Seck et al., 2020; Kerr, 2014). Schipper et al. (2018) predicted that cumulative demand for copper will surpass copper capacities by the year 2100. Other authors also observed a considerable increase in energy consumption during copper extraction due to poor ore quality (Azadi et al., 2020). Consequently, copper reuse and recycling can significantly help in resolving this issue. Copper is one of the few materials that can be repeatedly recycled without any negative impact of the recycling process on material properties, so there is no difference between the quality of recycled copper and that obtained from primary production (Eheliyagoda et al., 2020).

The technological process of waste copper processing poses potential technogenic and ecological risks. As a general principle, risk is understood in terms of the frequency of the influence of stressors, resulting unwanted effects, and consequence levels on a given element of the technosphere and the environment. With regard to technogenic and/or ecological risk, the

operation of units that recycle electrical cables in order to obtain copper granules was analyzed and verified using the REHRA method.

TECHNOLOGICAL PROCESS OF OBTAINING GRANULATED COPPER

The purpose of the technological process of waste electrical cable processing is to separate copper with a 99.95% degree of efficiency, which depends on the following factors:

- cable type and construction (single-core or multi-core cables with different types of insulation, coatings, and conductor wires);
- the thickness of the cable or cable harness;
- presence of other metals and nonmetals (Al, PVC, and PE insulation, steel, lead, impregnated paper, textile fibers, and others);
- presence of special insulators in layers of gelatinated compounders, which poses a particular problem during recycling;
- properties of cables (different types, thicknesses, and lengths) (Figure 1).

Figure 1. Different types of waste electrical cables

The technological process comprises the following operations:

- cable sorting;
- cable cutting;
- cable stripping;
- cable grinding and granulation; and
- air-gravity separation.

The SINCRO 950 unit is intended for gravity separation of electrical cables up to the diameter dmax = 4 mm (Figure 2). The unit consists of a primary granulator, a secondary granulator, and a vibrating air separator, which separates copper granules from plastic granules.

Figure 2. The SINCRO 950 unit

The unit's processing capacity ranges from 350 to 450 kg/h. It is equipped with a WAMECO dedusting system, type FS3J 24 VA/Tp71.

The plastic granules obtained through gravity separation in SINCRO 950 are transported via a belt conveyor to the reception hopper of a screw conveyor, from which they are directly fed into the RECO MILL 50 for further separation (Figure 3).

Figure 3. RECO MILL 50 unit

Screw conveyors provide a constant input of the material in the RECO MILL 50, which performs additional separation of copper and plastic, resulting in high-purity plastic (99.8%) (Figure 4).

Figure 4. Plastic and copper granulate

The gravity separation systems are equipped with dedusting systems, which contain enclosed filter chambers with eight filter bags each and dust collection drawers at the bottom of the dedusting unit.

TECHNOGENIC RISK ASSESSMENT

During the operation of units for electrical cable recycling and separation of copper as a raw material, technogenic risk, which is associated with the formation and development of hazards in the technosphere, involves hazards related to unit operation and fire hazards. During risk assessment using the REHRA (Rapid Environmental and Health Risk Assessment) method, the first step was to present the risk as a quantity of already manifested or expected unwanted effects on persons, property, or specific environmental elements due to accidents in the course of regular operations or unexpected events (European Union Risk Assessment Report, 2008).

The use of the REHRA methodology enables a qualitative and quantitative risk assessment by calculating the installation hazard index (IHI), the accident risk index (ARI), and the installation risk index (IRI).

The installation hazard index (IHI) is the frequency of accidents expected within a given installation. IHI was calculated based on the information about the technical characteristics of the units, work organization system, natural phenomena that may affect safety inside the plant, and the type and amount of substances fed into the units.

The calculations also implement the installation general index (IGI), the natural hazard index (NHI), and the installation dangerous substance index (IDSI).

IGI is a function of the installation technological factor (ITF) and the establishment organizer factor (EOF).

To calculate the IHI, the IDSI index is also considered, as it pertains to the presence of substances used in technological procedures, whereby the installation dangerous substance factor (IDSF) is determined, expressed as the sum of the ratios of substances used in a technological procedure and their predicted limit quantities. The IDSI is considered in risk assessment only if the substances used in the technological procedure can be classified as dangerous according to their physicochemical and toxicological properties. The technological procedure of electrical cable recycling for the purpose of obtaining copper as a raw material involves cutting and shredding plastic and rubber cable jackets, which may contain dangerous substances. The most recent studies focus on the analysis of the environmental presence and impact of plastic and rubber

microparticles, which enter the environment after various treatment processes. Knowing the chemical composition of plastic and rubber used as electrical cable insulation, it is reasonable to assume that toxic substances are present in dust products with particles over 10 μm in diameter and floating particles smaller than 5 μm. The percentage and classification of these substances are still being investigated and there is sparse literature covering them.

Figure 5 shows the schematic of the IHI calculation for the SINCRO 950 unit, used to determine technogenic risk.

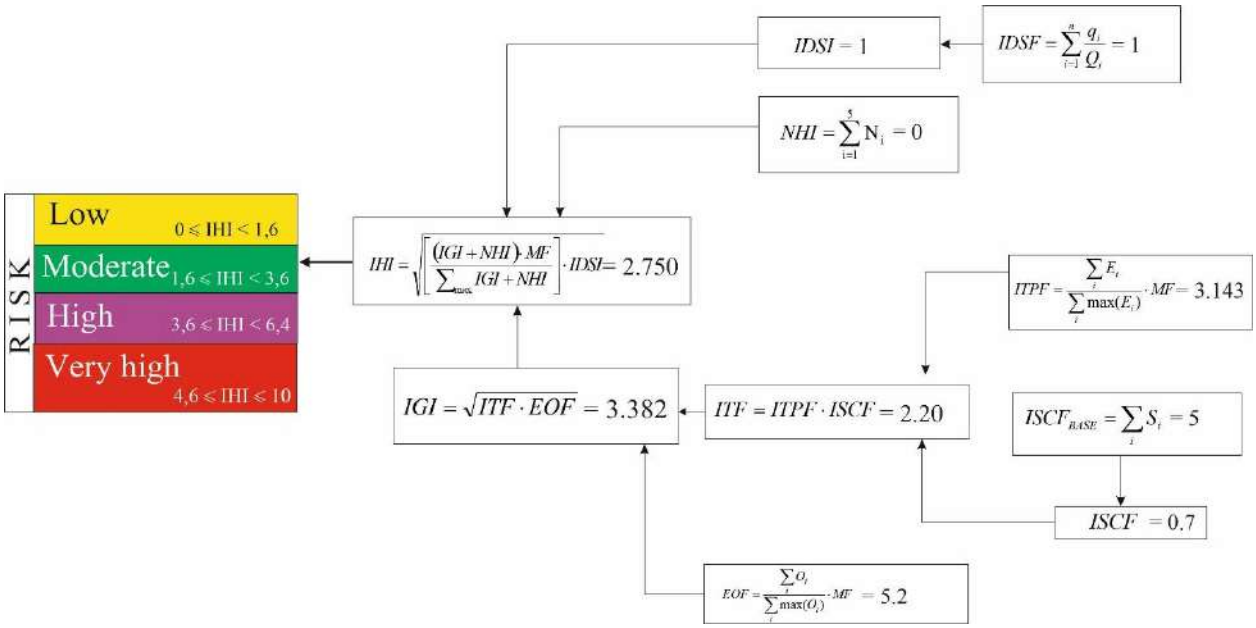

Figure 5. Qualitative and quantitative hazard evaluation for the SINCRO 950 unit

Technogenic risk dependent on the installation risk index (IRI) of the SINCRO 950 unit falls into the moderate risk category with an IHI of 2.750. The IHI value for SINCRO 950 can be reduced through periodical and planned safety training for all employees, which would in turn decrease the value of the EOF, which refers to human activities in processes ('human factor') (Figure 5). For EOF calculation, the least favorable option was considered – the employees had received no safety training whatsoever.

The qualitative and quantitative assessment of the installation risk index (IRI) begins with the consideration of ecological risk and quantification of expected unwanted effects on persons, property, or specific environmental elements due to an accident. IRI is dependent on the domino effect (IDEF) and the risk conditioned by each individual with an accident within a given production unit (ARIi). For Sincro 950, the risk increase factor dependent on the domino effect (IDEF) considers only accidents involving a fire, which is caused by human negligence during work, human incompetence, or faulty electrical wiring as the initial factor of a fire breakout. A fire is the only initial factor that can cause serious damage to the plant housing the unit for waste electrical cable recycling, so the risk conditioned by each accident within a given production unit (ARI) is considered in terms of fire. Figure 6 shows the calculation schematic for the installation risk index (IRI).

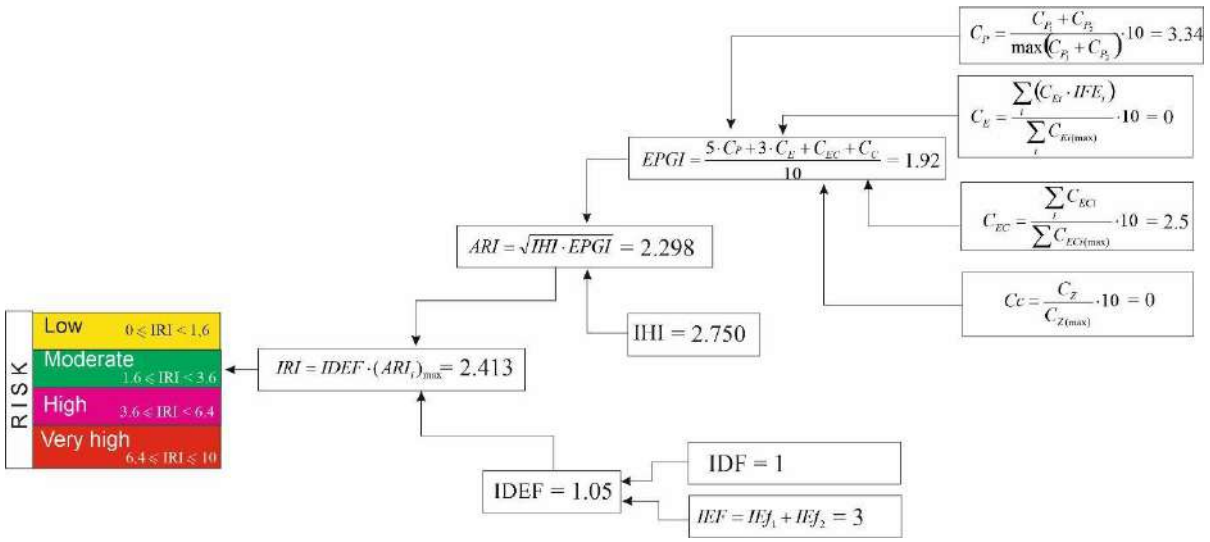

Figure 6. Risk classification based on the installation risk index for the SINCRO 950 unit in the event of an accident

Based on the given risk calculation, the risk in the event of a fire-related accident can be classified as moderate. The value of the accident risk index (ARI) pertaining to the accident selected from all possible accidents (a fire) in the given unit is expressed as a function of the installation hazard index (IHI) and the environment and population gravity index (EPGI) (Figure 6). Accordingly, the installation risk index (IRI) can be reduced indirectly through IHI values by introducing periodical and planned safety training for all employees, as previously stated, which would thus reduce the calculated IRI value of 2.413 (Figure 6).

CONCLUSION

The importance of using non-ferrous metals from secondary raw materials lies in the economic effects produced through the preservation of natural resources, energy savings, and prevention of environmental pollution. Production of non-ferrous metals from secondary raw materials is far more cost-effective than production from primary raw materials, primarily because of lower energy consumption. Copper recycling consumes 85% less energy than primary copper production. Owing to the increasing demand for copper, recycling significantly increases the quantities available on the market. One of the key advantages of copper is that it does not lose its properties upon recycling and that it can be modified if necessary. In addition, recycling non-ferrous metals from secondary raw materials utilizes natural resources more rationally and reduces the amount of waste materials, which directly protects the environment.

After the calculations of the installation hazard index (IHI) and the installation risk index (IRI) for the production unit SINCRO 950, used for electrical cable recycling to obtain copper as raw material, the technogenic risk was classified as moderate, based on the IHI value of 2.75 and the IRI value of 3.6.

The assessment of the environmental gravity of electrical cable recycling and copper granulation using the REHRA method showed that the risk was moderate. It was concluded that the only possible accident is one involving a fire and that no significant environmental degradation is to be expected. Therefore, the copper obtained from waste electrical cables is an environmentally

friendly product that can be reused as a raw material in all branches of the industry after it receives the end-of-waste status.

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TRANSFORMATION OF ANALYTICAL CHEMISTRY EDUCATION THROUGH DIGITALIZATION

František Č.[1], Živančev N.[2], Špánik I.[1]

[1]Slovak University of Technology in Bratislava, Faculty of Chemical and Food Technology, Radlinského 2101/9, Bratislava, Slovakia

[2] University of Novi Sad, Faculty of Technical Sciences, Trg Dositeja Obradovića 6, Novi Sad, Serbia (e-mail: nevenazivancev@uns.ac.rs)

Abstract: The outbreak of the COVID-19 pandemic created an urgent need for the rapid development of digital educational resources to ensure continuity in learning. In fields such as analytical chemistry, the scarcity of available materials became evident, resulting in the initiation of the development of the Erasmus+ project Digitalization of laboratory exercises in classical and instrumental analytical chemistry - DigiLabAC. The primary goal of the DigiLabAC project was to develop a comprehensive online platform in order to provide students with an immersive learning experience. This online platform includes detailed manuals, informative audiovisual materials, and interactive computer simulations for essential aspects of analytical chemistry. Additionally, a virtual laboratory is established, offering the flexibility to generate laboratory tasks for different student group sizes, providing a seamless and effective virtual laboratory experience. The DigiLabAC project demonstrates the potential of digitalization in overcoming the challenges posed by the COVID-19 pandemic and transforming traditional laboratory education into an innovative and accessible virtual environment. This paper presents the key features and functionalities of the project outcomes, highlighting its profound impact on analytical chemistry education. As a result of the project, a strong foundation for a more dynamic and inclusive learning environment in a world increasingly reliant on digital solutions has been made.

Keywords: *digitalization; education; analytical chemistry; online platform.*

INTRODUCTION

Transformation through scientific technology and digitalization across various spheres of human life has led to innovations and progress in the modern world. From revolutionizing agriculture to healthcare, these advancements are significantly enhancing efficiency and productivity. The impact has been the most profound in education, where the integration of digital technologies has opened new frontiers for learning and teaching (Obloberdievna, 2022).

The outbreak of the COVID-19 pandemic in early 2020 brought an unprecedented disruption, challenging traditional ways of education. Faced with the necessity to maintain continuity in a global crisis, educational institutions promptly shifted their approach, embracing digitalization (Babacan, 2022). Online learning emerged as a viable solution, providing the opportunity for students, teachers, and researchers to stay connected, share knowledge, and collaborate in the situation of physical separation. Online education represents a contemporary and transformative pedagogical shift, impacting the traditional methods of learning and teaching. This innovative approach has redefined the entire education system, transcending physical boundaries and bringing education to the virtual realm (Rosak-Szyrocka, 2022).

In response to the lack of digital materials in the field of analytical chemistry, a dedicated group of university professors from Slovakia, Serbia, the Czech Republic, and Slovenia came together to

pioneer the transformative project DigiLabAC. Recognizing the challenges posed by the absence of digital resources in this essential discipline, the collaborative effort aimed to overcome these problems and revolutionize the way analytical chemistry education is delivered and experienced. The DigiLabAC team developed digital learning materials, equipping students and educators with cutting-edge tools and resources to elevate their understanding and proficiency in analytical chemistry.

Since higher education plays a critical role in achieving Sustainable Development Goals (SDGs), it is of great importance to equip the next generation of students with the necessary skills to navigate the opportunities and complexities of sustainable development. (Pu, 2022). The DigiLabAC project has an opportunity to promote SDGs, as embracing digital technology has become increasingly essential for Higher Education for Sustainable Development (HESD). Utilizing digital products, technologies, and methodologies, HESD can advance to a new stage of development (Xiao, 2019).

PREPARATION OF DIGITAL MATERIALS

For the realization of DigiLabAC project goals, the DigiLabAC team brought together expertise in laboratory education, digital technology, and video production to create an innovative approach to teaching laboratory exercises. The project team designed and compiled a database of laboratory tasks covering various topics in classical and instrumental analytical chemistry. Each laboratory task was carefully curated to ensure alignment with course objectives and learning outcomes.

An online platform was developed to host the database of laboratory tasks. The platform offers a user-friendly interface for students and teachers, enabling easy access to the materials and resources.

Digital materials created for the platform include detailed manuals with photos and comprehensive descriptions for each laboratory task, video materials documenting the entire laboratory task, simulations of the task, and a virtual laboratory.

All prepared materials are produced in multiple languages: Slovak, Czech, Slovenian, Serbian, and English, providing accessibility for students in diverse linguistic regions. This approach enables the use of materials in countries with similar teaching systems.

During the use of the online platform, both students and teachers are encouraged to give feedback and evaluations of the material, and based on the results, the project team will continuously improve and update the platform and materials to enhance the overall learning experience and ensure the relevance to current educational needs.

PROJECT OUTCOMES

The developed online platform includes all materials in five languages: Slovakian, Czech, Serbian, Slovenian, and English. The desired language can be chosen from a drop-down list (Figure 1).

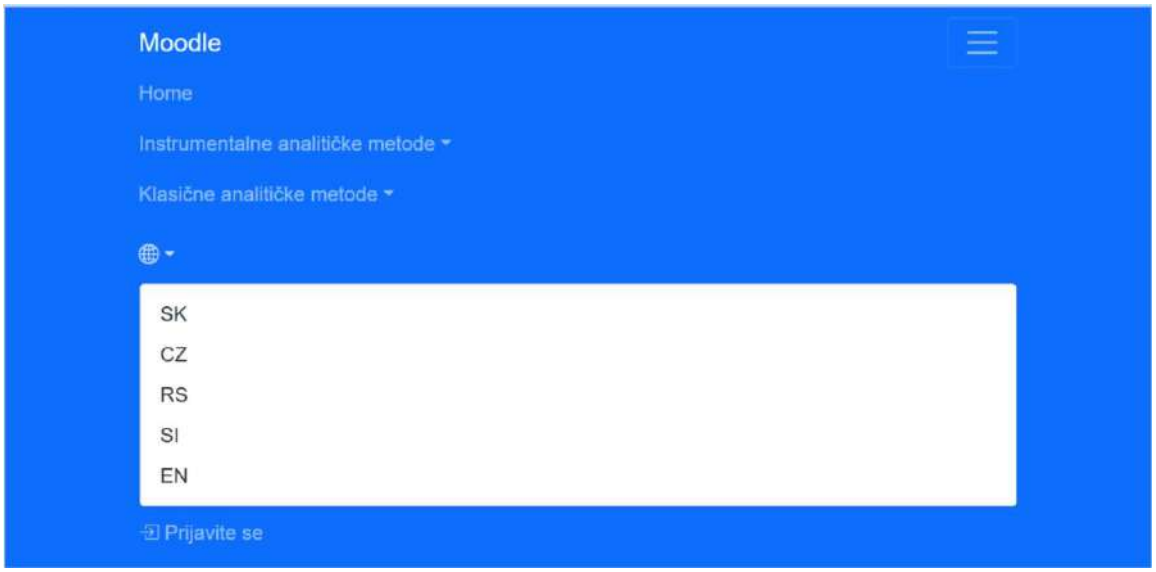


Figure 1. The possibility of choosing from five languages on the online platform

The DigiLabAC project outcomes include tasks from both classical and instrumental analytical chemistry, as well as essential water sampling procedures (Figure 2). Additional supporting materials are also available, designed to support students' learning experiences, such as detailed instructions for preparing burettes, standard solutions, etc.

Figure 2. List of laboratory tasks (in Serbian)

The project outcomes in classical analytical chemistry comprise a total of 15 diverse and engaging tasks. These tasks cover fundamental concepts and techniques, equipping students with a solid foundation in traditional analytical methods.

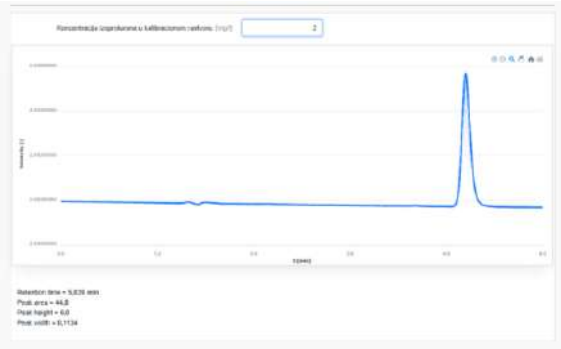
The instrumental analytical chemistry part is derived into 30 tasks with instrumental analytical techniques. These tasks include state-of-the-art methods, instruments, and data analysis processes.

Recognizing the vital importance of water analysis in various fields, the online platform also includes four essential water sampling tasks. These tasks train students in the proper collection and handling of water samples, crucial for environmental and public health studies.

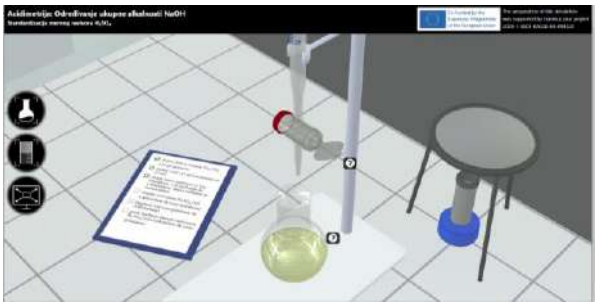
Each task has a detailed manual with step-by-step explanations, audiovisual material following each step of the task, simulation for the results of the task, or virtual laboratory (Figure 3).

a)

b)



c)



d)

Figure 3. Examples of a) instruction manual, b) audiovisual material, c) simulation, and d) virtual laboratory

During the implementation phase, the DigiLabAC project was piloted in several educational institutions, demonstrating encouraging results. Student involvement and motivation levels noticeably improved due to the interactive and dynamic nature of the digital tasks. Moreover, the incorporation of instrumental techniques has better-prepared students for the demands of modern analytical laboratories and research settings.

An essential aspect of the project's success lies in its adaptability and accessibility. The digital nature of the tasks allows for flexible learning, enabling students to participate in self-paced and remote learning environments.

CONCLUSION

The successful implementation of the DigiLabAC project not only addressed the immediate challenges posed by the COVID-19 pandemic but also paved the way for a transformative approach to analytical chemistry education. By leveraging digitalization, the project has unlocked new avenues for enhancing the learning experience, fostering student interests, and promoting scientific research within the field of analytical chemistry.

The development of the online platform with accompanying materials has truly enriched the educational experience by enabling remote teaching, student engagement, and innovating the learning process. The project results can be used by other universities facing similar teaching challenges, highlighting the transformation of traditional educational approaches.

The outcomes of the DigiLabAC project mark a significant step forward in analytical chemistry education. By accepting the power of digitalization, the project has provided students with an improved and innovative learning experience, providing them with the necessary knowledge and skills to face real-world analytical challenges. Collaboration between educators, researchers, and students will be vital in refining and expanding this transformative approach to analytical chemistry education.

The incorporation of digital technologies in the field of analytical chemistry within higher education has the potential to advance Sustainable Development Goals (SDGs) and Higher Education for Sustainable Development (HESD). This is an additional opportunity for ensuring the DigiLabAC project results sustainability.

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FLAME RETARDANTS: A CONDENSED REVIEW OF ENVIRONMENTAL IMPACTS AND POSSIBLE SUSTAINABLE ALTERNATIVES

Golubović T.[1], *Živković S.*[1], *Rađenović T.*[1]

[1] University of Niš, Faculty of Occupational Safety, Čarnojevića 10a, Niš, Serbia (e-mail: tatjana.golubovic@znrfak.ni.ac.rs)

Abstract: The widespread usage of plastic-based products since the mid-twentieth century was associated with an increasing concern related to fire safety. As plastics with high hydrogen-carbon content are more flammable than previously used materials, the request for better fire safety has increased. Having in mind that fires result in loss of lives, livelihood, property damage, as well as economic loss, one of the solutions was to incorporate flame retardants into the polymer materials. Flame retardants are a heterogeneous group of structurally and physico-chemically different chemicals. They can be classified into two major groups, inorganic and organic (halogenated and organophosphate) compounds. Flame retardants are beneficial, but, not all of them are environmentally safe. Based on that fact, some governmental institutions enforced regulations that prevent the production and utilization of some halogenated flame retardants. The regulations, on the other hand, imposed the use of green, bio-based, and sustainable flame retardants and accordingly increased their demand.

Keywords: *flame retardants; sustainability; environmental safety; toxicity; environmental management.*

INTRODUCTION

The permanent use of plastics in structures, the automotive industry, and various industrial and commercial applications has significantly increased the production volume in recent years. According to Plastic Europe's 2022 report, the global production of plastics (including fossil-based, post-consumer recycled, as well as bio-based plastics) has been growing continuously from 2018 until 2021 (Plastic Europe's 2022 report, 2022). After stagnation in 2020 due to the Covid-19 pandemic, global plastics production increased to 390.7 million tonnes in 2021. In 2021, China reached almost one-third of the world's plastics production (32%). Due to serious fire hazards and the high fuel values of plastics, there is a need to use flame retardants to meet suitable fire standards. According to a 2020 market study by IHS Consulting, the consumption of flame retardants has grown significantly in the past 4 years (Flameretardants-Online). Also, a further increase is predicted until 2025 (with a growth rate of 2.7% annually). Asia consumed the largest amount of flame retardants in 2019 with a contribution of 51%. The major individual consumer was China (27%). Based on a 2020 market study by IHS Consulting, the most frequently used FR is aluminum hydroxide (38%). Organophosphate flame retardants (OPFRs), including three classes of halogenated alkyl-OPFRs, aryl-OPFRs, and alkyl-OPFRs, are largely used (18%). Halogenated flame retardants (brominated - 17% and chlorinated - 4%) account for 21%, although they are prohibited in many countries due to their adverse effect on the environment and human health. However, they are still in use in significant amounts, especially in Asia. The world consumption of flame retardants in 2019 is presented in Figure 1 (different regions) and Figure 2 (different types of flame retardants).

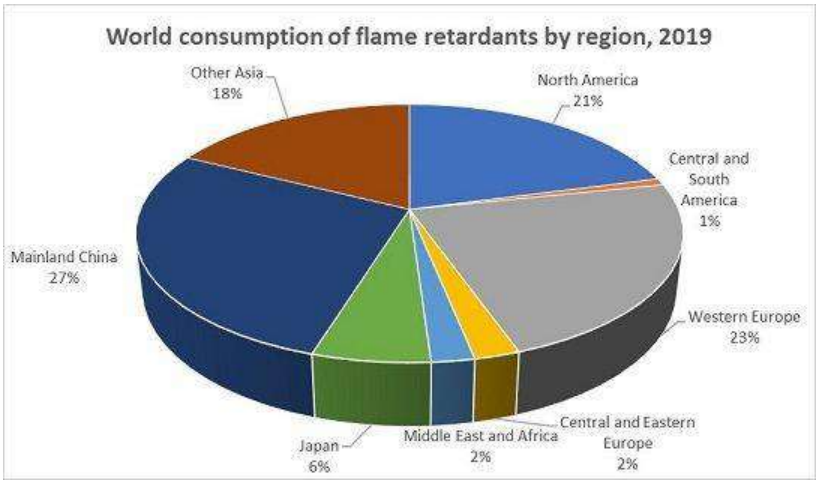

Figure 1. World consumption of flame retardants by region, 2019 (Flame retardants-Online)

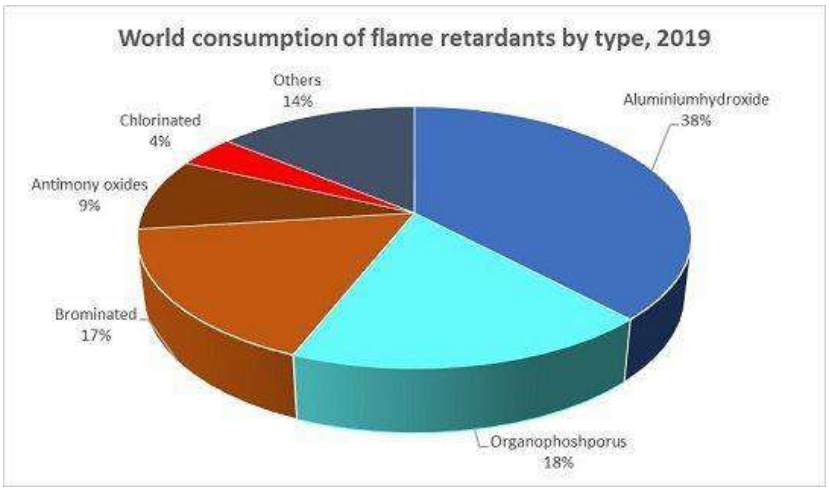

Figure 2. World consumption of flame retardants by type, 2019 (Flame retardants-Online)

Flame retardants are a heterogeneous group of structurally and physico-chemically different chemicals. More than 175 commercial FRs are available on the market. They inhibit or delay the spread of fire by suppressing the chemical reactions in the flame or by the formation of a protective layer on the surface of a material. Flame retardants can be used as additive as well as reactive. Additive flame retardants are included in the polymer before, during, or after polymerization, without chemical bonding. As a result, they may be released from the polymer to the environment. Reactive flame retardants are added during the polymerization process and become a structural part of the polymer. The result is a modified polymer with flame-retardant properties and a different structure in contrast to the native polymer molecule. This prevents flame retardant release from the polymer and keeps the flame retardant properties intact over time with low emissions to the environment (Harju, 2008; Lassen, 1999). Mineral flame retardants are typically additive, while organohalogen and organophosphorus compounds can be either reactive or additive.

ENVIRONMENTAL IMPACT OF FLAME RETARDANTS

Despite the fact that flame retardants are effective in improving the fire performance of plastics, they have been the subject of concern regarding environmental issues.

Brominated flame retardants (BFRs) are increasingly present in the environment (Figure 3). The adverse effects of these chemicals can be connected to their persistence, bioaccumulation, and biomagnification potential (Eljarrat, 2004). However, in some environmental conditions, a number of abiotic and biotic processes can affect the mentioned characteristics.

As additives, polybrominated diphenyl ethers (PBDEs) are physically mixed into product applications, rather than chemically bound. Therefore, they have the potential to migrate from the plastic matrix into the environment. PBDEs can be released into the air, water, and soil at places where they are produced or used. The important characteristics of PBDEs, persistence, low water solubility, high binding affinity to particles, and a tendency to accumulate in sediments, explain their fate in the environment.

PBDEs as semivolatile substances get into the atmosphere as a result of combustion from domestic and industrial sources, emissions from waste incineration, as well as from illegal and legal e-waste landfills.

The occurrence and atmospheric behavior of PBDEs depend on the environmental conditions, amount, composition, and size of suspended particles, as well as the physicochemical characteristics of a particular PBDE congener. Deposition of PBDEs has subsequently been identified in soils, and water all over the world, even in far areas including the Antarctica and Arctic.

Aquatic environments are exposed to PBDEs not only through atmospheric deposition but also through effluent and sewage sludge from wastewater treatment plants and landfill leaches (Aigars, 2017; Klinčić, 2020). Owing to their low vapor pressure, low water solubility, and high octanol/water partition coefficient, PBDEs are, in aquatic environments, adsorb onto the organic fraction of sediments, suspended particulate matter, or enter aquatic organisms. The highly lipophilic properties of these compounds enable them to absorb into the fatty tissues of living organisms and bioaccumulate through the various levels of the food chain.

The concentration levels of semi-volatile organic compounds in soil and air are highly influenced by air–soil gas exchange and atmospheric deposition, which may partly affect the regional or global transport/fate of semi-volatile organic compounds (Golubović, 2020; Cetin, 2019; Tombesi, 2017). Atmospheric deposition is an important pathway of semi-volatile organic compounds to the soil surface in remote areas. Atmospheric deposition of PBDEs in different areas (rural, urban/suburban, factory areas, lake regions, and coastal areas) has been the subject of many scientific studies (Vecchiato, 2015; Arellano, 2014). On the other hand, studies on air–soil gas exchange of PBDEs are still scarce (Degrendele, 2016). When certain amounts of PBDEs reach the soil, such sites may become PBDE sources and re-emit these substances. Dry and wet particle deposition fluxes are primarily influenced by atmospheric particle concentrations and temperature, while wet dissolved depositions are controlled by precipitation and total atmospheric concentrations. According to the measurement of atmospheric deposition and air–soil exchange fluxes of PBDEs in one of the regional background sites in Central China (Jinsha), it can concluded that the soil was an important sink for PBDEs, and atmospheric deposition played a more important role compared with air–soil gas exchange, especially particle deposition for

high-brominated PBDEs and wet dissolved deposition for lowbrominated PBDEs. Air–soil gas exchange fluxes were largely lower than deposition fluxes, indicating that the re-volatilization of PBDEs from the soil was not significant (Zhan, 2019).

Figure 3. Some pathways for environmental contamination and human exposure to BFR (Sharkey 2019)

Hexabromocyclododecane (HBCD) flame retardants are solid substances with negligible to low water solubility. Based on the available bioaccumulation and persistence data, the Environmental Protection Agency (EPA) has determined that HBCD should be classified as a persistent, bioaccumulative, and toxic chemical. HBCD has been detected in almost all environmental media and is considered to be a ubiquitous contaminant. HBCD has been detected in air at very remote sites, suggesting that it undergoes long-range atmospheric transport. Due to their hydrophobic character, HBCDs are strongly bound to solid particles such as soil, sediment, and sewage sludge. The high amounts of HBCDs in sewage sludge are a result of diffuse leaching from flame-retarded products into wastewater streams. Applying these sludges to agricultural or other land may redistribute the contained HBCD to the soil sediment compartment and further into aquatic or terrestrial food chains (Law, 2005). HBCD has been found in river sediments downstream of urban centers or known industrial sources. HBCD has also been detected in both freshwater and marine biota (Law, 2005). The main intake of HBCD for the general population is from food, outdoor air, particularly near-point sources, and indoor air or dust.

Polybrominated biphenyls (PBBs) exist predominantly in the particulate phase in the atmosphere. In water, PBBs are expected to adsorb strongly to suspended solids and sediment and may bioconcentrate in aquatic organisms. As regards soil, PBBs are adsorbed to the solid phase.

Organophosphate flame retardants (OPFRs) can leach out of treated materials and exist extensively in the environment (Ding, 2017). They are found in various environmental matrices, including dust, sediment, soil, arctic air, marine surface waters, and biota samples (He, 2015). OPFRs have also been detected in both human and wildlife tissue (Yao, 2021).

In general, prediction of the transport and fate of organic pollutants (OPs) in the environment strongly depends on their partitions between different environment phases, and thus determination of these partition coefficients is essential for modeling the environmental behavior of OPFRs. As a key indicator of the partitioning of OPs between the atmosphere and terrestrial organic phases, the octanol-air partition coefficient (KOA) is recognized. Also, it has been widely used to evaluate long-distance transport and deposition of persistent organic pollutants (POPs) (Yao, 2021). KOA has been successfully applied to model the surface-air distribution of OPs to soil, vegetation, and aerosol. Therefore, KOA is an indispensable parameter for assessing environmental fate and risk assessments of OPFRs (Yao, 2021).

SUSTAINABLE AND ENVIRONMENT-FRIENDLY FLAME RETARDANTS

Despite the fact that FRs are beneficial, not all of them are environmentally safe. In recent years, some governmental institutions enforced regulations that prevent the production and utilization of halogenated FRs. Due to adverse environmental and health effects, penta- and octa-commercial PBDEs were banned by the European Union in 2004 (Prevedouros, 2004) and voluntarily phased out in the US (Ward, 2008). In 2009, commercial octa-BDE and penta-BDE were recognized as persistent organic pollutants (POPs) with the potential to cause harmful effects, why they were added to the list of POPs under the Stockholm Convention (UNEP 2009), and the deca-formulation was added in 2017. The regulations, on the other hand, imposed the use of green/eco-friendly, bio-based, and sustainable FRs and hence increased their demand (Mensah, 2022).

Sustainable FRs are produced from green or biodegradable chemicals or waste in order to minimize the environmental footprints and effects on human health while simultaneously improving the fire performance of materials. Available literature data indicate that innovative bio-based fire retardants produced from protein, phytic acid, and chitin as well as biomass waste such as rice husk, eggshells, oyster shell powder, etc. have been developed. *Phytic acid*, as a naturally occurring phosphorous-containing compound abundantly present in plant tissues, forms a char layer that prevents the spreading of flame. *Deoxyribonucleic acid (DNA)*, due to its significant content of nitrogen, and phosphate compounds, shows great FR properties. *Tannic acid (TA)* is a natural phenolic compound abundant in plants. Its characteristics of low combustion and good absorption make it useful in the flame retardant field. *Lignin* is a biodegradable polymer, which has been widely applied as a part of flame retardant systems in polymers. *Chitin* (the second most abundant biopolymer in nature) has a wide application prospect in the field of flame-retardant polymers because it contains both amino and hydroxyl groups in its molecule. However, chitin is difficult to dissolve and modify, which limits its application in flame retardants.

As mentioned previously, some biomass waste (e. g. chicken eggshell) is a valuable resource in the fire-retardant business. Chicken eggshell is a useful bio-filler made from chicken eggshell waste. It has high thermal stability in bulk, contains 95% calcium carbonate in the form of calcites and 5% organic matter, it is lightweight, which makes it a cost-effective and ecologically beneficial choice. Also, coffee biowastes could potentially be useful in flame retardancy due to their composition (lignin, cellulose, and hemicellulose), which have been found to be promising green flame retardants for different polymers (Vahabi, 2021). The investigation of Bigdeloo and coworkers emphasized the significance of visionary management of food industry biowastes such as spent coffee ground biowastes (Bigdeloo, 2021). As discussed previously, there are serious

health and environmental concerns about the use of conventional FRs. Life cycle analysis (LCA), as an environmental management technique for evaluation of the environmental (including toxicity) impacts of a product over its entire life cycle, has been used to evaluate the environmental impacts of conventional and bio-based fire retardants (Samani, 2020).

Degradation of bio-based FRs in the recycling process drastically reduces emissions of GHG gases compared to the conventional FRs.

From an economic point of view, it is important to note that the application of biomass products reduces costs since these are usually waste products.

CONCLUSION

Flame retardants are produced to prevent fires and thus can have a direct and evident benefit. Despite these benefits, there are concerns regarding the potential environmental and health impacts of flame retardants. The adverse effects of these chemicals can be connected to their persistence, bioaccumulation, and biomagnification potential. Due to adverse environmental and health effects, some of them were banned and recognized as persistent organic pollutants (POPs) with the potential to cause harmful effects, why they were added to the list of POPs under the Stockholm Convention. The regulations, on the other hand, imposed the use of green/eco-friendly, bio-based, and sustainable flame retardants and hence increased their demand. Sustainable flame retardants are produced from green or biodegradable chemicals or waste in order to minimize the environmental footprints and effects on human health while simultaneously improving the fire performance of materials. Some sustainable biobased FRs for plastic materials are phytic acid, tannic acid, deoxyribonucleic acid (DNA), etc., as well as coffee waste, and eggshells. From the sustainability point of view, the use of biowaste materials in flame retardant systems can be considered a promising solution to waste disposal. From an economic point of view, it is important to note that the application of biomass products reduces costs since these are usually waste products. Finally, it can be concluded that the use of sustainable flame retardants will be a link between economic growth, environmental safety, and health.

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CONSTRUCTED WETLANDS: CRITERIA AND TOOLS RELATED TO IMPLEMENTATION & SOCIAL SUSTAINABILITY PLANNING

Grabić J.[1], Srđević Z.[1], Benka P.[1], Antić S.[1], Ilić M.[1], Vranešević M.[1]

[1]University of Novi Sad, Faculty of Agriculture, Department of Water Management, Trg D. Obradovića 8, 21000 Novi Sad (e-mail: jasna.grabic@polj.edu.rs)

Abstract: The generation of wastewater and the need for its treatment represent an imperative for present efforts in environmental protection. Lately, more attention has been paid to Nature-based Solutions and constructed wetlands as a way to treat wastewater. Apart from the fact that these solutions are efficient in effluent removal, eco-friendly, and fit the environment of the lowland landscape of Vojvodina, for implementation planning additional elements are necessary to be taken into account. These elements include spatial analyses for finding proper locations and examining social and economic aspects by conducting surveys and upon it further analyses to reach social acceptability. The paper provides a review of existing tools and approaches which are necessary to be taken into account for a comprehensive overview of the problem of implementation within the Vojvodina region, Serbia.

Keywords: *nature-based solution (NbS); wastewater purification; geographic information system (GIS); decision-making process; stakeholders.*

INTRODUCTION

The growing human population and the wastewater it generates are becoming one of the main issues in environmental protection. Although, in developed countries, conventional energy-consuming wastewater treatment (WWT) systems/facilities represent a standard, a few decades ago more attention was paid to cheaper, low energy-consuming systems which are belonging to Nature-based Solutions (NbS) (Saquib et al., 2022). These NbSs use using potentials of living organisms, i.e. photosynthetic organisms and bacteria to absorb nutrients and degrade or immobilise other important pollutants from wastewater. The applicability and design of such NbS differ according to the character of wastewater, and available space within the landscape. One of the most frequently used solutions is constructed wetlands (CWs). These solutions also vary in construction, size, and the choice of used plant species, which are core for the water purification process (Vimazal, 2010). However, apart from the selection of the appropriate design of a CW, for successful wastewater purification, it is simultaneously important to reach the goal of social sustainability. Therefore, for the fulfillment of the second role, the right choice of location within the landscape (Grabić et al., 2020), as well as investigating the social environment is of extreme importance (Grabić et al., 2021). In this process consultation, public debate, or any other way of stakeholders' survey is crucial. In general, it seems that, besides the criteria of pollution removal efficiency, other criteria necessary for CW implementation include choice of location and social aspect – social acceptability.

The paper aims to present all criteria necessary to be taken into account and actions to be conducted to reach the goal of a CW's long-term efficiency and sustainability in operation for its implementation in the Vojvodina region, Serbia.

CRITERIA RELATED TO CWS EFFICIENCY OF POLLUTION REMOVAL

The method of CWs has been widely investigated during the past few decades, both in terms of efficiency and different construction designs. In Serbia, the first and the most durable CW represents a facility established in 2004 next to the Gložan settlement (nearly 2000 PE), located near the Danube bank, in the south part of the Bačka district, Province of Vojvodina. Dundjerski et al. (2015) monitored the sustainability of the Gložan CW, based on the characteristics of effluents. The investigated facility was designed as a three-segment reed bed (*Phragmites australis* (Cav.) Trin. ex Steud.) with horizontal subsurface flow. The quality of effluents concerning total suspended solids (TSS) and 5-day biochemical oxygen demand (BOD5) after the first 8-year exploitation period has not been compromised. The efficiency of pollutant reduction for TSS was 93–96% and the reduction of organic compounds, expressed in terms of BOD5, was in the range of 79–84%. However, the efficiency of purification depends widely on a type of CW. The review made by Vymazal (2010) considered different types of CWs, i.e. designed as free water surface CWs, with vertical flow and horizontal subsurface flow. It encompasses the most important parameters for the WWT process, such as total nitrogen (TN), total phosphorus (TP), total ammonia (NH4-N), BOD_5, and TSS. The efficiency of removal was 33-58% for TN, 34-56% for TP, 39-73% for NH4-N, 72-90% for BOD_5, and 75-89% for TSS. Nevertheless, the efficiency of pollution removal is influenced by climate conditions and varies throughout the calendar year. During the vegetation period, i.e. March-October, vigorous plant growth contributes to the efficiency of WW purification. In the non-vegetation part of the year, since influent contributes to maintaining higher temperatures than in the surrounding, microbiological components are still active and mainly responsible for WW purification. In addition, apart from nutrients CWs are proven to be successful in removing heavy metals and enteric pathogens (Odinga et al., 2013), pharmaceuticals and personal care products (Kumar et al., 2022), different dyes from textile wastewater (Saeed and San, 2013), etc.

SUITABILITY OF LOCATION SELECTION WITHIN THE LANDSCAPE

A flat landscape intersected by the dense hydrographic network is the most emphasized feature of the Pannonian part of Serbia, the Vojvodina Province. Edges of water bodies are marshy and overgrown with wetland plants. There, marshy vegetation forms dense uniform stands simultaneously, providing nesting places for birds and shelter for other organisms. Common reed, an indigenous species for the region, is the dominant species that overgrows moist areas. Concerning the fact that the same plant species is the most frequent plant in CWs, these WWT facilities are well-fitting the landscape of the region (Josimov-Dundjerski et al., 2013; Josimov-Dundjerski et al., 2015; Garbić et al., 2021). In addition, the majority of settlements are below 5000 PE. This fact is also favorable for the implementation of CWs since these facilities are suitable for smaller effluent discharges of decentralized type (Ibrahim and Shirazi, 2021).

Apart from this general outlook on suitability for establishing CWs within Vojvodina province, for more accurate determining the location of CWs for cases of individual settlements a more accurate spatial analyses has to be performed. This can be easily resolved by the application of a geographic information system – GIS. This system is intended for spatial data processing through operations of collecting, storing, handling, analysis, and presentation of data (Grabić et al., 2020; Grabić et al., 2021). The main criteria for positioning CWs could include the following spatial features:

· *Distance from a settlement* – Cost-saving request, a CW had to be in the vicinity of a settlement;

· *Distance to water bodies* – To be close to the watercourse, where purified wastewater will be discharged;

· *Land use* – After the exclusion of arable land, the aim is to choose between abandoned areas or those covered by grass (namely, unsuitable for cultivation) and

· *Elevation* – When building any WWT facility, it must be positioned at a lower altitude than the settlement, thus enabling the free low-pressure gravitational flow of wastewater through the sewage network until the WWTF.

SWOT ANALYSES AND SOCIAL ACCEPTABILITY & SUSTAINABILITY

There is no doubt that CWs possess many advantages even in comparison to conventional WWTP. Their efficiency in operation is proven and environmental suitability is also an argument for the implementation being the NbS. However, there are also some weak sides and threats which need to be taken into account during the planning of the implementation process. In this manner, there were recent attempts to analyze pros and cons related to CWs (Srdjevic, et al., 2017; Ibrahim et al., 2021; Stefanakis, 2020). One of the methods often used for analyzing issues related to the organization or properties of some other phenomenon is the SWOT method.

SWOT analysis is comprised of 4 parts/categories and for each of them a list of factors affecting one issue has to be provided. The categories address addressing positive or negative effects of some phenomena and simultaneously focus either on internal or external surroundings. In this respect the categories are the following: *strengths* – S (positive, internal), weaknesses – W (negative, internal), *opportunities* – O (positive, external), and *threats* – T (negative, external). The obtained lists for each category could be subjected to further analysis such as multicriteria analysis of a water management system (Srdjevic, et al., 2017). In this paper, we tried to summarize all important criteria necessary for the implementation of CWs in the climate and social environment regarding Vojvodina by the application of SWOT analyses (Figure 1).

Strengths ● satisfactory removal of polluting substances ● eco-friendly ● zero or low energy input ● easy maintenance ● buffering changes in WW composition	**Weaknesses** ● winter low temperatures lead to a decrease in pollutant efficiency removal ● accidental release of harmful substances might imbalance the system ● occasionally unpleasant odor
Opportunities ● fitting the landscape ● removes CO_2 and generates O_2 ● harvesting and reusing plants can generate income ● increases the biodiversity of the landscape	**Threats** ● mismanaged CWs might lead breeding of undesirable insects or rodents which might represent vectors for diseases transmission

Figure 1. SWOT analyses of CWs implementation concerning the region of Vojvodina

The results of the SWOT analyses indicate that the most prominent *strengths* are the removal of polluting substances within satisfactory limits and the capability to buffer changes in WW composition; low energy consumption (in some cases it might be even "0") and easy maintenance, as well as eco-friendly nature of the facility itself. Among the *opportunities* are the identified possibility of capturing CO2 and producing O2, fitting the landscape, and increasing biodiversity. In addition, there is a possibility of generating income by utilizing harvested read plants. Concerning *weaknesses*, due to low temperatures in winter the system has a deceased capability of pollution removal, and problems may arise if some harmful substances enter the system. The biggest *threat* is inhabiting the facility with undesirable insects, such as mosquitoes, or other animals e.g. rodents, which are potential vectors for transmitting diseases.

To examine the important criteria for the implementation of a CW to treat municipal WW from a village, a survey was conducted involving 14 stakeholders of different professional orientations (Grabić et al., 2020). The respondents were given a list of 6 criteria related to a CW implementation and their task was to rate them on a scale of 1 to 100. The criteria were the following:

1. The area CW occupies
2. Efficiency of the purification process
3. Costs of building and installation of a CW
4. Auxiliary objects and infrastructure (access roads, pipelines, forested protective wind belts, etc.)
5. Exploitation costs (including energy consumption for pumps and electricity, periodic maintenance of infrastructure and plants)
6. Several permanent employees, i.e. labor

The results of the survey showed that the most important criterion was the efficiency of purification with 49 points, followed by costs of building and exploitation with 14 points; auxiliary objects and exploitation costs won 8 points and the area CW occupies was followed by 7 points. Figure 2 presents a word cloud (done in WorlCloud.com) formed according to the results obtained from the survey.

Figure 2. World cloud indicating the most important criteria for implementation of a CW according to stakeholders' opinion

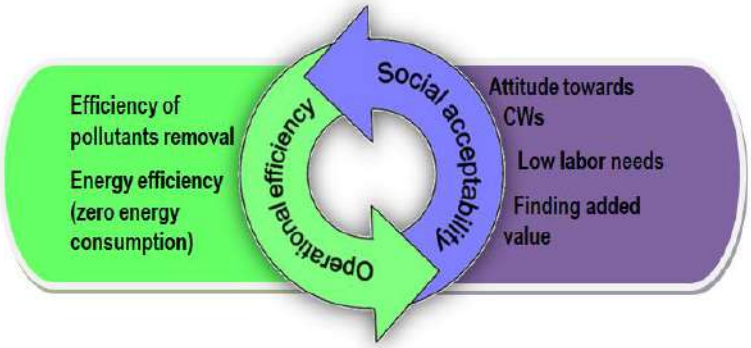

Figure 3. The interrelatedness of the two components necessary for successful CWs establishing & sustainability

For the above-mentioned, the issue of implementation of CWs is not only a question of the efficacy of effluent removal but represents a more complex scheme including many social-economic issues and overall social acceptability reflected through stakeholders' attitudes and operational efficiency, which includes economic aspects (Figure 3). Therefore, further in-depth analyses can incorporate the application of different decision support systems (multi-criteria decision-making) which allow the analysis of CWs construction details (Srdjević et al., 2012), but also other important socio-economic issues (Srdjevic et al., 2017; Grabić et al., 2020).

CONCLUSION

Wastewater treatment by CWs is a promising solution especially since it is one of NbS where natural processes represent core for the pollutant removal. Besides, these solutions fit the landscape of Vojvodina province and are suitable for decentralized WWT effluents of small settlements. Apart from the efficiency of pollutant removal and construction design, during the process of implementation planning, it is of equal importance to consider location selection and socio-economic factors. For performing spatial analyses GIS tools represent crucial instruments, while regarding social and economic issues conducting surveys among stakeholders and applying multicriteria decision support tools contributes to finding solutions that would fit to implementation of a CW within a certain landscape and given socio-economic environment.

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MATERNITY PROTECTION - ANALYSIS, CHALLENGES AND PERSPECTIVES

Ilić Petković A. [1], *Stratijev M.* [2]

[1]University of Niš, Faculty of Occupational Safety in Niš, Čarnojevića 10a, Niš, Serbia, (e-mail: aleksandra.ilic@znrfak.ni.ac.rs)

[2] Attorney at law, Vojvode Tankosića 10/54, Niš, Serbia

Abstract: This paper provides an analysis of the legal protection of maternity and parenthood with a focus on legislation, policies, and legal mechanisms aimed at ensuring equal labor rights for employed pregnant women, women in the postpartum period, nursing mothers, as well as employed parents with certain family responsibilities. Through the analysis of relevant international and national legal sources, we examine the valid legal protection of these categories of employees.

The research results show that maternity and parenthood protection is present in international legal sources, primarily the United Nations, the International Labor Organization, and the Council of Europe. The protection of these categories of employees is also guaranteed by the labor legislation of the Republic of Serbia, which establishes a whole series of legal institutes that protect maternity and parenthood. With a critical review of the current legislation in this area, this paper gives a deeper insight into maternity and parenthood protection and provides guidelines for further research. Also, we propose some specific actions in this area, such as the reform of regulations.

Keywords: *maternity; parenthood; legal regulations; occupational safety.*

INTRODUCTION

Employee protection is one of the most important tasks of an employer. Occupational safety can be divided into two types - general and special. General occupational safety includes measures, means, and activities that protect the safety and health of employees, regardless of the place and nature of their work. Special occupational safety is aimed at protecting the health and safety of certain categories of employees. In addition to the general, it provides specific protection of certain sensitive categories of employees. One of the most significant forms of special occupational safety is the protection of women (maternity) and the protection of parenthood (Ilić Petković, 2020). Maternity protection in the workplace is a vital element in ensuring women's and children's well-being (Stumbitz et al, 2018).

This issue has been recognized by relevant international organizations - International Labor Organization, European Union, Council of Europe. The most significant document of the International Labor Organization in this area is the Maternity Protection Convention (No. 183) (Misailović, 2020). An important regulation of the European Union is Directive 92/85/EEC on the introduction of measures to encourage improvements in the safety and health at work of pregnant workers and workers who have recently given birth or are breastfeeding (Popović, 2018), and the Revised European Social Charter of the Council of Europe (Misailović, 2020).

The legislation of the Republic of Serbia guarantees the protection of working women in the context of parenthood and family obligations through a series of regulations, starting with the Constitution, which explicitly guarantees special protection at work for these employees (Constitution of the Republic of Serbia, 2006). The basic law that defines and regulates maternity

and parenthood is the Family Law (Family Law, 2005). This is also the basic legal document regulating marital and family relations in the Republic of Serbia, including marriage, marital relations, cohabiting relations, child-parent relations, adoption, foster care, guardianship, financial care, property relations in the family, protection from domestic violence, actions related to family relations and personal name. In the context of labor law protection, working women and parents with family responsibilities are primarily protected by the Constitution, Labor Law, and a number of secondary legal acts. This category of employees is not specifically protected by the Law on Safety and Health at Work, but there is a regulation adopted based on this law - the Rulebook on measures for the safe and healthy work of working women during pregnancy, postpartum, and breastfeeding periods.

This paper analyses the mentioned international and national documents. We made a short critical review of certain basic and most important legal solutions that they contain. This can be a useful platform for potential regulatory reform.

INTERNATIONAL LABOR LEGISLATION

The most important legal regulation on maternity protection, which is legally binding for the Republic of Serbia, is Maternity Protection Convention No. 183 (Maternity Protection Convention, 2000). This Convention aims to ensure adequate maternity protection for women employed in all sectors. Women are guaranteed the right to paid maternity leave of at least 14 weeks. The Convention recognizes the importance of protecting women's health during pregnancy and after childbirth, including the provision of medical assistance, maintaining working conditions that are safe and healthy for pregnant women, and ensuring the right to return to the same or similar position after maternity leave. The Convention promotes non-discrimination against women on the basis of pregnancy or maternity. Employers are required not to terminate the employment of a woman due to pregnancy or maternity. Also, these reasons shall not constitute a source of discrimination in promotion and starting an employment relationship. The objective of the Convention is to ensure that women have access to working conditions that are compatible with motherhood and that they are supported in maintaining a balance between family responsibilities and professional goals. This Convention is considered an important instrument for promoting gender equality and protecting women's rights at work worldwide.

Directive 92/85/EEC on the introduction of measures to encourage the improvement in the safety and health at work of pregnant workers and workers who have recently given birth or are breastfeeding is a legislative document of the European Union related to the protection of the health and safety of pregnant and nursing women at the workplace (Council Directive 92/85/EEC on the introduction of measures to encourage improvements in the safety and health at work of pregnant workers and workers who have recently given birth or are breastfeeding, 1992). The Directive defines certain obligations of employers towards pregnant and breastfeeding women. Employers are obliged to provide appropriate protection measures to pregnant women and women who are breastfeeding in order to avoid exposure to risks that could negatively affect their health or the health of their children. They should identify working conditions and activities that could pose a risk to pregnant and breastfeeding women and take appropriate protective measures. This may include adjusting working hours, providing appropriate equipment, changing work tasks, or transferring to another suitable position. The Directive guarantees the right to paid leave during pregnancy and maternity leave, as well as the right to return to the same or similar

position after maternity leave. The Directive aims to ensure that pregnant and breastfeeding women have fair working conditions and occupational safety and health, which contributes to their well-being, as well as the well-being of their children. The Directive promotes a balance between professional engagement and motherhood and ensures protection against discrimination in the workplace based on pregnancy or maternity status.

With regard to the Council of Europe, the Revised European Social Charter from 1996 emphasizes the need for a longer period of leave due to pregnancy before and after childbirth. Instead of 12 weeks of leave before and after childbirth, which was prescribed by the European Social Charter, the Revised Charter provides 14 weeks of leave. This sets standards regarding the length of leave from work for women during pregnancy (The European Social Charter (Revised), 1996). The Revised Charter identifies protection against dismissal due to pregnancy and maternity leave as an important element of maternity protection. Employers cannot terminate an employment contract during maternity leave. It is considered unlawful to give a woman notice of dismissal in the event that the notice period expires during maternity leave. The Revised Charter extends the period of protection against dismissal, starting from the moment when the employer is informed of the employee's pregnancy, until the end of the maternity leave. This period of time is highly important in ensuring the safety and protection of maternity.

NATIONAL LABOR LEGISLATION

The protection of women related to their specific role in biological reproduction refers to pregnancy, childbirth, and motherhood. This type of protection for working women is primarily guaranteed by the Labor Law (2005). This law identifies special protection measures in such cases. Thus, during pregnancy, maternity leave, leave from work for child care, and leave from work for special child care, the employer cannot terminate the employment. If the employee has established a fixed-term employment relationship, the duration of the employment contract is extended until the expiration of the right to the aforementioned leave. During pregnancy and breastfeeding period, an employed woman cannot perform tasks that are harmful to her health and the health of the child. The employer is obliged to organize the performance of other suitable tasks, and if there are no such tasks, to send her on paid leave. During pregnancy and breastfeeding period, an employed woman cannot work overtime and at night, if such work would be harmful to her health and the health of the child. During pregnancy, an employed woman has the right to a paid leave from work during the daily working hours in order to perform medical examinations related to pregnancy. The employer is obliged to provide the employed woman who returns to work prior to the expiry of a year after the child's birth the right to one or more daily breaks during the daily working hours in total duration of 90 minutes, or the right to reduce the daily working hours for 90 minutes, in order to be able to breastfeed her child if the daily working hours amount to six or more hours. An employed woman has the right to maternity leave and leave of absence to nurse a child for a total of 365 days. On the grounds of a finding of a competent health agency, the maternity leave commences 45 days at the earliest, but imperatively 28 days prior to the time set for childbirth. Subsequently, a leave of absence for nursing a child can be used until the expiration of 365 days from the day the maternity leave commenced. The father of a child may exercise this right in the event that the mother abandons the child, dies, or is prevented from using this right for other justified reasons. For the third and each subsequent newborn child, the right to maternity leave and leave of absence for nursing a child can last two years in total.

Maternity protection refers to several rights that belong to one of the parents, regardless of gender (Labor Law, 2005). Thus, one of the parents of a child not older than three years of age may work overtime and during the night only with their own written consent. A single parent of a child not older than seven years of age or a disabled child can work overtime and during the night only with their own written consent. The employer can redistribute the working hours of an employed woman during pregnancy and an employed parent of a child not older than three years of age or a child with severe psycho-physical impairment only with their own written consent. Also, one of the parents of a child in need of special care due to a serious degree of psycho-physical impairment has the right to, upon expiry of the maternity leave and the leave of absence for nursing a child, be absent from work, or to work half of the full working hours, the longest until the child becomes five years old. When working half of the full working hours, the employee has the right to a salary, and for the other half of full working hours - salary compensation.

The Law on Safety and Health at Work does not identify employed women (pregnant women, women in the postpartum period, and mothers in general) as a category of employees who should be given special protection, which can be justified considering the content and nature of the matter it regulates (Law on Safety and Health at Work, 2023). This matter is regulated by a special rulebook adopted on the basis of the law - the Rulebook on Measures for the Safe and Healthy Work of Working Women during Pregnancy, Postpartum, and Breastfeeding period, which introduces requirements for safe and healthy work of these women (2016). It prescribes the measures that the employer applies in order to prevent, remove, and reduce the risk to the safety and health of employees. The employer is required to provide workplace inspection when there is a risk of hazards and working conditions listed in the Review of hazards and working conditions, which includes the effects on pregnancy and breastfeeding. The inspection should include the assessment of the nature, level, and duration of exposure. Consequently, a risk assessment act should be adopted in order to determine ways and measures to eliminate or reduce the risk. A pregnant woman shall not work at a workplace where a risk assessment has determined a dangerous level of exposure to hazards listed in the Review of hazards and working conditions. This Review is an integral part of the Rulebook. Physical harm and strain may pose a risk to the fetus and result in fetal injury or placental abruption. These risks can arise for various reasons. Exposure to shocks, vibrations, or sudden movements can cause injuries to the fetus. Manual handling of loads, body movements and positions, travel during work, mental and physical fatigue and other physical stresses associated with work activities can also be harmful. Biological hazards can be different and with different levels of danger to safety and health at work. As far as dangerous chemical substances are concerned, the Rulebook identifies lead and lead derivatives as harmful if absorbed. In terms of working conditions, underground work in a mine is recognized as dangerous.

Thirdly, maternity protection can be complemented by regulations on financial support to families with children, such as the Law on Financial Support to Families with Children (2017). Among other things, financial support is provided for the purpose of harmonizing work and parenthood. The rights to financial support to families with children include salary compensation during maternity leave, leave from work for child care and leave from work for special child care, other allowances based on childbirth, child care and special child care, parental allowance, etc. This Law further regulates the procedure of exercising these rights, the information system for payment, collection, updating, and storage of data, etc. This Law is accompanied by a series of by-laws.

CONCLUSION

The subject of this research was the legal protection of working women in the context of maternity and parenthood. The basic international and national documents in this area were briefly analyzed, namely: International Labor Organization – Maternity Protection Convention No. 183, European Union – Directive 92/85/EEC on the introduction of measures to encourage the improvement in the safety and health at work of pregnant workers and workers who have recently given birth or are breastfeeding, Council of Europe – Revised European Social Charter, Republic of Serbia – Constitution, Labor Law, Law on Safety and Health at Work, Rulebook on measures for the safe and healthy work of working women during pregnancy, postpartum and breastfeeding period, Law on Financial Support to Families with Children.

The research results show that maternity and parenthood protection is present in international legal sources, primarily the United Nations, the International Labor Organization, and the Council of Europe. The protection of these categories of employees is also guaranteed by the labor legislation of the Republic of Serbia, which establishes a whole series of legal institutes that protect maternity and parenthood (e.g. maternity leave, other types of leave related to parenthood, non-discrimination, etc.) (Radovanović, 2013). The aim of these documents is to provide protection against discrimination based on pregnancy and parenthood, as well as ensure the return of the employees to the same or similar position after the end of maternity leave or other similar types of leave (Paustian-Underdahl, at all, 2023). This is supported by the fact that the Labor Law prohibits the termination of employment for a certain period of time during maternity leave and leave from work for child care (Balnožan, 2021).

However, there are still certain challenges in the application of these regulations and work standards. Thus, there is a difference in the implementation of legal provisions among countries, which can lead to unequal and insufficient protection for mothers and fathers. While some countries have advanced legal norms that provide adequate support and flexibility for parents, other countries encounter difficulty in this area. In addition, there is a need for greater awareness among employers and society as a whole about the importance of supporting maternity and parenthood.

Therefore, we can conclude that further harmonization of national labor legislation with international standards of maternity and parenting protection is recommended, in order to ensure equal rights and justice for all parents. Also, it is important to continuously work to raise awareness of these issues to create a culture that supports the balance between professional and family life. Only through the joint efforts of governments, employers, unions, civil society, and scientific and professional institutions can we create an environment that provides fair and adequate maternity and parenthood protection, which will have a positive impact on the well-being of parents, children, and society as a whole. This should be a strategic commitment of our society toward improving the legal position of working women and all employees with parental responsibilities.

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LEGAL PROTECTION OF EMPLOYEES AGAINST PSYCHOSOCIAL RISKS

Ilić Petković A. [1], *Živković, S.*[1]

[1] University of Niš, Faculty of Occupational Safety in Niš, Čarnojevića 10a, Niš, Serbia (e-mail: aleksandra.ilic@znrfak.ni.ac.rs)

Abstract: This paper investigates how the protection of employees from psychosocial risks is legally regulated. Psychosocial risks are factors that can cause adverse effects on the mental and physical health of employees, as well as on their productivity, efficiency, and social relations. The aim of this paper is to analyze the literature and relevant international and national regulations and policies that regulate the protection of employees from psychosocial risks with the idea of proposing measures that employers can take to ensure a safe, healthy, and productive work environment.

Keywords: *psychosocial risks; safety and health at work; legal regulation.*

INTRODUCTION

The occupational health and safety system aims to protect employees from various types of health problems caused by work activities. The work environment has a significant impact on both the physical and mental health of employees (Ilić Petković, 2020). In recent decades, the growing importance of psychosocial factors has been recognized as a key determinant of employee health.

Psychosocial risks include factors such as stress, workload, violence at work, mobbing, discrimination, lack of support, job insecurity, and other similar situations that can negatively affect the well-being of workers. They can negatively affect the work efficiency, the quality of work, and, consequently, the productivity of the organization. This is evidenced by many studies that have been conducted (Ćirović, Bojović, 2021). For example, EU-OSHA's Enterprise Survey on New and Emerging Risks explores how psychosocial risks are perceived and managed across European enterprises, identifying the main drivers, barriers, and needs for support (EU-OSHA, 2023). The survey shows that psychosocial risks are believed to be more challenging to manage than traditional occupational safety and health risks.

The significance of this issue is proved by the fact that the International Labor Organization made a list of occupational diseases, updated in 2010, which covers mental and behavioral disorders, including post-traumatic stress disorders. EU countries tend to follow the European schedule of occupational diseases provided for under the European Commission Recommendation No. 2003/670/EC. A report published by the European Commission in 2013 reviews the situation concerning occupational diseases in EU member States and EEA/EFTA States (Hupke, 2012). The following EU countries included mental and stress-related disorders in national lists of occupational diseases: Denmark (PTSD), Hungary (diseases due to psychosocial factors), Italy (PTSD, and chronic adjustment disorders such as anxiety, depression, behavior or affective disorders), Latvia (diseases caused by overload, and psychoneurosis), Lithuania (occupational diseases due to stress), the Netherlands (occupational stress-related disorder and burnout, job-related depression, PTSD, alcohol addiction), Romania (psychoneurosis caused by long-term care of psychopathic people in psychiatric units), while in Finland mental and behavioral disorders are covered in the national disability registers (F: ICD-10) and its open system. Work-related mental

disorders are also compensated in the Swedish open system and through the complementary system in some other EU member states, such as Belgium, Denmark (for stress-related disorders other than PTSD), and France. Due to all of this, we believe that it is important to continuously monitor psychosocial risks for the safety and health of employees and actively create policy measures in this area. One of the basic measures is the legal regulation of this issue. On the international level, this is primarily dealt with by the International Labor Organization and the European Union (EU-OSHA), as the two most influential organizations in the field of safety and health at work. Their regulations and policies set the standards that member states should reach. The states themselves pass their own regulations and thus lay the foundations of occupational safety and health systems based on the frameworks set by these two organizations. For this reason, the subject of interest in this paper is the analysis of the basic documents of the International Labor Organization and the European Union in the field of protection against psychosocial risks, as well as the basic laws and by-laws of the Republic of Serbia.

IDENTIFICATION, CAUSES, AND CONSEQUENCES OF PSYCHOSOCIAL RISKS

Psychosocial risks, or PSRs, are a set of occupational risks that affect the physical or mental health of an employee. These psychological or physical concerns have a real impact on the company and its operations since they can put employees in no condition to do their jobs effectively. They are one of the recently discovered occupational diseases affecting mental health and present many risks to physical and mental health (IPAG, 2022). There are many forms of psychosocial risks. Stress, acute or chronic, can be aggravated by assignments, a work environment, or an unsuitable job. If it persists over time, stress can have an irreversible psychological effect on a person. Also, burnout is a serious depressive disorder. Employees suffering from it can no longer find meaning in their work, they are physically and morally exhausted and cannot achieve the desired results. They lose complete control over their professional life, which almost always has an impact on their personal life. Depression is characterized by a loss of interest in one's usual activities, great sadness, and low self-esteem and is often accompanied by feelings of guilt. Depression also causes fatigue and difficulty concentrating. Harassment can be sexual harassment, physical harassment, and mobbing. Bullying can be direct, indirect, collective, or individual. Harassment can contribute to burnout, depression, and stress. In the most serious cases, it can lead to suicide. Also, isolated or repeated moral or physical attacks are part of psychosocial disorders. Each of these can interact with others. It is important to understand the causes of psychosocial risks at work in order to anticipate and combat them. These include insecurity of the job and the work situation, lack of autonomy, poor relations within the company, high demands at work, too many emotional demands, and conflicts of values (IPAG, 2022).

The consequences of psychosocial risks for the safety and health of employees can be different and can relate to physical and mental health, as well as the overall well-being of employees. Some of the more frequent consequences are reduced productivity, increased absence, impaired mental health, and other negative implications. The most frequent consequences of psychosocial risks are poor mental health of employees, increased risk of burn-out at work, reduced productivity at work, increased rate of errors, bad working atmosphere, conflicts among colleagues, etc.

INTERNATIONAL REGULATIONS ON THE PROTECTION OF EMPLOYEES FROM PSYCHOSOCIAL RISKS

For this paper, we analyzed basic regulations on the protection against psychosocial risks at work of the two most important international organizations whose work is devoted to occupational safety and health - the International Labor Organization and the European Union.

The International Labor Organization has several basic regulations which refer to the protection of employees against psychosocial risks. The most important are Occupational Safety and Health Convention No. 155 (1981), Violence and Harassment Convention No. 190 (2019) and Violence and Harassment Recommendation No. 206 (2019), Hours of Work and Rest Periods (Road Transport) Recommendation No. 161 (1979). Strategies for the Prevention and Management of Psychosocial Hazards and Risks (2016) and Stress Prevention at Work Checkpoints (2012) are also relevant in this context. Occupational Safety and Health Convention No. 155 from 1981 sets a general framework for improving safety and health at work, including protection against psychosocial risks. It requires member states to adopt policies and measures to ensure a safe and healthy work environment, including the identification and mitigation of psychosocial risks. Violence and Harassment Convention No. 190 from 2019 and the accompanying Violence and Harassment Recommendation No. 206 (2019) are relatively recent. They aim to protect workers from workplace violence and harassment, including psychosocial violence and abuse. Hours of Work and Rest Periods (Road Transport) Recommendation No. 161 from 1979 provides guidelines for workload management, i.e. during working hours, in order to prevent harmful effects on the health of employees. In 2016, the International Labor Organization established Strategies for the Prevention and Management of Psychosocial Hazards and Risks and published them as guidelines to help employers, unions, and governments identify, prevent, and manage stress in the workplace. The guidelines include strategies for early recognition of stress, employee and manager training, and employee support policies. Stress Prevention at Work Checkpoints from 2012 is another help for employers and employees in dealing with psychosocial risks. Fifty checkpoints that have been established are based on the experiences of experts and they list the activities for improving safety and health at work in terms of recommendations for reducing stress at work. Those recommendations are grouped into several categories and relate to leadership, job requirements, physical environment, protection against abusive behavior, etc. All these regulations and guidelines are key instruments of the International Labor Organization for the promotion of a safe and healthy work environment, including the protection of employees from psychosocial risks. Member states of the International Labor Organization may adopt these guidelines into their national legislation to ensure better protection of workers in their territories.

Basic regulations of the European Union related to psychosocial risks at work include Council Directive 93/104/EC concerning certain aspects of the organization of working time (1993), Directive 2019/1158 of the European Parliament and of the Council on Work-Life Balance for Parents and Carers (2019) and Framework Agreement on Stress at Work (2004). Council Directive 93/104/EC concerning certain aspects of the organization of working hours, rest, and work schedule (1993) aims to ensure fair working hours in order to reduce the negative psychosocial effects of overwork and stress. Directive 2019/1158 of the European Parliament and of the Council on Work-Life Balance for Parents and Carers (2019) ensures the right to decent working conditions and a work-life balance, which can help in the prevention of stress and psychosocial problems. Framework Agreement on Stress at Work (2004), signed by the European

social partners, aims to identify, prevent, and manage stress at work. It encourages employers and unions to cooperate in creating a safe working environment. These regulations represent the basic framework for the protection of employees from psychosocial risks at work in the European Union. Each member state can additionally develop and implement its own laws and measures to ensure adequate protection of employees.

NATIONAL LEGAL REGULATION

Labor Law (2006) is the basic regulation that pertains to rights and obligations from the employment relationship. Although there is no separate article specifically referring to psychosocial risks, the Labor Law as a whole regulates the relationship between employer and employee with the aim of preserving occupational safety and health. It contains an explicit provision obliging the employer to provide the employee with safe and healthy work.

Law on Safety and Health at Work (2023) prescribes a general framework for ensuring a safe and healthy work environment for employees. It also does not contain explicit provisions on protection against psychosocial risks, but it provides a broad basis for the adoption of by-laws related to the identification and assessment of psychosocial risks, as well as the obligations of employers regarding the prevention of negative consequences for the health of employees.

Law on Prevention of Harassment at Work (2010) regulates the prohibition of work-related harassment and harassment at work, measures to prevent it and improve relations at work, the procedure for the protection of persons exposed to harassment, and other issues of importance for the prevention and protection from harassment.

The Rulebook on the method and procedure of risk assessment at the workplace and in the working environment (2006) prescribes the methodology and procedure for the identification and assessment of all types of risks at the workplace, including psychosocial risks. Employers are obliged to conduct a risk assessment and take protective measures based on the results obtained. Stress, monotony, insufficient motivation for work, conflict situations, etc. are recognized as risks that should be evaluated. This regulation can be considered the most important document for the protection of employees as it prescribes the risks that should be assessed by the employer, including psychosocial risks. Based on the risks assessed, the Act on Risk Assessment establishes concrete measures of protection at work.

Rulebook on the rules of behavior of employers and employees in relation to prevention and protection against abuse at work (2010) thoroughly regulates the behavior of employers and employees in relation to the protection of employees from abuse at work. It also prescribes the obligations of employers regarding the prevention and response in such situations.

These regulations represent the basic legal framework for the protection of employees from psychosocial risks at work in Serbia. Employers are required to comply with these laws and regulations in order to provide a safe and healthy work environment for their employees. They can, with their internal acts (labour regulations, occupational safety, and health regulations, collective agreement with the employer) guarantees broader rights than those provided by the regulations.

CONCLUSION

Psychosocial risks in the occupational safety and health system represent a significant challenge for organizations and society as a whole. Identification, assessment, and adequate management of these risks is key to creating a healthy and productive work environment. The combination of preventive measures and interventions can lead to the improvement of the mental health of employees, reduction of stress, and increase of work efficiency. The starting points for the prevention of psychosocial risks at work are the assessment of psychosocial risks at the workplace, promotion of healthy work culture, training of employees in stress and conflict management, implementation of mental health support programs, flexible work arrangements, and work-life balance. All of the above indicates that a preventive, holistic, and systematic approach to managing psychosocial risks is believed to be the most effective. Legal regulation is one of the important instruments. Regulations at the international and national level lay the foundations of the occupational safety and health system. The regulations of the International Labor Organization and the European Union mainly harmonize the rights and obligations of employers, employees, and the states themselves in these matters. National legislation further elaborates on these issues in more detail. It is adapted to specific circumstances in the country. Finally, it is up to the employers to regulate all those issues that are specific to that particular work organization with their internal acts.

Based on all of the above, it can be concluded that a comprehensive approach is necessary to protect employees from psychosocial risks at work. This implies complementary and synchronized action of the state, employers, and employees themselves (individually or through various forms of their association). Although employers have a legal responsibility to ensure that workplace risks are properly assessed and controlled, it is essential that workers are also involved. Workers and their representatives have the best understanding of the problems that can occur in their workplace. Their inclusion will ensure that the measures put in place are both appropriate and effective. When each of the mentioned subjects undertakes specific measures and activities that are within their competence, and in the context of the circumstances of the specific case, the best effects on the well-being of the employees can be expected.

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APPLICATION OF ANALYTIC HIERARCHY PROCESS FOR MULTI-CRITERIA DECISION-MAKING IN RANKING OF ENERGY SOURCES

Javor D.[1], Krstić D.[2], Raičević N.[3]

[1]University of Niš, Faculty of Occupational Safety, Department of System Research in Safety and Risk, Čarnojevića 10a, 18000 Niš, Serbia (e-mail: dario.javor@znrfak.ni.ac.rs)

[2]University of Niš, Faculty of Occupational Safety, Department of Energy Processes and Safety, Čarnojevića 10a, 18000 Niš, Serbia

[3]University of Niš, Faculty of Electronic Engineering, Department of Theoretical Electrical Engineering, Aleksandra Medvedeva 14, 18000 Niš, Serbia

Abstract: The Analytic Hierarchy Process (AHP) is applied to obtain the weights of criteria in multi-criteria decision-making (MCDM) for the microgrid's generators ranking. The economic criteria for this problem are operational, maintenance, and fuel costs (OMF costs) and the environmental criteria are emissions of harmful gasses CO_2, SO_2, NO_X, CO, and particulate matter (PM). The 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 as multi-criteria optimization methods for the ranking of four energy sources: diesel generator, microturbine, fuel cells, and the main grid. Microturbine is the best-ranked energy source from the environomic (environmental/economic) point of view by all MCDM methods.

Keywords: *distributed energy sources; environomic criteria; microgrids; multi-criteria optimization methods; weighting methods.*

INTRODUCTION

Microgrids are relatively small electricity infrastructures with defined electrical boundaries, usually installed in small geographic areas, that can operate connected to the main grid at the distribution voltage level, or in an islanded mode. Microgrids require sophisticated energy management systems (EMS) because they have to operate efficiently and optimally while using real-time control of the distributed energy resources (DERs). They usually include non-dispatchable DERs such as photovoltaic panels and/or wind generators, and dispatchable DERs such as gas turbines, microturbines, fuel cells, gas and diesel internal combustion engines (ICEs), etc. If photovoltaic or wind generators do not provide enough energy for the microgrid or the energy can be sold to the main grid at higher prices, dispatchable DERs have to be used. The criteria for their starting, shutting down and intervals of operation 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.

The weights of environomic criteria depend on the microgrid owner's economic strength and a goal or obligation to meet the requirements for environmental protection, on government's regulations, feed-in-tariff for the generation option, penalties for the release of harmful gases at the given location of the microgrid, etc. These weights can be estimated based on the decision maker's preferences. However, in the decision-making process using multi-criteria optimization,

determining the weights of criteria plays an important role. Weighting coefficients for the chosen environomic criteria (as the alternatives' attributes) can be calculated by some of the weighting methods. For their determination, there are a large number of methods that can be grouped into subjective, objective, and integrated or hybrid methods (Şahin, 2021). Subjective methods use only subjective evaluations of criteria defined by the decision maker. These methods include Linear programming techniques for multi-dimensional analysis of preferences (LINMAP), the Delphi method, Analytic hierarchy process (AHP), (Saaty, 1986), Simple multi-attribute rating technique (SMART), Point allocation, Direct rating, Best–worst method (BWM), (Rezaei, 2015), and other. Objective methods can prevent errors in the assessment of criteria. They use mathematical models and data without taking into account the decision-maker's preferences. These methods include Criteria importance through inter-criteria correlation (CRITIC), Method of maximizing deviation, Standard deviation, Mean weighting, Entropy (Xu, 2004), and others. Hybrid or integrated methods combine the decision maker's preferences with the result of an objective method to obtain criteria weights and use the advantages of both types of methods.

In this paper, the subjective method AHP is used for the chosen microgrid's problem, as the decision maker's preferences are the most important in this case. After obtaining the criteria weights, multi-criteria decision-making (MCDM) methods are used. The often used methods are Elimination and Choice Translating Reality (ELECTRE), (Roy, 1968); Preference Ranking Organization Method for Enrichment of Evaluations (PROMETHEE), (Brans, 1982), (Brans, Mareschal, Vincke, 1984); Technique for Order Performance by Similarity to the Ideal Solution (TOPSIS), (Hwang, Yoon, 1981), (Hwang, Lai, Liu, 1993), analyzed in the review paper (Huang, Keisler, Linkov, 2011); Multicriteria optimization compromise solution (in Serbian: Višekriterijumska optimizacija i kompromisno rešenje – VIKOR), (Duckstein, Opricović, 1980), (Opricović, Tzeng, 2004, 2007), used in (San Cristóbal, 2011) for the selection of renewable energy projects; Weighted Sum Method (WSM); Weighted Product Method (WPM); Organization, Storage, and Synthesis of Relational Data (ORESTE), etc.

The AHP method is used for weighting the six criteria: operational, maintenance, and fuel (OMF) costs, emissions of gasses CO_2, CO, SO_2, NO_X, and particulate matter (PM).

Afterward, PROMETHEE, TOPSIS, and VIKOR methods are used as MCDM methods to select the best among the four alternatives of energy sources in the microgrid: microturbine, fuel cells, diesel generator, and main grid. The results of the three combinations of methods (AHP-PROMETHEE, AHP-TOPSIS, AHP-VIKOR) are presented in this paper. The best choice is the microturbine, with respect to the chosen criteria evaluation by AHP.

PROBLEM DEFINITION

Microgrids usually have a variety of distributed energy resources and EMS has to take into account their characteristics. Some important characteristics are given in Table 1 (EPRI report, 2003), (Marti, 2005), (SEE Power Exchange, 2022), and taken as criteria for the ranking of generators. These data are used in (Javor, Krstić, Raičević, 2023).

Table 1. Alternatives of energy sources in the microgrid and their characteristics.

	OMF costs ($/kWh)	CO_2 emissions (g/kWh)	SO_2 emissions (g/kWh)	NO_x emissions (g/kWh)	CO emissions (g/kWh)	PM emissions (g/kWh)
Diesel generator (DG)	0.15	697	0.22	0.5	1	0.2
Microturbine (MT)	0.11	670	0.0036	0.186	0.4	0
Fuel cell (FC)	0.242	441	0.0022	0.0136	0.01	0.01
Main grid (MG)	0.2	889	1.8	1.6	0.01	0.3

RESULTS OF THE WEIGHTING METHOD AHP

AHP enables the determination of weighting coefficients of criteria based on subjective evaluations and comparison of the attributes of different alternatives.

In the first step, pairwise comparisons of the criteria for the alternatives are made, based on the scale with grades from 1 to 9, and the relative importance of the attributes at each level is determined. Grade 1 means equal importance of both attributes and greater grades mean more importance. To determine the weight of attributes using AHP, a pairwise comparison matrix is formed. The matrix A is of dimension n x n for n criteria. Each element of the matrix a_{ij} indicates the relative preference of the i-th criterion in relation to the j-th criterion. For the selected example, there are six criteria: A_1 (OMF costs), A_2 (CO_2), A_3 (SO_2), A_4 (NO_x), A_5 (CO) and A_6 (PM emissions). The comparison matrix of these criteria is given in Table 2.

In the second step, the normalized matrix of criteria comparison A^N is formed (Table 3). Each element a_{ij} of the criterion comparison matrix A is divided by the sum of the elements of the matrix A of the corresponding j-th column to obtain the element a_{ij}^N of the normalized matrix A^N.

In the third step, the weights of the criteria CW_i, for $i = 1, \ldots, 6$, are determined as the mean values of the i-th row elements of the A^N matrix.

In the fourth step, the consistency of the solution is checked. Each element a_{ij} of the matrix A is divided by the weight of the criterion CW_j and thus the elements a_{ij}^C of the consistency matrix A^C are obtained, which are given in Table 4.

Table 2. Pair-*wise* comparison matrix A.

	A_1 (OMF)	A_2 (CO_2)	A_3 (SO_2)	A_4 (NO_X)	A_5 (CO)	A_6 (PM)
A_1 (OMF)	1	3	4	5	9	8
A_2 (CO_2)	0.333	1	2	3	7	6
A_3 (SO_2)	0.250	0.500	1	2	5	3
A_4 (NO_X)	0.200	0.333	0.500	1	4	3
A_5 (CO)	0.111	0.143	0.200	0.250	1	0.500
A_6 (PM)	0.125	0.167	0.333	0.333	2	1

Table 3. Normalized matrix of criteria comparison A^N.

	A_1 (OMF)	A_2 (CO_2)	A_3 (SO_2)	A_4 (NO_X)	A_5 (CO)	A_6 (PM)
A_1 (OMF)	0.495	0.583	0.498	0.432	0.321	0.372
A_2 (CO_2)	0.165	0.194	0.249	0.259	0.250	0.279
A_3 (SO_2)	0.124	0.097	0.124	0.173	0.179	0.140
A_4 (NO_X)	0.099	0.065	0.062	0.086	0.143	0.140
A_5 (CO)	0.055	0.028	0.025	0.022	0.036	0.023
A_6 (PM)	0.062	0.032	0.041	0.029	0.071	0.047

Table 4. **Consistency** matrix A^C.

	A_1 (OMF)	A_2 (CO_2)	A_3 (SO_2)	A_4 (NO_X)	A_5 (CO)	A_6 (PM)
A_1 (OMF)	0.450	0.698	0.558	0.496	0.282	0.377
A_2 (CO_2)	0.150	0.233	0.279	0.297	0.220	0.283
A_3 (SO_2)	0.113	0.116	0.139	0.198	0.157	0.141
A_4 (NO_X)	0.090	0.078	0.070	0.099	0.125	0.141
A_5 (CO)	0.050	0.033	0.028	0.025	0.031	0.024
A_6 (PM)	0.056	0.039	0.046	0.033	0.063	0.047

Table 5. Weighted summary values WSV_i, criteria weights CW_i, and consistency ratios CR_i, for i = 1, … , 6.

A_i	WSV_i	CW_i	CR_i
A_1 (OMF)	2.861	0.450	6.357
A_2 (CO_2)	1.461	0.233	6.271
A_3 (SO_2)	0.865	0.139	6.221
A_4 (NO_X)	0.603	0.099	6.093
A_5 (CO)	0.191	0.031	6.157
A_6 (PM)	0.284	0.047	6.051

Weighted summary values WSV_i, criteria weights CW_i, and criteria consistency ratios CR_i, for i = 1, … , 6, are given in Table 5. The mean value of the criterion consistency ratios:

$$\lambda_{\max} = \sum_{i=1}^{6} \mathrm{CR}_i \tag{1}$$

determines the consistency index (CI):

$$\mathrm{CI} = \frac{\lambda_{\max} - n}{n-1}, \tag{2}$$

where n is the number of criteria. In the chosen example n = 6, $\lambda_{\max} = 6.192$, so that CI = 0.038. The relative consistency index (CR) is determined as the ratio of the consistency index CI and the randomness index (RI) according to the relationship:

$$\mathrm{CR} = \frac{\mathrm{CI}}{\mathrm{RI}}, \tag{3}$$

where RI is taken from the table determined by (Saaty, 1986), based on the number of criteria. As CR = 0.031 is less than 0.1, the conclusion is that the solution for criteria weights is consistent. The weight coefficients of the criteria obtained by applying AHP for the selected example are 45% for OMF costs, 23.3% for CO_2 emissions, 13.9% for SO_2 emissions, 9.9% for NO_x emissions, 3.1% for CO emissions, and 4.7% for PM emissions.

RESULTS OF THE MCDM METHODS

The weighting coefficients obtained by AHP can be used for the ranking of generators in the microgrid by applying some of the MCDM methods (ELECTRE, WSM, WPM, ORESTE, PROMETHEE, TOPSIS, VIKOR, …).

Results of the sources' ranking by using AHP - PROMETHEE

The results of the ranking of alternatives obtained by using both AHP and PROMETHEE methods are presented in Figure 1 and Table 6. A microturbine is the best choice, as shown in Figure 1, followed by a fuel cell, a diesel generator, and a main grid.

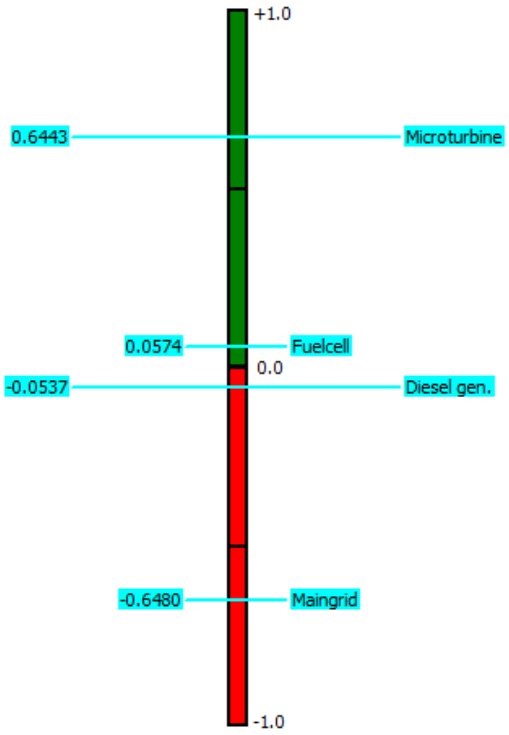

Figure 1. Ranking of generators by using AHP and PROMETHEE methods.

The comparison of alternatives is made based on the net flow:

$$\mathrm{Phi} = \mathrm{Phi}^{+} - \mathrm{Phi}^{-}, \tag{4}$$

for the positive (or leaving) flow Phi^{+} and the negative (or entering) flow Phi^{-}. Values of Phi for all alternatives are given on the left of the diagram in Figure 1, obtained by the computer program PROMETHEE (Brans, Mareschal, 2005), (Mareschal, 2011-2023).

Table 6. Ranking of generators by using AHP and PROMETHEE methods.

i	Alternative a_i	Rank
1	Diesel generator (DG)	3
2	Microturbine (MT)	1
3	Fuel cell (FC)	2
4	Main grid (MG)	4

Results of the sources' ranking by using AHP - TOPSIS

If the TOPSIS method is used after applying AHP, the obtained results of sources' ranking for the same example of the microgrid are given in Table 7.

Table 7. Ranking of generators by using AHP and TOPSIS methods.

i	Alternative a_i	Rank
1	Diesel generator (DG)	2
2	Microturbine (MT)	1
3	Fuel cell (FC)	3
4	Main grid (MG)	4

Results of the sources' ranking by using AHP - VIKOR

The sources are ranked also by the VIKOR method for the same example of the microgrid and the weights obtained by AHP. The results of ranking the alternatives are given in Table 8. The best-ranked energy source is again the microturbine.

Table 8. Ranking of generators by using AHP and VIKOR methods.

i	Alternative a_i	Rank
1	Diesel generator (DG)	2
2	Microturbine (MT)	1
3	Fuel cell (FC)	3
4	Main grid (MG)	4

CONCLUSIONS

Modern energy management systems are necessary in order to efficiently control microgrids, decrease the costs of energy production, and reduce harmful gas emissions and environmental pollution. Nowadays, multi-criteria optimization methods are used to improve the energy management of power systems, especially for microgrids.

This paper presents the application of the weighting method AHP to evaluate the ecological and economic (environomic) criteria. The obtained weights are used in MCDM for the ranking of microgrid's energy sources as alternatives. The best ranked generator from the environomic point of view is the microturbine according to the methods PROMETHEE, TOPSIS, and VIKOR, and the worst ranked energy source is the main grid. However, the results of the PROMETHEE method ranking for the fuel cell and the diesel generator differ, if compared to the results of the TOPSIS and VIKOR methods. The presented procedure can be used in further research for a greater number of various criteria and microgrid energy source alternatives.

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OCCURRENCE, SOURCES, AND DETERMINATION OF BENZO(A)PYRENE OUTDOOR AIR CONCENTRATIONS IN NOVI SAD: A MULTIVARIATE APPROACH

Jovanović Andersen Z.[1], Brborić M.[2], Radonić J.[2], Radović S.[2], Dmitrašinović S.[2], Turk Sekulić M.[2]

[1]Section of Environmental Health, Department of Public Health, University of Copenhagen, Øster Farimagsgade 5, Copenhagen, Denmark

[2] University of Novi Sad, Faculty of Technical Sciences, Department of Environmental Engineering and Occupational Safety and Health, Trg Dositeja Obradovica 6, Novi Sad, Serbia (e-mail: majabrboric@uns.ac.rs)

Abstract: A number of air pollutants pose severe health risks and can sometimes be fatal even in small amounts. One of these toxic pollutant categories includes polycyclic aromatic hydrocarbons (PAHs), including the most important representative of this group - benzo(a)pyrene. The paper reports the results of one–year field measurements of ambient B(a)P concentrations in four monitoring sites representative of different environmental conditions in Novi Sad during 2020. Average ambient B(a)P levels were between 0.22 ng/m^3 and 19.52 ng/m^3 for urban environments with different local characteristics. Exceeding the annual prescribed values was recorded at three investigated localities. In order to determine the sources that contribute to B(a)P contamination in air samples, various statistical methods were used. According to principal component analysis, two major origins were extracted, indicating that traffic and combustion processes have a great impact to harmful effect on human health, especially at locality MM1-Kać, MM2-NS1, and MM3-NS2, which was confirmed using the cluster analysis.

Keywords: *benzo(a)pyrene; air pollution; novi sad; PCA; HCA.*

INTRODUCTION

Air pollution is considered a major risk factor for public health worldwide, contributing to morbidity and mortality from lung cancer, and respiratory, cardiovascular, and cerebrovascular diseases. According to the World Health Organization (WHO), each year, air pollution is responsible for nearly seven million deaths around the globe. WHO data show that almost all of the global population (99%) breathe air that exceeds WHO guideline limits and contains high levels of pollutants, with low- and middle-income countries suffering from the highest exposures. Patients with respiratory problems and diseases, both children and adults, are the most susceptible to the effects of air pollution (Andersen et al., 2012). Also, the health risk for the occurrence of respiratory diseases depends on the gender, age, and health status of the population. The increased concentration of basic and specific pollutants in the air represents a risk to human health that is greater among sensitive population groups (children, pregnant women, nursing mothers, elderly, and sick people). The respiratory tract is the first portal of entry for pollutants from the air, and accordingly, the effects of air pollution on the respiratory system have been the most intensively studied for decades (Gowers et al., 2012). Air pollution affects the lungs, starting during pregnancy and continuing throughout life. Typical biological effects of air pollution include a suppressed immune system, inflammation and oxidative stress effects, lung growth disorders in children, decreased lung function in children and adults, and carcinogenic effects (Wang et al.,

2019). Therefore, long-term exposure to air pollution in healthy people increases the risk of developing new respiratory diseases, such as asthma in children and adults, chronic obstructive pulmonary disease (COPD), acute lower respiratory tract infections, and lung cancer (Guarnieri and Balmes, 2014; Liu et al., 2021a; Liu et al., 2021b). Also, the risk of premature death due to respiratory or cardiovascular diseases increases.

The direct harmful effect of polluted air on human health is manifested by inhalation of pollutants, which can further lead to acute and/or chronic diseases of the respiratory organs. Acute diseases of the respiratory organs will manifest themselves in large and suddenly occurring processes that will lead to the sudden release of large amounts and concentrations of pollutants in the air (stressed industrial work, accidents, traffic collapses...). The chronic effect of polluted air manifests itself in long-term inflammatory, degenerative, carcinogenic, mutagenic, or teratogenic changes in the respiratory and circulatory organs, all depending on the type of pollutants in the air, the concentration of the present pollutants and the length of human exposure to polluted air. Air pollution represents a significant burden in the daily life of patients with respiratory diseases, where exposure to short-term elevated levels of pollutants in the air can cause exacerbations of the manifested disease (such as asthma attacks), increased use of medicaments, more frequent emergency interventions, hospitalization and even death (Denholm et al., 2020). Due to the proven connection with several different diseases (the onset of diabetes, neurodegenerative diseases, neonatal death, the onset of cancer, etc.) and ubiquitous exposure, air pollution is the fourth leading risk factor based on the mortality rate in the world, so that this "silent killer" is considered one of the most important determinants of health.

In the literature, there are many proven toxic pollutants that are responsible for the consequences for human health if they are present for a long period of time in elevated concentrations in the air. One of them is certainly polycyclic aromatic hydrocarbons (PAHs) expressed as benzo(a)pyrene [B(a)P] in suspended PM_{10} particles. Benzo(a)pyrene is ubiquitously in by–products of incomplete combustion and pyrolysis of carbon–containing fuels and has been identified in ambient air, surface water, drinking water, wastewater, and in charbroiled foods. The emission rate, composition, and size distribution are strictly connected to the combustion source. It is primarily released into the air and is mostly associated with the particulate matter (PM) phase. It may be removed from the atmosphere by photochemical oxidation and dry deposition to land or water. B(a)P is one of the four indicator compounds used for the purposes of emission inventories of PAHs considered in the UN–ECE Convention on Long–range Transboundary Air Pollution–CLRTAP (Gianelle et al., 2013). The EU Directive 2004/107/EC proposes B(a)P as a marker for the carcinogenic risk of PAHs in ambient air, setting a target value of 1 ng/m^3 for the annual mean value (EC, 2004).

In order to quantify the concentration levels of B(a)P, one of the most significant pollutants from the group of polycyclic aromatic hydrocarbons, as well as to determine potential sources of pollution in the territory of the City of Novi Sad, outdoor air monitoring was carried out daily. The obtained data represent a very significant database in order to indicate the harmful effects on the human population and the unwanted consequences that the presence of these pollutants can leave after long-term exposure of the population to polluted air.

MATERIALS AND METHODS

Sampling sites

Twenty-four-hour measurements of B(a)P were performed in 2020 at four sampling sites in Novi Sad, a highly industrialized and populated city in Serbia (around half a million inhabitants). The sampling points are representative of different environmental conditions, comprehending monitoring sites classified by the 2008/50/EC Directive as urban and suburban, traffic and background stations (Figure 1) (EC, 2008). Air sampling in order to determine the concentration of B(a)P was conducted at representative measuring points: MM11- Kać (MZ "Kać", Kralja Petra I, no. 2 and Elementary School "Đura Jakšić", Kralja Petra I, no. 9, Kać ("suburban traffic")); MM2-NS1 (JKP "Vodovod i kanalizacija", Jiričekova 2, Novi Sad ("urban background")); MM3-NS2 (Corner of Rumenačke and Bulevar Jaše Tomić, Novi Sad (PM10) ("urban traffic")) and MM4-SK (Sremska Kamenica, SOS Children's Village "Dr. Milorad Pavlović", Sremska Kamenica 1-14, Novi Sad ("suburban background")) during one year in accordance with the standard SRPS EN 12341:2015 and processed by experts from the Center for Hygiene and Human Ecology of the Institute of Public Health of Vojvodina.

Figure 1. Measuring points for B(a)P sampling in the City of Novi Sad during 2020

Sampling and analytical methods

Air sampling equipment used to determine the concentration of B(a)P pollutants in the air was Sven Leckel, LVS3 (6019, 6020) Sven Leckel SEQ 47/50-RV (6900) Comde-Derenda GmbH (7300). The name of the method for determining the concentration of pollutants in the air was SRPS EN 12341:2015, point 5.1, while the name of the method for determining the concentration of pollutants in the air was SRPS EN 15549:2010. The measuring instrument used to determine the concentration of pollutants in the air was a gas chromatograph (GC/MS).

Data analyses

B(a)P concentrations measured at 4 monitoring sites in one year were analyzed through basic statistical parameters (i.e., average, median, standard deviation, standard error of the mean, minimum, maximum, number of values under the detection limit). Both the standard deviation of data and standard error of the sample mean were provided to give information respectively on the spread of the data and the stability of the sample means. Data under the detection limit were considered equivalent to half of the limit.

Further statistical analyses were conducted on B(a)P data in order to identify groups of sampling sites with similar characteristics providing an indication of the contributions of emission sources. For this purpose, a hierarchical cluster analysis (HCA) and principal component analysis (PCA) were performed on monthly average B(a)P with the application of Varimax rotation and Kaiser normalization. Statistical analysis was implemented by applying the IBM SPSS Statistics 25 software (IBM Corporation, Armonk, New York, U.S.). The proposed methodologies and results obtained in this paper provided valuable assessment using the PCA and HCA visualization capabilities and highlighted zones of priority that might require additional investigations and also provided productive pathways for effective decision-making and remedial actions.

RESULTS AND DISCUSSION

At the measuring point in the City of Novi during 2020 (MM1-Kać, MM2-NS1, MM3-NS2, and MM4-SK), the average daily value of the concentration of benzo(a)pyrene in suspended particles PM_{10} during one controlled year, determined deterministically, were in range of 0.22 ng/m^3 (site MM4) to 19.52 ng/m^3 (site MM1). The monthly B(a)P concentrations, ranging between 0.49 ng/m^3 observed in MM4 and 7.993 ng/m^3 observed in MM1, are shown in Figure 2. The mean monthly concentration of B(a)P for MM1, MM2, and MM3 were 2.23 ng/m^3, 1.22 ng/m^3, and 1.31 ng/m^3, respectively, which exceeds the target value for total polycyclic aromatic hydrocarbons in the air at an annual level of 1 ng/m^3, compared to the prescribed norm. At the mentioned measuring site during the one year, the minimum value of the daily concentration of polycyclic aromatic hydrocarbons expressed as benzo(a)pyrene on a monthly level was below the detection limit of the applied analytical method (<0.5 ng/m^3), and the maximum was 7.99, 4.39 and 4.51 ng/m^3, respectively. Only at the site MM4-SK, the prescribed value of B(a)P in the air (mean = 0.92 ng/m^3) was not exceeded.

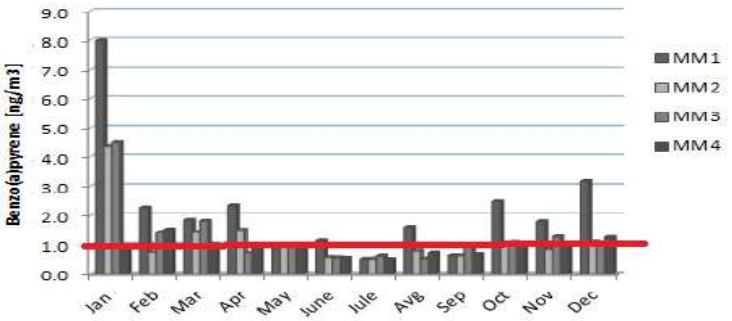

Figure 2. B(a)P air concentrations during 2020

Principal component analysis

The PCA with Varimax rotation was applied to ascertain the quantitative contribution of different P(a)P sources and provide the most convincing results. Two principal components explaining 98.34% of the variance are presented in Figure 3. PC1 explained about 49.96% of the variance, with high loadings at site MM1 indicating combustion processes, while PC2 explained about 48.38% of the variance with high loadings of MM3 indicating the traffic emissions caused by the combustion of diesel and gasoline motor vehicles. Locality MM2 and MM4 have moderate loading for both factors.

Considering that Novi Sada was included in the research framework, which is an urban region with significant traffic, but also combustion processes, where polycyclic aromatic hydrocarbons are produced both from pyrolytic and pyrolysis emission processes, the dominance of pollution sources based on the assumed city zone can be confirmed. However, it can be confirmed that the sources of B(a)P, as one of the most toxic PAHs, are present throughout the territory of Novi Sad, which should cause concern especially because of its carcinogenic, mutagenic, and teratogenic effects (Brborić et al., 2019) on the human population.

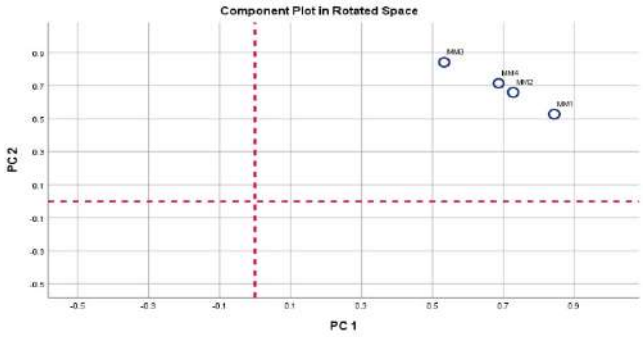

Figure 3. Principal component analysis after Varimax rotation for B(a)P

Hierarchical cluster analysis

Results of Cluster analysis are presented graphically, as the cluster tree. The dendrogram of the cluster analysis of sampling sites is presented in Figure 4. The first group includes the sampling sites MM1, MM2, and MM3, while the second cluster covered only the MM4 locality, selected according to the increased concentrations of B(a)P.

The first three locations were singled out due to the strong presence of B(a)P in the ambient air, exclusively due to the winter period, where combustion processes are most pronounced, both from individual furnaces (MM1) and due to the presence of the "NIS Gazprom Neft" Oil Refinery, production facilities and oil and gas processing, along with the transportation of oil derivatives, as well as the proximity of the cogeneration system, significantly contribute to the increased concentrations of B(a)P at locations MM2 and MM3.

Based on the cluster analysis, location MM4 in Sremski Karlovci is considered less burdened in terms of B(a)P emissions, because there is not as much traffic as in the city center (as in locations MM2 and MM3) and there is not as many individual fireplaces with the purpose of heating households during the winter season as in the locality MM1 so that in terms of B(a)P emissions and air pollution, it is considered a better and safer place to live.

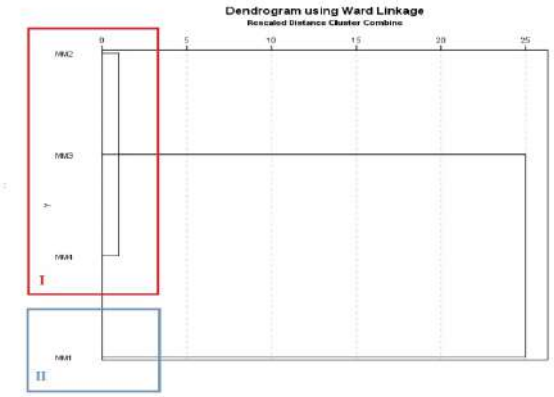

Figure 4. Dendrogram of monthly B(a)P air concentrations

CONCLUSIONS

The results reported in this work provide highly valuable information on the current status of B(a)P air contamination in Novi Sad. Our findings revealed elevated concentrations at most of the sampling sites compared with the maximum permissible concentrations Serbia prescribed for outdoor air. Source of B(a)P, as determined by the PCA method, revealed the prevalence of contaminants of pyrolytic origin at all studied sites, with the exception of MM1, where petrogenic origin was dominant. Due to the high presence of this "light" PAH in the air, localities could be characterized as areas with fresh contamination. These results suggest that the main B(a)P contributors at all sites are local sources, i.e., intense traffic activities of the local residents and combustion processes. Using a hierarchical cluster analysis, it was established that the location in Sremski Karlovci has the lowest burden due to air contamination with B(a)P.

The present study provides baseline data about the origin of contaminants and B(a)P levels in the outdoor air for future monitoring studies in Serbia. As such, it represents a significant step towards achieving sustainable development, climate change mitigation, and resource efficiency in this environmentally delicate area. In future investigations of polluted air in Serbia, the focus should be on the impact of the area designated for extensive and intensive use of agricultural land, as well as areas characterized by industrial pollution from various sources as it is likely that these will introduce new stressors.

ACKNOWLEDGEMENTS

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SURFACE WATER-QUALITY MONITORING OF TWO WETLAND ECO-SYSTEMS IN CROSS-BORDER PROTECTED AREAS

Keser T.[1], Obrovski B.[2], Mihajlović I.[2], Vojinović Miloradov M.[2], Sremački M.[2], Brkić M.[3]

[1] University in Osijek, Faculty of Electrical Engineering, Computer Science and Information Technology Osijek, Josip Juraj Strossmayer, Kneza Trpimira 2B, 31000 Osijek, Croatia

[2] University of Novi Sad, Faculty of Technical Sciences, Department of Environmental Engineering and Occupational Safety and Health, Trg Dositeja Obradovića 6, 21000 Novi Sad, Serbia (e-mail: ivanamihajlovic@uns.ac.rs)

[3] University of Novi Sad, Faculty of Technical Sciences, Department of Power, Electronic and Telecommunication Engineering, Trg Dositeja Obradovića 6, 21000 Novi Sad, Serbia

Abstract: The contamination of surface water in Zobnatica Lake in Serbia and the Wetlands of Tompojevci in Croatia was evaluated due to the similarity of two wetland ecosystems in cross-border protected zones. The main objective is to determine the impact of anthropogenic activities on surface water quality. An independent sample t-test was used for the comparison of concentrations for eight physico-chemical parameters. A significant difference compared to the cross-border protected area, Zobnatica Lake in Serbia and Wetlands of Tompojevci in Croatia, was observed for concentrations of nitrate ($p=0.023$), sulfate ($p<0.0005$), chloride ($p<0.0005$) and iron ($p=0.017$). The results obtained within the two-year monitoring are highly essential for the detection of pollution sources, which could lead to the reduction of surface water contamination in protected areas.

Keywords: *surface water; monitoring; protected areas; agricultural activities.*

INTRODUCTION

Lakes and wetland areas as natural water resources represent sensitive and vulnerable ecosystems where human activities can lead to water body contamination (McLaughlin and Cohen, 2013; Chen et al., 2019). Changes in water quality and identifying anthropogenic sources of pollutants could be obtained with surface water monitoring. A comprehensive database on the current state of water quality is essential for enabling prompt and preventive responses to minimize water contamination. Agriculture, industrial processes, waste disposal, and urbanization, are the main anthropogenic activities that significantly contribute to the contamination of wetlands' surface and groundwater (van Asselen et al., 2013; Wang et al., 2014; Davidson, 2014). Run-off water formed by washing soil treated with minerals, pesticides, and natural fertilizers can lead to the contamination of surface water. The negative impact of run-off water is dependent on the concentrations of fertilizers and pesticides as diffuse (non-point) sources of contamination and need to be examined (Sebilo et al., 2013).

Temporal and spatial distribution of physico-chemical parameters, especially nitrogen and phosphorous compounds, is essential for the evaluation of surface water quality. Urbanization of protected areas influences surface water contamination with nutrients due to the discharge of mixed industrial and communal wastewater. Chlorides, which occur naturally in aquatic systems as soluble salts, can be used as indicators of contamination. The discharge of wastewater from industrial processes and run-off water from agricultural fields may contribute to the presence of iron metal cations in surface water, posing a potential risk of contamination.

The aim of this research paper is to conduct a comparative analysis of surface water contamination levels in two cross-border protected areas, Lake Zobnatica in Serbia and the Wetlands of Tompojevci in Croatia. These two regions share significant similarities, as both are located between urban settlements and surrounded by agricultural land with vegetation belts where similar types of crops are grown. The study is focused on the monitoring of the key physico-chemical parameters in surface water over a two-year period to better understand and compare water quality in the protected areas.

MATERIAL AND METHODS

Sampling site

Lake Zobnatica with an area of 250 ha is located in the North Bačka District near the town of Backa Topola. Zobnatica was declared a nature park in 1976. Water from the Lake is used for irrigation of agricultural areas as a primary anthropogenic activity in the region. Industrial facilities are located seven kilometers from Lake Zobnatica and include the meat and meat processing industry. The lake's urbanization has resulted in the development of tourism, with several tourist attractions including beaches, sports facilities, hotels, and restaurants. The wetlands of Tompojevci are located in the eastern part of Vukovar-Srijem District, Tompojevci municipality, with 5700 ha of cultivable land. Agricultural production is the primary anthropogenic activity in the region. Wetland is a total length of 48 km with a natural depression depth of up to 15 m, where run-off water from agricultural land is accumulated. The wetland area is surrounded by cultivable land with narrow and wider vegetation belts with parts overgrown in reed.

Samples of surface water were collected from Lake Zobnatica at three locations and two locations from a water body of Wetlands of Tompojevci (Table 1). The sampling campaigns were conducted for a period of two years. Samples were collected with a telescopic sampler, poured into 1 L bottles, stored in a hand refrigerator at 4 ^{0}C, and transported to the laboratory. Analyses were carried out in an accredited Laboratory for environmental and occupational monitoring, Department of Environmental Engineering and Occupational Safety, Faculty of Technical Sciences, University of Novi Sad.

Table 1. Coordinates of water sampling sites from Serbia and Croatia

Zobnatica Lake, Serbia	Wetlands Tompojevci, Croatia
SW1 (45^{0}85‘7.11“ N, 19^{0}62’23.58“ E)	POV1 (45^{0}24’33.95‘‘ N, 19^{0}11’19.88‘‘ E)
SW2 (45^{0}88‘20.36“ N, 19^{0}60’92.59“ E)	POV2 (45^{0}24’29.82‘‘ N, 19^{0}09’67.98‘‘ E)
SW3 (45^{0}84‘03.13“ N, 19^{0}62’60.93“ E)	

The standard EPA and HACH methods were used for all Laboratory measurements - EPA 365.3, HACH 8507, HACH 8192, HACH 8155, HACH 8051, HACH 8113, SRPS ISO 8245.2007, and HACH 8146. The concentrations of the selected parameters were measured in the laboratory by UV-VIS spectrophotometer (DR 5000, HACH, Germany).

Statistical data analysis

The IBM SPSS (Statistical Package of Social Science) software package version 25 was used for statistical data processing. An independent sample t-test was performed for the purpose of data analysis in order to compare the surface water pollution between the two observed cross-border protected areas.

RESULTS

The wetland in Croatia significantly influences the quality of the Natura 2000 site, whereas the site in Serbia is currently proposed for designation as a Nature Park. Both protected areas have great similarities, characterized by the presence of agricultural land with the vegetation belts surrounding lakes and wetlands. The same crops, such as wheat, corn, and sunflower, are cultivated in these areas. The protected sites in both regions have also been impacted by urbanization over recent years. Therefore, surface water quality in Zobnatica Lake and Wetlands Tompojevci was examined to compare the water quality.

According to the results of the examined samples, the water of Zobnatica Lake and Wetlands Tompojevci belongs to the III class of surface water with moderate ecological status (Table 2). The concentration of orthophosphates affects the surface water quality in these transboundary areas. An excessive intake of orthophosphates leads to eutrophication, negatively impacting the aquatic ecosystem and limiting water use. Eutrophication results in increased organic matter growth, reduced oxygen levels in the water, formation of the excess of nutrients, and anaerobic conditions in the bottom layer.

Statistical analyses of the concentration of key physico-chemical parameters in the surface water of the transboundary areas were conducted (Table 3). There was a significant difference in the concentration of nitrates, sulfates, chlorides, and iron cations. Nitrate concentrations are higher in Zobnatica Lake than in Wetlands Tompojevci, but both belong to the same water quality class. The concentration levels of sulfates and chlorides are elevated in Zobnatica Lake and belong to the second class of water quality in relation to Wetlands Tompojevci, whose surface water belongs to the first class in terms of quality. Sulfate concentrations are significantly elevated in the surface water of Lake Zobnatica. The concentration of iron cations is elevated in the surface waters of Wetlands Tompojevci in relation to the surface water of Lake Zobnatica.

Table 2. Surface water quality class

Parameters	Zobnatica Lake	Wetlands Tompojevci
PO_4^{3-}	Class III	Class III
NO_2^-	Class I	Class II
NO_3^-	Class I	Class I
NH_4^+	Class I	Class I
TN	Class II	Class I
SO_4^{2-}	Class II	Class I
Cl^-	Class II	Class I
Fe^{2+}	Class I	Class II

Table 3. Comparison of key physicochemical parameters in surface water by locations

Parameters	Zobnatica lake	Wetlands Tompojevci	Significance (p-value)
PO_4^{3-}	0.282 ± 0.401	0.479 ± 0.57	0.225
NO_2^-	0.009 ± 0.013	0.041 ± 0.003	0.099
NO_3^-	0.019 ± 0.012	0.010 ± 0.008	0.023*
NH_4^+	0.045 ± 0.053	0.183 ± 0.330	0.145
TN	2.103 ± 1.539	1.48 ± 1.335	0.247
SO_4^{2-}	73.73 ± 29.96	10.14 ± 18.05	<0.0005*
Cl^-	59.5 ± 31.73	16.31 ± 10.47	<0.0005*
Fe^{2+}	0.074 ± 0.105	0.380 ± 0.416	0.017*

* Statistical significance at the level of 0.05

Based on the statistical evaluation of the data, it has been identified that agricultural activities are the primary source of contamination in the entire water system of the transboundary areas, Zobnatica Lake and Wetlands Tompojevci. To prevent further degradation of surface water quality, implementing preventive measures is essential. These measures could involve expanding the vegetation zone and adopting practices to reduce the utilization of fertilizers, pesticides, and other chemicals in crop treatment. By adopting such preventive measures, the adverse impacts of agricultural activities on the water quality in the protected areas could be effectively mitigated, ensuring the preservation and sustainability of their sensitive ecosystems.

CONCLUSION

The availability of real-time data is crucial to prevent environmental contamination, particularly in protected areas where food production takes place. As agricultural land relies on surface water for irrigation, ensuring the high quality of the water is of vital importance for human health. Given that agricultural activities contribute to surface water pollution in both Zobnatica Lake and Wetlands Tompojevci, it was observed that pollution is correlated between these regions. As a result, it is imperative to focus on minimizing contamination, particularly concerning phosphorous compounds (class III) at both locations. Further activities should be directed towards implementing measures that effectively reduce pollution levels, preserving the protected areas, and ensuring the quality of their water resources for both the environment and human health.

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INVESTIGATING BISPHENOL A OCCUPATIONAL EXPOSURE TRENDS AMONG LANDFILL WORKERS: A COMPREHENSIVE LITERATURE REVIEW

Koljančić N.[1], Adamov T.[1], Petrović M.[1]

[1]Slovak University of Technology, Faculty of Chemical and Food Technology, Institute of Analytical Chemistry, Radlinskeho 9, SK-812 37 Bratislava, Slovakia

[2]University of Novi Sad , Faculty of Technical Sciences, Department of Environmental Engineering and Occupational Safety and Health, Trg Dositeja Obradovića 6, Novi Sad 21000, Serbia (e-mail: tijana.adamov.tiki@gmail.com)

Abstract: The impact of plastic waste on human health has gained heightened attention. Microplastics and potential toxic additives present in plastic waste can leach into ecosystems, entering the food chain and potentially posing risks to human health. The accumulation of these particles and chemicals in organisms has raised concerns regarding long-term health effects. BPA, a synthetic chemical extensively used in the production of various plastics and thermal papers, has come under scrutiny. BPA exposure is widespread and has been associated with adverse health outcomes, including effects on the reproductive system, metabolic processes (obesity, metabolic dysfunctions, and diabetes), the immune system, and cognitive and behavioral development. BPA exhibits estrogenic activity and can interact with other hormone receptors. Despite numerous studies, the toxicological effects of BPA remain a subject of debate. Currently, BPA is classified as a reproductive toxicant category 1B under EU regulations, leading to restrictions on consumer products for babies and children. Regulations aimed at reducing BPA usage have led to the adoption of alternative bisphenols, such as bisphenol S (BPS) and bisphenol F (BPF), which may possess similar toxicological properties. However, limited information is available regarding the potential health impacts of these substitutes. The occupational exposure of workers to bisphenols in various industrial applications, including landfill workers, raises serious concerns. Landfill workers are at an elevated risk of exposure due to direct contact with plastic waste materials, potentially exceeding the exposure levels of the general population. This paper provides insights into occupational exposure pathways, quantification of BPA on landfill sites, and human biomonitoring guidance values. It highlights the importance of understanding real-world exposure scenarios and the need for continuous monitoring, evaluation of risks, strategies to mitigate risks, protect workers' well-being, and continue research in this field.

Keywords: *occupational exposure; bisphenol A; landfill leachate; municipal solid waste; hazardous compounds; waste management.*

INTRODUCTION

The widespread consumption of plastics has given rise to a corresponding surge in waste volumes, posing critical implications for both the environment and human health. In 2018, global plastic consumption reached 385 million metric tons (Mt), paralleled by the generation of a significant 250 million Mt of waste. This waste output accounted for a substantial 65% of the total plastics consumed, highlighting the urgent need for comprehensive waste management strategies to mitigate adverse impacts on the environment and human well-being (Horodytska et al., 2018).

The influence of plastic waste on human health has garnered increasing attention. Microplastics and potentially toxic additives found in plastic waste have been shown to leach into ecosystems and subsequently enter the food chain, with potential repercussions for human health. These

particles and chemicals have the potential to accumulate in organisms, raising concerns about long-term health effects (Rochman et al., 2013; Wagner et al., 2014). Bisphenol A (BPA or 4,4′-(propane-2,2-diyl) diphenol) is a synthetic chemical that has been used in a variety of industrial applications dedicated to the production of polycarbonate plastics, epoxy resins, other polymers, and thermal papers.

Human exposure to BPA is widespread and has been potentially linked to a variety of adverse health outcomes on the reproductive system, metabolic processes (obesity, metabolic dysfunctions, and diabetes), the immune system, and cognitive and behavioral development. Studies confirm that BPA exerts estrogenic activity, but it may also interact with other hormone receptors, like androgen, glucocorticoid, and thyroid receptors (Cimmino et al., 2020).

The toxicological effects of BPA are still controversial, despite numerous studies (ECHA, 2021). Notably, bisphenol A is presently classified as a reproductive toxicant category 1B under the EU CLP Regulation (Regulation 2016/1179) and its use is restricted in numerous consumer products for babies and children (Bousoumah et al., 2021).

Bisphenols classified as Repr. 1B will be restricted for use in consumer mixtures through the generic entry 30 in Annex XVII, and risk management measures at the workplace will be triggered through OSH (Directive 98/24/EC, 92/85/EEC, and 94/33/EC) to protect industrial and professional workers (including also pregnant and young workers).

Regulations for reducing the usage of BPA have resulted in an increasing replacement with other bisphenols that might possess similar toxicological properties. Most common are bisphenol S (BPS; 4,4′-sulfonylbisphenol) and bisphenol F (BPF; 4,4′-dihydroxydiphenyl-methane) which have been considered good substitutes in industrial applications. Significantly less information about potential negative health outcomes is available for BPF and BPS.

Since bisphenols are extensively used in different operations and applications in industry, occupational exposure, and health risks to workers have become a serious concern. The specific context of landfill workers introduces a specific dimension to the assessment of human exposure to bisphenols and other chemical additives commonly found in plastics. Due to their occupation involving direct contact with plastic waste materials, landfill workers are potentially at an elevated risk of exposure to various compounds, including bisphenols. This heightened exposure is likely to be greater than that of the general population due to the nature of their work environment.

The collected information has the potential to provide a deeper understanding of real-world exposure scenarios and help formulate strategies to mitigate risks and identify opportunities for continual improvements as well as to ensure the well-being of landfill workers in their occupational environment.

OCCUPATIONAL HEALTH AND SAFETY LEGISLATION

The Framework Directive 89/391/EEC, along with subsequent directives that address specific aspects of occupational safety and health (OSH), form the cornerstone of European legislation in the field of workplace safety. The Framework Directive has a broad scope of application, encompassing both public and private sectors, with certain exceptions for specific public service activities like the armed forces, police, and certain civil protection services. As a foundational piece of legislation, it establishes essential principles for the prevention and protection of workers from occupational accidents and diseases. This directive outlines key principles related to risk

prevention, safety, and health protection, risk assessment, risk elimination, factors contributing to accidents, as well as mechanisms for informing, consulting, and actively involving workers and their representatives in safety measures.

Directive 98/24/EC addresses safety and health risks associated with chemical agents in the workplace, establishing essential safeguards for workers. This directive requires employers to identify and assess potential hazards posed by chemical agents present in the workplace or arising from work activities involving such agents. Employers are obligated to conduct thorough risk assessments and maintain documented records of these assessments, as stipulated in Article 9 of Directive 89/391/EEC. Furthermore, these assessments must remain current, especially in the event of significant changes or if health surveillance results indicate a need for updates. In cases where workers are exposed to multiple hazardous chemical agents, the risk assessment must consider the combined risks posed by all such agents.

Additionally, employers must implement suitable fire safety measures, and the work equipment and protective systems utilized must adhere to relevant Community provisions, notably Directive 2014/34/EU. This comprehensive directive aims to safeguard workers from chemical-related risks and uphold workplace safety and health standards.

HUMAN EXPOSURE PATHWAYS

Distinguishing between various routes of human exposure in workplace environments, assessing hazardous substances, and quantifying their presence are crucial tasks that demand attention. These tasks can be effectively accomplished through meticulous planning, the establishment of appropriate exposure limits, and the implementation of measures outlined in relevant directives.

Upon oral ingestion, the majority of BPA (almost 100%) is excreted in urine as conjugated forms, namely BPA glucuronide (BPAG) and BPA sulfate (BPAS). Within 24h roughly 93% of the absorbed dose can be recovered in urine. Only a minor fraction (lower than 1%) of total BPA is excreted as unconjugated (most often referred to as “free”). Unlike free BPA, the conjugated forms are considered biologically inactive, since they don't bind to the estrogen receptor (Bousoumah et al., 2021).

Landfill workers are primarily exposed to bisphenol A (BPA) through two significant occupational pathways: inhalation and transdermal contact. Notably, unlike oral exposure, BPA absorbed through dermal contact or inhalation directly enters the bloodstream without undergoing the initial liver metabolism process (Ougier et al., 2021). Consequently, dermal absorption of BPA can result in extended exposure to free BPA when compared to oral ingestion (Bousoumah et al., 2021). This leads to higher ratios of free BPA to total BPA in the bloodstream when absorbed via the skin or through inhalation, as opposed to the oral route. Moreover, the slow absorption of BPA through the skin results in prolonged exposure compared to oral ingestion, and presumably, inhalation as well (Ougier et al., 2021). This highlights the significance of understanding these specific exposure pathways for landfill workers in assessing potential health risks associated with BPA exposure.

QUANTIFICATION OF BPA ON LANDFILL SITES

Given the limited extent of research conducted in the realm of occupational exposure to BPA and its substitutes, coupled with the scarcity of recent records, this section aims to provide a comprehensive presentation of quantification findings of BPA at landfill sites. Specifically, we will focus on the presence of BPA in either the air or leachate. Table 1 presents an overview of the data compiled from relevant scientific research papers.

Table 1. Overview of studies quantifying BPA in different mediums of landfill sites.

BPA concentration	Medium	Study
2343 µg/kg (bottom ash sorting) - 50651 µg/kg (WEEE fragmenting)	BPA concentration in the PM10 dust	Morin et al., 2015
1000 pg/m3 for outdoor samples (landfills and WEEE/Vehicle A) - 10000 pg/m3 for indoor samples (either near the waste defragmentation and sorting area or near the waste loading dock)	PM10-bound BPA in the indoor and outdoor air of landfill sites	Morin et al., 2015
0,7-200,0 µg/l for landfills 5,0-100,0 µg/l for WEEE/vehicle facilities	Leachate	Morin et al., 2015
138 - 473,977 ng/l	Leachate	Yi et al., 2017
11 µg/l	Leachate	Ambauen et al., 2020
0,70 – 2,72 mg/l	Leachate	Narevski et al., 2021
1,363 - 5,565 ng/l as a range of medians for different landfills	Leachate	Rezaei Adaryani and Keen, 2022

Notably, Morin et al. (2015) conducted a study that quantified BPA levels both indoors and outdoors in waste handling facilities in Norway. Furthermore, the concentrations of BPA in leachate exhibited variations, which can be attributed to factors such as the volume of disposed waste, the age of the landfill, and climate disparities influencing degradation processes, among others. In support of these findings, Narevski and Cooperates (2021) focused on BPA quantification in leachate from five municipal solid waste landfills in Serbia and corroborated the presence of BPA in all collected samples.

HUMAN BIOMONITORING

Human biomonitoring (HBM) entails the measurement of chemical concentrations or their metabolites in human body fluids and tissues. This approach enables the assessment of the cumulative exposure of an individual to a particular substance, encompassing all potential sources of exposure, including food, air, water, and soil. HBM considers various intake pathways, such as inhalation, ingestion, and dermal absorption. Additionally, it considers individual factors like nutritional habits and metabolism, providing a comprehensive understanding of the body's overall chemical burden.

Human Biomonitoring Guidance Values

A human biomonitoring guidance value (HBM-GV) is a specific biomarker concentration detected in a biological matrix. It serves as a reference point, indicating that, based on current knowledge, exposure to the substance at or below this level is not expected to result in adverse health effects (Ougier et al., 2021).

The primary routes of BPA absorption in the workplace are likely through dermal contact and inhalation. These pathways can result in higher concentrations of free-BPA in plasma when compared to oral intake. Therefore, a value of 13.6 x 10-3 µg/l for free-BPA in plasma at the end of the working week and the working shift could potentially serve as the HBM-GV for workers. However, it's important to note that this value can only be considered if there are analytical capabilities that meet the stringent quality assurance and quality control (QA/QC) conditions and requirements necessary for accurate quantification.

For BPA in its inhalable form, occupational exposure limits (OELs) are detailed in Table 2.

Table 2. Occupational exposure limits for BPA, as inhalable fractions (Ougier et al., 2021).

	OELs
	mg/m^3
German Research Foundation (DFG)	5
Scientific Committee on Occupational Exposure Limits (SCOEL)	2
Health Council of the Netherlands	3.3

The derived no-effect level (DNEL) values for workers are established at twice the levels set for the general population. Specifically, the oral DNEL is set at 8 µg/kg bw/day, and the DNEL for dermally absorbed total BPA dose is set at 0.2 µg/kg bw/day (Ougier et al., 2021).

CONCLUSIONS

Landfill workers face a unique dimension of exposure to bisphenols and other chemical additives found in plastics due to their occupation, which involves direct contact with plastic waste materials. Consequently, they are potentially at a heightened risk of exposure compared to the general population, given the nature of their work environment. The presented information provides valuable insights into real-world exposure scenarios for landfill workers, helping formulate strategies to mitigate risks and identify opportunities for improvement to ensure the well-being of these workers in their occupational setting. Addressing the complex issue of bisphenol exposure in the workplace, especially among landfill workers, requires a multidisciplinary approach, encompassing legislation, biomonitoring, and quantification efforts. It is essential to continue research in this field to enhance understanding of the risks and to develop effective measures to safeguard the health and safety of workers in the waste management sector.

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DOSIMETRY AND MONITORING OF ELECTROMAGNETIC RADIATION IN THE WORKING ENVIRONMENT AS A PREREQUISITE FOR EMPLOYEE HEALTH PROTECTION

Krstić D. [1], *Malenović Nikolić J.*[1], *Zigar D.*[1], *Jovanović U.*[1], *Milošević L.*[1], *Krstić M.*[2]

[1] Faculty of Occupational Safety, University of Niš, Čarnojevića 10a, Niš, Serbia (e-mail: dekikrs@gmail.com)

[2] Syrmia way doo, Niš , Aleksandra Nenadovića 6, Serbia

Abstract: Dosimetry of electromagnetic radiation as a scientific field studies received energy quantities, absorbed energy received by an employee who works with sources of non-ionizing radiation. Science has shown that biological effects are correlated with the amount of energy absorbed from non-ionizing electromagnetic radiation. Since these facts are not adequately recognized in the legal legislation of the Republic of Serbia in the protection against non-ionizing radiation, the paper aims to point out the need to innovate national legislation. Continuous monitoring of sources of electromagnetic radiation in the working environment is rarely implemented, and there is a need to introduce continuous monitoring of personal doses of employees, similar to what is implemented in the framework of protection against ionizing radiation. In this way, the protection of employees from non-ionizing electromagnetic fields that occur at power plants, electrolysis plants, and emission systems of telecommunication systems would be improved.

Keywords: *low-frequency electromagnetic fields; continuous monitoring; absorbed dose; radiofrequency radiation.*

INTRODUCTION

Man arose in the earth's electric and magnetic fields, which had undergone small changes over the previous millions of years. Man has adapted and adjusted biological processes to such fields and most biological processes and homeostasis of the human body are aligned with these fields. However, the development of electrical engineering led to the use of direct and alternating currents in industry, and we cannot imagine a modern man without them. Every flow of electricity produces variable electromagnetic fields (EMP) in their surroundings, and telecommunications taught us how to use electromagnetic fields to transmit information, thus beginning the modern information age. The production and distribution of electricity as the dominant source of "clean" energy has shown that the characteristic of all energy is diffusion and that inevitably there is a process where part of that energy goes into the environment and has a biological effect on the environment and man. Energies of electromagnetic fields and waves that "contaminate" the environment, which we call non-ionizing electromagnetic radiation (EMR), and often electromagnetic smog. In industry, a person is always in the vicinity of various electrical plants, machines, or telecommunication modules that transmit a part of the energy into free space, and the human body partially absorbs this energy. All medical studies have shown that absorbed energy is proportional to biological effects.

Modern society and its countries, wanting to protect themselves from the unwanted effects of electromagnetic (EM) radiation, have launched a series of scientific research into the effects of electromagnetic radiation, and in the previous decades, about seventy thousand scientific articles

were written about the effects of these fields on humans. However, we do not have definitive answers, partly because we are designing and producing new sources that work with different frequencies every day, research and evidence collection continues, and industry and development are moving forward.

The scientific community and several international organizations (ICNIRP, IEEE) are trying to consolidate the current knowledge, group it, draw conclusions, appropriate guidelines regulations – directives, standards and make proposals for the improvement of national legal regulations.

The basic division of EMR is about the frequency at which the device operates and emits an electromagnetic field. These can be unwanted radiations during the operation of the equipment, or they are radiations designed - desired as an established characteristic of that equipment to emit and transmit informational communication waves (RF radiation). Since the propagation and absorption characteristics, as well as the processes in biological tissues, depend extremely on the frequency of the emission of the source, the norms for protection are divided into two large groups: electromagnetic fields of industrial frequency (power frequency or low frequency) and electromagnetic radiation of telecommunication devices (radio frequency radiation - high frequency). The subject of research in this paper is electromagnetic fields and radiation in the working environment.

PRINCIPLES OF PROTECTION AGAINST ELECTROMAGNETIC RADIATION

The basic idea in protection is to find out which levels (intensities) are harmful and where the limit of the size of the electromagnetic field (strength of the electric field, strength of the magnetic field, and density of radiation energy) is proven to cause harmful health effects. Scientific research, with the influence of industry, manufacturers, and professional organizations, was to some extent transformed into guidelines (CEI IEC 61786, ICNIRP Guidelines, SRPS EN 50413:2010], regulations – directives (Directive 2004/40/EC, CEI IEC 61786), standards (SRPS EN 50413, SRPS EN 62110:2011), laws (Law on protection, 2009), and Rule books - Regulations (Rulebook on limits, 2009 - Rules on the procedure, 2023). All these documents are in the field of electromagnetic radiation, procedures for use, testing, measurement, control, and management with the least possible consequences for people and the environment.

Standards and guidelines are based on dosimetric considerations combined with absorption characteristics of the body at different frequencies of EM waves. The basic premise is that any adverse effects are proportional to the rate of radiofrequency (RF) energy absorbed, and the specific absorption rate (SAR) is a common measure for characterizing the prescribed limits.

Protection against electromagnetic non-ionizing radiation in the Republic of Serbia is based on the Law on protection against non-ionizing radiation, but the by-laws are significantly different in the working and living environment.

Protection against electromagnetic radiation in the working environment in the Republic of Serbia is based on measurement in the working environment by Rules on the procedure for inspecting and checking equipment for work and testing working environment conditions (Rules on the procedure, 2023), and standardization based on the Rulebook on preventive measures for safe and healthy work when exposed to electromagnetic fields.

The measurement of variable electromagnetic fields is a complex task that can be performed correctly if the procedure is repeatable, and this is made possible by the standardization of the measurement method, the measurement procedure, and the precise definition of the measuring apparatus and measurement points where the measurement is performed (Methodology of examining, 2012).

This Rulebook on limits of exposure to non-ionizing radiation, 2009, defines 2 terms in the protection of employees, namely:

- limit values (exposure limit values monitored by health effects and exposure limit values monitored by sensory effects) and
- action values.

In Article 3 of the Rulebook, the definition of exposure limit value and action value is given, quoted: Exposure limit values - are the limits of exposure to the effect of electromagnetic fields that are directly based on the established health effects and their biological reasons, and compliance with which ensures that employees exposed to electromagnetic fields are protected from all known harmful effects on health; and action values - are directly measurable parameters given in the form of electric field strength (*E*), magnetic field strength (*H*), magnetic flux density (*B*) and surface power density (*S*), where one or more measures determined by this regulation must be taken. Adherence to the action values ensures that the exposure limit values will not be exceeded.

Table 1 . Table of action and limit values according to this Rulebook, for f = 50 Hz

		Head and body current density J (mA/m^2) (RMS)	Electric field E (V/m)	Magnetic field H (A/m)	Magnetic flux density B (μT)
1.	Action values	10			
2.	The limit values		10,000	400	500

By looking at Table 1, it is noticeable that the action value (current density) which should be directly measurable according to the regulations, cannot be, but can only be calculated or estimated. The only thing left is to measure limit values and take protective measures based on them.

Basic limitations in radiation protection methodology

In addition to technical inconsistencies in the Rulebook on preventive measures for safe and healthy work in the Republic of Serbia, the analysis of almost all standard limit values refers to values that are allowed indefinitely (during the entire working time). Opportunities for additional analysis and consideration are identified here:

1. When measuring in accordance with the parameters of the work process, operating currents, voltages, and powers can change significantly, so the measured values do not necessarily reflect the most common or average value of the electric and magnetic fields to which the worker is exposed. This can lead to wrong conclusions and inappropriate exposure.

2. There is no exposure time in the standards and regulations (international standards and national legislation in the Republic of Serbia).

If it is known that the biological effects are dominantly related to the absorbed energy of the electromagnetic field, summarizing both comments, it can be concluded that we have omitted the main parameter of the biological effect when forming the permissible values, (Krstić, 2023).

It has been shown for most physical and chemical harms that the effects of exposure have a cumulative effect, i.e. that there must be an effect of accumulation of harmfulness (dose) and a threshold at which the organism can no longer carry out correction or suppression and a negative biological consequence have to occur. So far, science has not discovered this threshold of accumulated radiation for several reasons: because we do not monitor ie. we do not measure the size that would correspond to the absorbed amount of radiation energy, so we can't even see that threshold, and we haven't looked at all the biological interactions of electromagnetic fields with parts of the body, from cells, tissues, organs to organ systems and the whole body.

The analysis of the biological effect is extremely complex because the action of electromagnetic fields must be observed at several functional and organizational levels. Thus, it is necessary to analyze the effect of EMP on the cell, parts of the cell, cell structures, the effect on the functioning of the cell membrane, effect of ions on intercellular substances, effect of chemical reactions in the cell, effect on enzymes, effect on cell metabolism, effect on performance of functions of groups of cells at the tissue level, organs, systems and the manifestation of pathological deformations to the level of the occurrence of disease and the impact on fatal outcomes of the individual.

DOSIMETRY OF NON-IONIZING RADIATION

Radiation dosimetry is a scientific discipline born out of the need to relate human exposure to ionizing radiation and the biological effects of that radiation. During the period of development of nuclear energy and atomic weapons, dosimetry was supposed to define doses, enable their measurement, connect doses with effects, and help in the formation of protection. From this came the ALARA principle of using radiation "as low as reasonably achievable".

At first, dosimetry of non-ionizing radiation (radiofrequency dosimetry) arose with the use of radio waves for military purposes (radar technique). With the development of wireless telecommunication systems, it was necessary to include these electromagnetic waves in dosimetry and to form new dosimetric quantities such as SAR.

By observing the biological effects of electric and magnetic fields of power frequency, it is necessary to form sizes that would have the form of a dose and that could be suitable for connecting with the health effects of these fields, (Krstić, 2023).

RADIATION MONITORING

In industry, many processes, technologies, and devices use high energy, where there are sources of high voltage levels and where large currents flow. These are places where strong electric and magnetic fields can arise. Employees are often in these places and their bodies are subjected to electromagnetic forces and induced currents in the body. Since we cannot measure these fields

in the body and tissues, it is only possible to place instruments to measure the field components on the surface of the body. If these instruments do not interfere with work, they are acceptable to wear and can be the basis for continuous monitoring of each employee, i.e. for personal monitoring of the employee. The intensities of the fields should be recorded, but also the periods in which they are exposed to a specific value of the field. At a frequency of 50Hz, it is necessary to separately analyze the electric and magnetic components of the field.

That is why the authors of this paper were tasked with designing a personal magnetic field meter - a personal dosimeter of non-ionization radiation.

PERSONAL MAGNETIC FIELD DOSIMETER

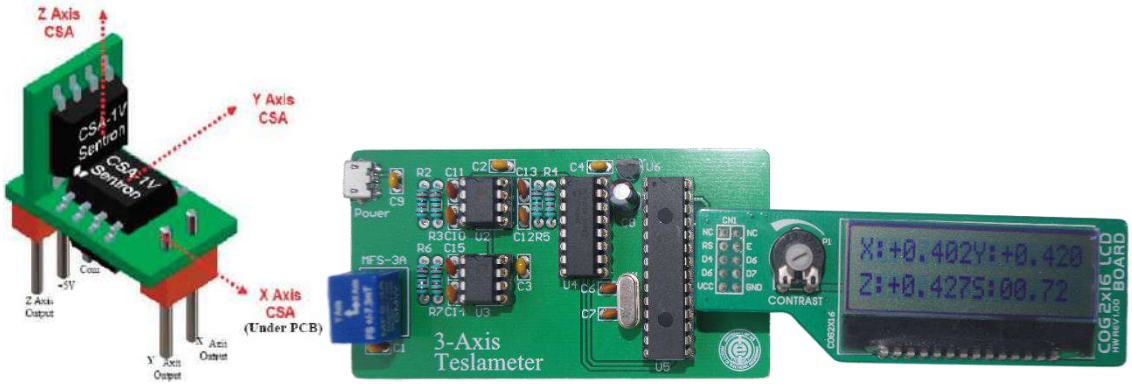
To enable individual monitoring of the electric or magnetic field in which the employee resides, it is necessary to implement a portable instrument that the employee can easily carry without reducing the employee's working abilities and that is precise enough to measure the fields that exist in the industry. The requirement for the instrument is to be small, sensitive, precise, with a high dynamic range, resistant to adverse working conditions, to record the exposure time, and that the data can be easily read from it. Additional conditions are an acceptable price that can be easily acquired by all workers who work, move, or stay for a long period near the source of strong fields.

It is suitable for this purpose for an instrument called a teslameter which consists of a magnetic field probe and an electronic processing circuit. Hall effect sensors emerged as the preferred selection for magnetic field probes due to their increasing accuracy and low prices (Popović 2023, Jovanović, 2021). Proper exposure to magnetic field monitoring requires measuring its intensity in all three axes, meaning that a three-axis probe should be used. This instrument measures the magnetic field (magnetic flux density). The key design requirements the proposed teslameter must fulfill are a simple design, low cost of components, and good temperature stability and accuracy.

The low-cost teslameter based on the MFS-3A three-axis magnetic field sensor is realized (Figure 1, Figure 2)). The measurement range of the proposed teslameter is ±5 mT. The proposed dosimeter was calibrated using the Helmholtz coil and the state-of-the-art Senis 3MH3A teslameter was employed as the reference instrument. It was important to minimize angular errors by carefully paralleling the MFS-3A and 3MH3A probes inside the Helmholtz coil. After the calibration, the maximum relative measurement error recorded in the entire measurement range was less than ±0.5 percentage compared to the corresponding measurements taken by the Senis 3MH3A teslameter.

The realized instrument records measured values and measurement times in its memory unit and the measurement interval is defined by the user (from 0.1s to 30s). An interval of 0.5 seconds is quite satisfactory for monitoring the movement of an employee in the plant.

By recording the intensities of the magnetic field and the exposure time and calculating their product, we arrive at the definition of a new quantity that represents the derivative of energy and can be a dosimetric quantity of exposure, which we will call ExpMind (Exposure of magnetic induction).



Figures 1. a) Structure of the MFS-3A magnetic field sensor, b) Photo of the realized dosimeter (electronic circuits and display)

Figure 2. Photo of dosimeter in the box and in carrying position on the employee

CONCLUSION

To improve the protection of employees from non-ionizing radiation, it is necessary to undertake several legal-regulatory, organizational, and technical technological measures. For these tasks, the cooperation of state structures in charge of employee safety (administration for safety and health at work) and scientific and professional institutions that deal with this issue is necessary.

The promotion directions are:

- Analysis of the legal framework and its improvement (correction of the regulations and introduction of new scientific knowledge in the field of protection against non-ionizing radiation),
- Improving the work of inspection bodies through education in this area so that they can recognize risks in the field and order measures to protect employees
- Cooperation of competent ministries with scientific institutions (joint work in expert commissions for the analysis of the legal framework and transfer of knowledge), as well as the initiation of projects that would enable the development of technical solutions for monitoring the situation (monitoring, instruments) and help in their implementation
- Development of a system for monitoring the state of exposure to electromagnetic fields in the living and working environment (formation of source databases, monitoring and control of their work, continuous monitoring for the needs of the wider social community).

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REVOLUTIONIZING HIGHER EDUCATION: UNVEILING THE DIGITAL TRANSFORMATION OF OCCUPATIONAL HEALTH AND SAFETY SYSTEMS IN COURSES

Kumar K.U[1], Zölzer F[1], Petrović M[2],

[1]University of South Bohemia in České Budějovice, Branišovská 1645/31A, České Budějovice 2, Czech Republic

[2]University of Novi Sad, Faculty of Technical Sciences, Department of Environmental Engineering and Occupational Safety and Health, Trg Dositeja Obradovića 6, Novi Sad 21000, Serbia (e-mail: majadjogo@uns.ac.rs)

Abstract: In an era where the integration of Occupational Health and Safety (OHS) principles into higher education is a pressing imperative, Project DOHASS emerges as a transformative beacon of innovation. Graduates, particularly OHS engineers and analytical chemists, bear the responsibility of shaping secure and conducive workplaces. However, the scarcity of comprehensive OHS education at the university level underscores the compelling urgency of Project DOHASS. This project's overarching objective was to bolster the digital capabilities of higher education institutions, paving the way for high-quality online and remote OHS learning experiences. By harnessing innovative approaches, DOHASS aimed to revolutionize the landscape of OHS education. It embarked on a journey to modernize online lectures and course content, encompassing a diverse array of critical OHS domains. These domains spanned preventive measures, risk assessment, safety management system design, environmental safety, and analytical chemistry. The project unfolded as a rich tapestry of openly accessible educational resources, textbooks, and the creation of an Online Educational Platform (OEP). These materials transcended linguistic boundaries, extending their benefits not only to Serbia, Slovakia, and the Czech Republic but also to nations with kindred OHS study programs.

Keywords: *occupational safety and health; higher education; open accessible educational resources.*

INTRODUCTION

The literature underscores the limited availability of comprehensive OHS education programs at the university level, leaving graduates ill-prepared to address the multifaceted demands of modern workplaces. Existing higher education systems often prioritize theoretical knowledge acquisition, neglecting practical skills and competencies required for effective OHS management (Johnson, 2017).

Rapid changes in work environments, including the rise of technology and new forms of employment, have introduced novel OHS challenges that demand updated education approaches (Frick, 2020). Emerging risks, such as those related to environmental safety and analytical chemistry, require OHS professionals to adapt and stay current in their field.

The digital transformation of education has become a global trend and OHS education should not lag. Leveraging digital tools and online platforms can enhance the quality and accessibility of OHS education (UNESCO, 2020).

OHS is an interdisciplinary field that demands collaboration among professionals with diverse expertise, including OHS engineers, work medicine experts, analytical chemists, and data

scientists. An integrated approach to education is vital. OHS principles transcend borders, making it crucial to develop educational resources that can benefit not only specific regions (Serbia, Slovakia, and the Czech Republic in this case) but also other countries with similar OHS study programs (International Labour Organization, 2020).

OHS professionals must bridge the gap between theoretical knowledge and practical application (Hale and Borys, 2021). Practical skills, laboratory experience, and fieldwork are essential components of OHS education.

The inception of Project DOHASS (Digitalization of Occupational Health and Safety Systems) was driven by a comprehensive need analysis that identified critical gaps and challenges in the field of Occupational Health and Safety (OHS) education. This analysis was rooted in a recognition of the fundamental importance of OHS principles in ensuring the well-being of workers and the significance of equipping future professionals with the necessary knowledge and skills to navigate the complex landscape of workplace safety.

The literature underscores the limited availability of comprehensive OHS education programs at the university level, leaving graduates ill-prepared to address the multifaceted demands of modern workplaces. Existing higher education systems often prioritize theoretical knowledge acquisition, neglecting practical skills and competencies required for effective OHS management.

Rapid changes in work environments, including the rise of technology and new forms of employment, have introduced novel OHS challenges that demand updated education approaches. Emerging risks, such as those related to environmental safety and analytical chemistry, require OHS professionals to adapt and stay current in their field.

The digital transformation of education has become a global trend and OHS education should not lag. Leveraging digital tools and online platforms can enhance the quality and accessibility of OHS education. The COVID-19 pandemic further underscored the need for robust online and remote learning options in higher education.

OHS is an interdisciplinary field that demands collaboration among professionals with diverse expertise, including OHS engineers, work medicine experts, analytical chemists, and data scientists. An integrated approach to education is vital. OHS principles transcend borders, making it crucial to develop educational resources that can benefit not only specific regions (Serbia, Slovakia, and the Czech Republic in this case) but also other countries with similar OHS study programs.

OHS professionals must bridge the gap between theoretical knowledge and practical application. Practical skills, laboratory experience, and fieldwork are essential components of OHS education.

Beyond responding to immediate needs, Project DOHASS aimed to create a sustainable digital infrastructure for OHS education, ensuring its long-term impact and relevance.

Ultimately, the need for Project DOHASS arises from the overarching goal of enhancing the competence of future OHS experts and contributing to safer workplaces, thereby safeguarding the well-being of workers.

A PEST ANALYSIS FOR THE IMPLEMENTATION AND SUSTAINABILITY OF DOHASS

A PEST analysis, which assesses the political, economic, social, and technological factors, is imperative for gauging the feasibility and sustainability of DOHASS implementation.

The political landscape in the participating countries (Serbia, Slovakia, and the Czech Republic) plays a pivotal role in shaping the framework for Project DOHASS. These countries have varying OHS regulations and standards, reflecting distinct political priorities. As such, ensuring compliance with these regulations emerged as a cornerstone of the project's success. Moreover, the level of government support and funding for education initiatives, particularly in the specialized field of occupational health and safety (OHS), carries significant implications for the project's sustainability. Government backing can provide vital resources and policy alignment to bolster Project DOHASS. Furthermore, considering that some partner countries are EU members (Slovakia and the Czech Republic), adherence to EU regulations and standards becomes particularly relevant. Given the project's aim to align with European best practices, navigating the intricacies of EU regulations was essential to ensure harmonization.

Economic conditions in the partner countries wield a considerable influence over the implementation of Project DOHASS. The availability of funding for the project hinges on the economic stability and budget allocations within these nations. Periods of economic downturns or stringent budget constraints can potentially impact the flow of financial support to the project. Moreover, the cost of acquiring and implementing digital technologies for online education, a central component of Project DOHASS, may vary depending on the economic circumstances. Economic factors are, therefore, pivotal in determining the feasibility of these investments and the project's overall financial sustainability.

Societal awareness and preferences are critical determinants of Project DOHASS's success. The demand for Occupational Health and Safety (OHS) education is closely linked to the extent to which society recognizes the importance of workplace safety. A growing awareness of workplace safety issues and their implications can drive increased interest and participation in the project. Additionally, understanding the social and cultural preferences of the target audience is imperative. Given the project's multi-country scope, catering to diverse linguistic and cultural preferences is essential for delivering effective online education materials.

Technology serves as the backbone of Project DOHASS's digitalization efforts. The quality and availability of digital infrastructure, encompassing aspects such as internet connectivity and access to devices, hold profound implications for the project's ability to effectively deliver online content. Adapting to the rapid pace of technological advancements is a central imperative. Staying at the forefront of technology is essential for creating a state-of-the-art online educational platform that meets the evolving needs of learners. Moreover, as the project involves handling educational resources online, robust cybersecurity measures and data protection are indispensable to safeguard the integrity of the project and protect sensitive information.

DOHASS IMPLEMENTATION RESULTS

One of the two main project outputs contains educational materials (integral texts and audio PPTs) for teaching courses. Each partner developed teaching material in 2 languages (English and national language). Prepared materials are made available to students throughout the DOHASS education platform. The initiative is a significant contribution in terms of innovation, impact, and

transferability. In terms of innovation, it leverages technology and the DOHASS education platform to create and share educational materials in multiple languages. This not only provides greater access to educational materials for students who may speak different languages, but it also demonstrates a forward-thinking approach to teaching and learning in higher education. In terms of impact, this output has the potential to positively impact student learning outcomes. By providing high-quality educational materials in multiple languages, students are better equipped to engage with the course content and achieve academic success. Additionally, the availability of audiovisual materials can enhance the learning experience and cater to different learning styles. In terms of transferability, output initiatives can be easily replicated and adapted by other universities around the world. The use of technology and multiple languages is a universal concept that can be applied to other educational contexts. Furthermore, the availability of audiovisual materials can also be leveraged in other disciplines and subject areas.

The second project output includes video materials with detailed instructions for regular, field, laboratory, and computational exercises. Each partner delivered a video with additional material in 2 languages (English and national language). Prepared materials are made available to students throughout the DOHASS education platform. Video materials are available for other universities in Slovakia, the Czech Republic, and Serbia, as well as other interested universities globally. The production of video materials with detailed instructions for regular, field, laboratory, and computational exercises in 2 languages (English and national language) is a significant contribution in terms of innovation, impact, and transferability. In terms of innovation, the use of video materials in teaching is an innovative approach that caters to the needs of modern learners. Video materials can provide a more interactive and engaging learning experience and can help students to better understand complex concepts and procedures. In terms of impact, the availability of video materials with detailed instructions can enhance student learning outcomes. Students can use the materials to better prepare for and engage with exercises in the regular, field, laboratory, and computational domains. The materials can also be used to support independent learning and self-paced study. In terms of transferability, the initiative can be easily replicated and adapted by other universities around the world. The use of video materials is a universal concept that can be applied to other disciplines and subject areas. Furthermore, the availability of these materials in multiple languages can be of benefit to universities with diverse student populations.

Table 1 presents a comparative analysis of units upgraded across five types of educational elements, namely Lectures, Exercises, Field exercises, Computational exercises, and Laboratory exercises, and the proposed number of units.

Table 1. Comparative analysis of proposed and delivered units

Type of the educational element	Number of proposed units (DOHASS project proposal)	Number of delivered units (DOHASS)
Lectures	25	**30**
Exercises	0	**21**
Computational exercises	3	**4**
Field exercises	15	**18**
Laboratory exercises	10	**11**

IMPACT OF DOHASS ON HIGHER EDUCATION LEVEL

Project DOHASS has the potential to positively influence universities by enhancing curriculum quality, promoting innovative teaching methods, facilitating international collaboration, and fostering a culture of continuous improvement in OHS education. This influence can benefit both students and academic institutions, contributing to the advancement of occupational health and safety education.

DOHASS aims to modernize and update the curriculum related to Occupational Health and Safety (OHS) in universities. Introducing innovative teaching materials, resources, and digital platforms, it can significantly enhance the quality and relevance of OHS education. Universities can benefit from this enriched curriculum by offering more up-to-date and practical courses to their students.

The project's emphasis on innovative teaching methods, including online lectures and interactive resources, can inspire universities to explore new pedagogical approaches. Faculty members can incorporate these methods into other subjects, promoting a culture of innovation and technology-enhanced learning.

DOHASS intends to create educational resources available in multiple languages. This can help universities cater to a more diverse student body, including international students. It can also encourage universities to offer courses in various languages, potentially attracting a broader audience.

DOHASS involves collaboration between universities in different countries. This international partnership can open doors for universities to engage in more global collaborations, joint research projects, and student exchange programs. It can foster a spirit of global cooperation and broaden universities' horizons.

As universities work on developing digital tools and resources for DOHASS, they may also engage in research related to online education, technology in education, and occupational health. This can lead to valuable research outcomes and publications.

DOHASS can contribute to raising awareness of the importance of OHS studies and professions. Universities may witness increased enrolment in OHS-related programs as students become more aware of the field's relevance and opportunities.

Faculty and staff involved in DOHASS may gain new skills and expertise in online education, curriculum development, and digital resource creation. These skills can enhance their professional development and benefit their broader roles within universities.

The project's focus on quality assurance can encourage universities to establish robust quality assurance mechanisms for their programs. This can be particularly important for accreditation purposes and ensuring that OHS programs meet international standards.

DOHASS is designed to be sustainable beyond its initial implementation. This can encourage universities to think about the long-term sustainability of their programs and the continuous improvement of OHS education.

Collaboration within DOHASS can lead to the formation of strong networks and partnerships among universities, OHS professionals, and relevant organizations. These networks can serve as valuable resources for universities for future initiatives and collaborations.

CONCLUSION

Project DOHASS stands as a shining example of how education can be a catalyst for progress and sustainability. Through its dedication to quality education, safer workplaces, innovation, and international collaboration, it not only revolutionizes OHS education but also plays a vital role in building a safer, more prosperous, and sustainable world for generations to come. Building on the collaborative model established in Project DOHASS, future initiatives could expand the network of partner universities and institutions to include a more diverse range of countries and regions. This would not only promote cross-cultural learning but also enable the sharing of best practices from a broader spectrum of OHS challenges. While Project DOHASS covered a comprehensive range of OHS topics, future initiatives could focus on developing specialized modules or courses that delve deeper into specific areas of OHS. For example, modules on emerging technologies' impact on workplace safety or advanced risk assessment methodologies.

ACKNOWLEDGEMENT

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ANALYSIS OF THE NUMBER OF OCCUPATIONAL INJURIES AS A KEY ELEMENT OF SAFETY SYSTEM AND ENERGY SECTOR MANAGEMENT

Malenović Nikolić J.[1], *Krstić D.*[2], *Jovanović U.*[2], *Ilić-Krstic I.*[2], *Milošević L.*[2]

[1]Faculty of Occupational Safety, University of Niš, Čarnojevića 10a, Serbia (e-mail: malenovicfznr@gmail.com)

[2] Faculty of Occupational Safety, University of Niš, Čarnojevića 10a, Serbia

Abstract: Analysis of the number of occupational injuries in terms of incidence, type, and share according to industry branch and territory is an important task in safety system management. Preservation of workers' safety and health is one of the basic necessities because Serbia is a country where conditions in the work environment are commonly less than adequate. This paper presents an analysis of the number of injuries with the aim to emphasise the need to present fatal injuries in the energy sector.

Keywords: *occupational injury; fatal injuries; management; energy sector; safety system.*

INTRODUCTION

Serbian Occupational Safety and Health Administration, operating within the Ministry of Labour, Employment, Veteran and Social Affairs, collects data on occupational injuries and classifies them according to severity, employer's field of activity, source and cause of injury, injured part of the body, and age and sex of the injured (Labour Report for 2022). Table 1 shows the number of injuries according to type, based on the analysis of data on fatal, major, and minor injuries from the Labour Reports for eight consecutive years.

Table 1. Number of injuries from 2015 to 2022, by year

Type of injury Year	2015	2016	2017	2018	2019	2020	2021	2022
Fatal injuries*	5	8	9	7	14	11	12	11
Major injuries *	724	763	898	788	1233	1226	1289	1127
Major injuries **	452	473	677	522	597	435	487	596
Minor injuries	6810	7820	8628	9087	11462	8623	9487	10958
Total	7991	9064	10213	10404	13306	10295	11275	12692

*At work, **While commuting

The analysis of the number of fatal injuries reveals an increasing trend of fatal outcomes from 2015 onward. A similar conclusion is made for the number of major injuries at work. It is interesting to observe that the maximum number of injuries at work and fatal injuries occurred in 2019. Unfortunately, the data on the number of fatal injuries by field of activity, which would identify the real issues, are not available. The number of commuting injuries varies less.

OCCUPATIONAL INJURIES – ELEMENT OF SAFETY SYSTEM MANAGEMENT

Analysis of the total number of occupational injuries shows significant differences in safety management among specific administrative districts in Serbia. Analysis of the Labour Report for 2022 reveals that the following districts had the most total injuries: the City of Belgrade (5720), South Bačka (3202), and Nišava (1576), as shown in Figure 1.

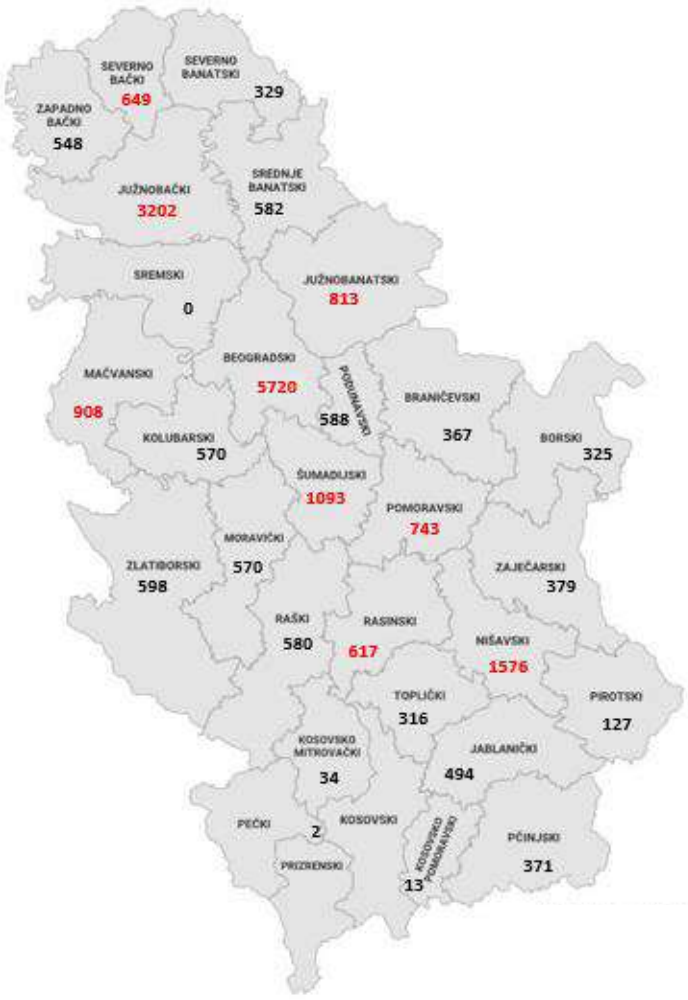

Figure 1. Number of occupational injuries in Serbia in 2022 by administrative districts

Labour inspectors conduct inspections when an occupational injury has been reported. Criminal charges are filed with public attorney's office sections throughout Serbia for failure to take occupational safety and health measures if such failure results in fatal, major, or collective occupational injuries; additionally, the outcomes of proceedings following the charges are considered. The public attorney's office analyses the committed crimes and regularly distributes data (Labour Reports, 2015-2021).

Labour Reports also include the data provided by the Ministry of Justice on the number of submitted requests for the initiation of misdemeanour proceedings pursuant to the Law on Occupational Safety and Health ("Official Gazette of the RS", no. 101/05 and 91/15, 35/2023) and the Law on Misdemeanours ("Official Gazette of the RS", no. 65/13, 13/2016, 98/2016 – decision of the Constitutional Court, 91/2019 and 112/2022 – decision of the Constitutional Court).

The analysed data from the Labour Reports from 2015 to 2022 confirm the regular publication of data on the number of submitted requests, the number of closed cases, the fines levied pursuant to the Law on Occupational Safety and Health, the fines levied pursuant to the Law on Misdemeanours, and the number of cases closed in a different manner pursuant to the same law (warning notices, request denials, dismissals, and release from responsibility of the accused).

Figure 2 shows the average values of total submitted requests, the total number of closed cases, and the number of cases closed pursuant to the Law on Misdemeanours, obtained after a detailed analysis of the presented values by year (Labour Reports from 2015 to 2022). The analysis aims to provide a clearer picture of the initiation of misdemeanour proceedings in 43 Serbian cities, in order to examine the relation between the number of injuries and the number of misdemeanour proceedings in a specific territory.

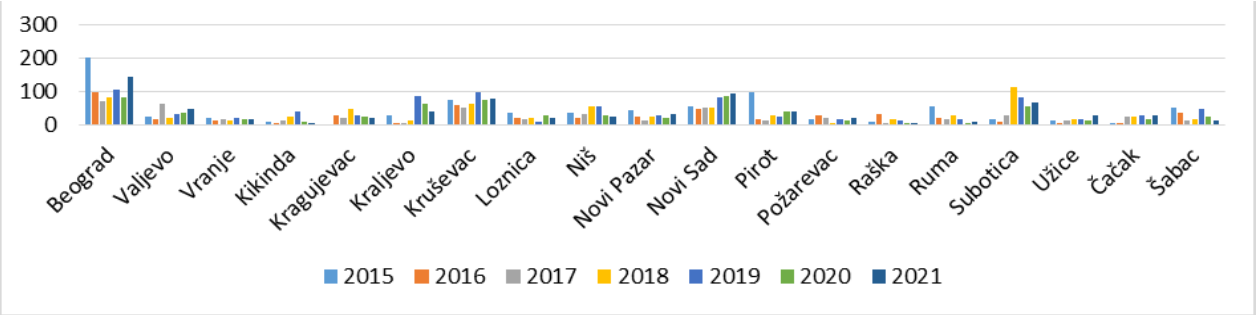

Figure 2. Total requests submitted from 2015 to 2021, by year

The graph in Figure 2 clearly shows that most requests for the initiation of misdemeanour proceedings (pursuant to the Law on Occupational Safety and Health) were submitted in Belgrade, Kruševac, Novi Sad, Pirot and Niš. The data for the requests submitted in Novi Sad are to be expected since the analysis showed that the South Bačka District ranks second in the number of reported occupational injuries (3202). Most requests overall were submitted in Belgrade, which is understandable considering the city's economic development and the number of injuries on record. The Nišava District ranks third in the number of occupational injuries, so a higher number of submitted requests for the initiation of misdemeanour proceedings.

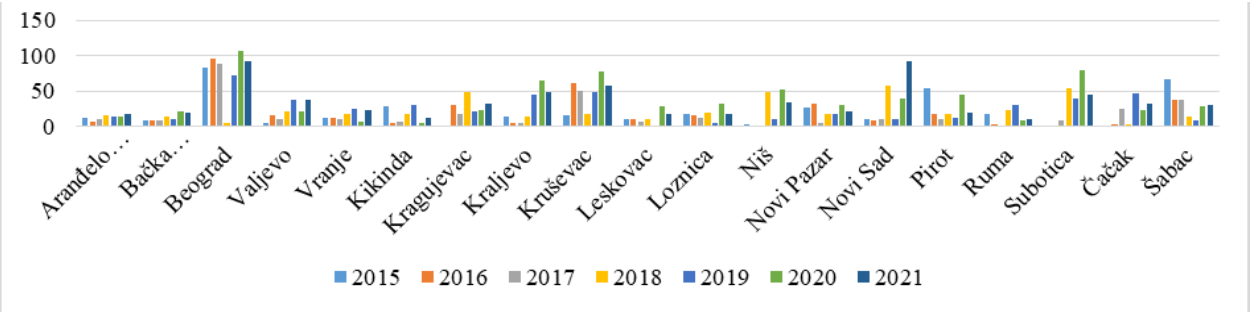

Figure 3. Total number of closed cases from 2015 to 2021, by year

Figure 3 shows that the highest average number of closed cases pertains to the public attorney's offices in Belgrade, Kruševac, Novi Sad, Subotica and Šabac.

Table 2. Total requests submitted from 2015 to 2021, by year

City	Average value		
	Total requests issued	Total no. of closed cases	Cases closed pursuant to the Law on Misdemeanours
Aranđelovac	14.29	13.43	4.00
Bačka Palanka	12.29	13.00	2.14
Beograd	111.29	77.71	53.00
Bečej	7.00	7.43	2.67
Valjevo	35.00	21.29	2.86
Vranje	17.57	15.71	9.86
Vršac	4.43	4.33	2.17
Zaječar	13.43	7.86	3.33
Zrenjanin	14.86	10.43	5.33
Jagodina	10.14	8.17	3.00
Kikinda	16.14	15.14	7.00
Kragujevac	24.43	24.71	16.71
Kraljevo	35.00	28.29	9.17
Kruševac	71.29	46.86	12.14
Lazarevac	1.43	2.29	0.57
Leskovac	13.71	11.86	5.00
Loznica	22.29	17.14	6.43
Mladenovac	3.86	2.57	1.83
Negotin	2.00	1.57	1.14
Niš	36.57	22.00	12.57
Novi Pazar	27.14	21.71	8.57
Novi Sad	67.43	33.00	12.57
Obrenovac	2.86	3.14	1.14
Pančevo	8.14	9.57	5.71
Paraćin	2.86	2.71	1.67
Pirot	37.00	25.29	4.14
Požarevac	17.43	9.57	3.71
Požega	4.71	3.71	1.67
Preševo	4.29	3.43	1.50
Prijepolje	3.00	1.14	1.20
Prokuplje	7.86	6.00	1.67
Raška	11.71	5.86	6.50
Ruma	22.14	14.14	7.00
Senta	14.29	8.29	2.60
Smederevo	10.00	7.86	2.71
Sombor	4.71	3.33	2.67
Srem. Mitrovica	12.71	7.57	2.14
Subotica	53.14	32.71	7.14
Trstenik	13.57	10.57	2.29
Užice	15.14	10.71	5.67
Čačak	18.43	19.43	4.86
Šabac	29.29	31.86	20.57

It is also relevant to examine the relationship between total submitted requests and the total number of closed cases (Table 2), which reveals significant differences. The analysis was performed based on average values for cities with the highest average number of reports and closed cases.

The analysis of the data presented in tables from the Labour Reports from 2015 to 2021 shows that the biggest difference between the average number of reports and closed cases was found for the public attorney's offices in Belgrade, Subotica, Kruševac, and Niš. The number of closed cases and other rulings (warning notices, request denials, dismissals, and release from responsibility of the accused) was considered for cities with the highest average number of cases for each year from 2015 to 2021.

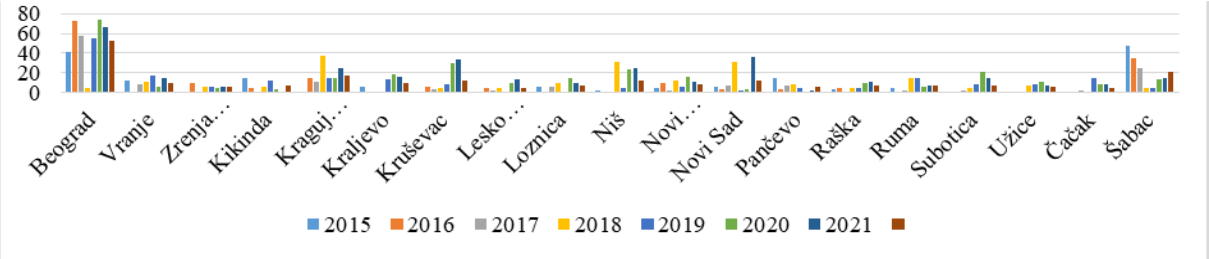

Figure 4. Total number of cases otherwise closed pursuant to the Law on Misdemeanours from 2015 to 2021, by year

Figure 4 shows that the highest number of warning notices, request denials, dismissals, and releases from the responsibility of the accused pertain to the public attorney's offices in Belgrade, Šabac, Kragujevac, Niš, and Novi Sad, which reflects the management of the occupational safety system.

OCCUPATIONAL INJURIES – ELEMENT OF ENERGY SECTOR MANAGEMENT

Energy sector management is an important task, especially in terms of worker safety. The number of occupational injuries in mining, distribution of electric power, gas, and steam, and air conditioning has been monitored since 2016. The Labour Report from 2015 contains collective data for mining and industry, according to which 272 fatal and major injuries were reported, which amounts to 37.31% of reported fatal and major injuries out of the total number of injuries in all fields of activity.

Table 3. Occupational injuries according to employer's field of activity from 2016 to 2022

Activity	Year: 2015	2016	2017	2018	2019	2020	2021	2022
Mining	/	26	36	27	43	41	50	27
Distribution*	/	56	71	62	68	99	63	47

*of electric power, gas, and steam, and air conditioning

The analysis of Labour Reports from 2016 to 2022 shows that the number of injuries in mining increased from 2019 to 2021. The biggest problem in terms of occupational safety was registered in 2020 in the distribution of electric power, gas, steam, and air conditioning (Table 3), which indicates a need for more adequate reporting.

Table 4. Occupational injuries according to work environment from 2016 to 2022

Work environment	Year: 2018	2019	2020	2021	2022
Open quarry, open-pit mine, excavation, and trench*	/	14	21	31	32
Underground mine	/	15	17	10	13

*including open-pit mines and quarries

Occupational injuries according to the work environment are included in Labour Reports as injuries in open-pit mines and quarries. These injuries show an increasing trend over the analysed period (Table 4). In underground mines, 10 to 17 injuries were reported annually.

CONCLUSION

Based on the data presented in the paper, it is apparent that a more detailed analysis is warranted for the number of fatal injuries by field of activity and that there is a need for more thorough efforts from inspection authorities in administrative districts with the highest number of injuries. The energy sector is characterised by high-risk jobs, which are classified as arduous or hazardous and involve early retirement, so the number of fatal and major occupational injuries is a crucial element for safety system management.

ACKNOWLEDGEMENT

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ANALYSIS OF THE IMPACT OF EXPANDED POLYSTYRENE ON THE ENVIRONMENT USING THE LCA METHOD

Medenica M.[1], *Glišović S.*[1], *Mančić M.*[1], *Ilić Krstić I.*[1]

[1] University of Niš, Faculty of Occupational Safety, Čarnojevića 10a, Niš, Serbia (e-mail: milena.medenica@znrfak.ni.ac.rs)

Abstract: Population growth, particularly in emerging nations, has become one of the largest issues in recent decades. In addition to demographic issues, there are also economic, social, urban, and environmental ones. The growth of urban areas and the subsequent rise in population result in a loss of resource capacity, which also lowers the standard of living for locals. The production of building materials and construction affects the environment. For this reason, a large number of manufacturers have switched to alternative insulation materials, which are environmentally friendly and made from renewable raw materials. Expanded polystyrene is one of the most often used insulators in Serbia, and it comes in a variety of thicknesses (plates ranging from 5 to 15 cm). Expanded polystyrene, which is 10 cm thick and used as an artificial insulation material in this study's applied analysis, allowed for a thorough knowledge of the ecological effects of the production system over the course of the system's lifetime. The LCA analysis performed for the purposes of this paper also represents an assessment of the impact of the production and installation of the most commonly used material (styrofoam) for insulating buildings on the environment. The aim of this paper is to determine the environmental impact of the insulation material (styrofoam) that is most often used in our area when it comes to family residential buildings by applying LCA analysis.

Keywords: *insulation materials; expanded polystyrene; environment; LCA analysis.*

INTRODUCTION

Any environmental improvement, deterioration, or change that results entirely or partially from a company's product or service activity is referred to as an environmental impact. Both positive and negative effects are possible.

One of the biggest problems in recent decades has been demographic growth, especially in developing countries. The problems that arise are not only demographic but also economic, social, urban, and environmental (Nikolić Topalović, 2018). Production of building materials and construction affects the environment.

The market is dominated by construction materials that offer high-quality and excellent thermal insulation properties, as well as the possibility of recycling and reducing the impact on the environment. On the other hand, the production of these materials, as well as some of their components, raises questions about their negative impacts on the environment and human health. Besides the fact that their production requires a lot of energy, most of these materials are based on the use of fossil fuels. Thermal insulation materials need to offer effective thermal insulation, fire protection, and recycling. They must also be affordable for both industrial manufacturing and widespread use.

Polyurethanes, materials of mineral origin, mortars, concrete, and goods of biological origin are the most often employed materials for thermal insulation in contemporary buildings (Colli, 2020).

The ecological component is becoming more and more significant because there are so many manufacturers and materials available. Expanded polystyrene, which comes in plates with a thickness ranging from 5 to 15 cm, is one of the most frequently used insulators in Serbia (Stanimirović, 2023).

Different construction materials have varying life spans. Technologies for the production of new materials are directed towards the possibility of material recycling, and this is one of the important items for the certification of new products and their application (Colli, 2020). From the exploitation of raw materials through transportation, production, installation, use, impact on the environment and people, recycling, and re-production, international and national certification agencies set the standards that materials must satisfy.

LCA analysis is one of the techniques that can be used to develop a conceptual framework for the development of architectural projects that are in line with the contemporary approach to sustainable construction. For LCA analysis, a variety of tools are employed, each serving a different function.

The aim of this paper is to determine the environmental impact of the insulation material (styrofoam) that is most often used in our area when it comes to family residential buildings by applying LCA analysis.

MATERIALS AND METHODS

Life cycle analysis (Figure 1) evaluates the various impacts of the life cycle of a material or product on the environment from five main points of view, namely: extraction (obtaining raw materials), processing to the final product, application of the product, and finally withdrawing the product from use at the end of its life cycle. life cycle (Colli, 2020).

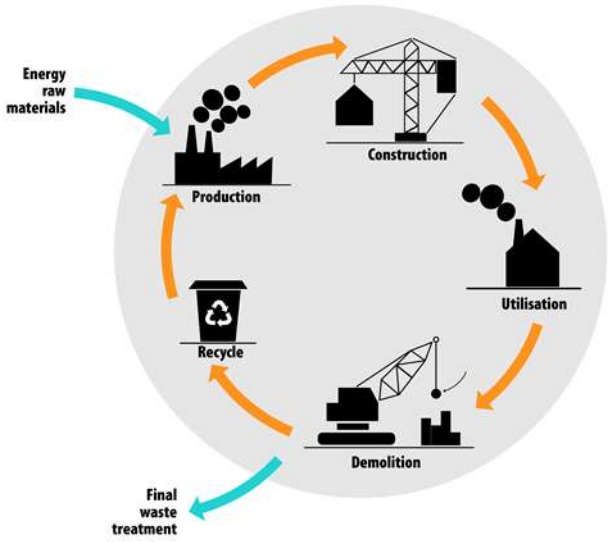

Figure 1. LCA cycle (Stanimirović, 2023)

The LCA analysis performed for the purposes of this paper also represents an assessment of the impact of the production and installation of the most commonly used material (styrofoam) for

insulating buildings on the environment. LCA is a multi-criteria and multi-phase environmental assessment, standardized according to ISO 14040 (International Standard ISO 14040:2006) and ISO 14044 (International Standard ISO 14044:2006).

The most common materials used for thermal insulation in modern construction are polyurethanes and materials of mineral origin, mortars, and concretes, as well as products of organic origin (Xu, 2023). Given that there are a large number of materials on the market as well as manufacturers, the ecological aspect is gaining more and more importance.

Expanded polystyrene is one of the most commonly used insulators in Serbia. Its thickness ranges from 5 to 15 cm for plates, although for the purposes of this study, styrofoam with a thickness of 10 cm was employed. The technique of suspension polymerization, which produces products from a raw material that resembles a grain of sugar and is steamed at roughly 100°C, is most frequently used to produce expanded polystyrene (EPS). Each grain increases in size by 30 to 50 times while losing 600 kg/m^3 of its density to 10 to 30 kg/m^3. Pre-expanded grains are placed in metal molds and sealed into their final shape after maturing in the air in ventilation silos. Ripening is needed to get rid of any pentane and water that may still be in the material after it has been taken out of the mold. Styrene monomers can be transformed into expanding polystyrene beads by the polymerization process using the batch procedure known as suspended polymerization. The expanded polystyrene beads are then sieved, coated, and packaged for onward transit once the suspension has cooled, been separated by centrifugation, rinsed, and dried (Pennacchioa, 2017). The material employed in this study's thermal properties is displayed in Table 1 (Stanimirović, 2023).

Table 1. Thermal characteristics of d expanded polystyrene

Thermal characteristics	EPS
Thermal conductivity λ (W/mK)	0.034-0.038
Flammability class	B 1 heavy combustible material
Water vapor resistance factor μ	30–70
Density (kg/m^3)	16–28

For the purposes of this work, the BAT (best available techniques) database was used, i.e., a reference document (BREF) that contains a database of the best available techniques. The BREF database considers the values of materials based on data on air emissions, water emissions, solid waste, and inputs. The presented values are given in the appropriate unit, and it is possible to compare the given results with a different choice of applied materials. The BREF database systematizes data in accordance with the international standards of ISO 14040. Apart from this standard, other standards are also included in the formation of the database. The BREF database

is free and available. It was created in the UK, and a significant amount of data and regulations are from this country.

RESULTS

When it comes to the production of polystyrene, the basic raw material for its production is oil, a non-renewable resource responsible for environmental pollution. Polystyrene is not biodegradable. If it gets into nature, it becomes dangerous for the environment in many ways. It releases harmful ingredients into the ground and thus pollutes the soil and water. The majority of the waste polystyrene ends up untreated and constitutes a threat to the environment because the collection of waste building polystyrene is not cost-effective due to tiny quantities, large volumes of mass, and high transport costs. When polystyrene has served its purpose, it can be burned, which results in the production of several hazardous gases as by-products (polycyclic aromatic hydrocarbons, carbon monoxide, styrene monomers, etc.).

Table 2 shows the permitted emissions according to the European standard, the maximum permitted emissions, and the emissions obtained by LCA analysis when using expanded polystyrene (styrofoam) with a thickness of 10 cm as insulation material.

Table 2. Presentation of emissions obtained by LCA analysis for the analyzed object for EPS with a thickness of 10 cm

	Unit	EPS 10cm	European Average	Maximum value
Air Emissions	Dust (g)	13.6944	13.6944	57.06
	Pentane (g)	456.48	1141.2	3651.84
	VOC1 (g)	273.888	319.536	1597.68
Water Emissions	COD2 (g)			2099.808
	Total solids2 (g)			3651.84
	Hydrocarbons total2(g)			18.2592
	Dissolved solids (g)		0.136944	0.182592
	Waste water2 (t)	2.2824	2.73888	4.10832
	Cooling tower purge water (t)		0.776016	1.1412
	Phosphate as P_2O_5 (g)			9.1296
Solid Waste	Hazardous (kg)	1.36944	1.36944	5.47776
	Non-hazardous (kg)	2.73888	3.65184	7.76016
Inputs	Total energy (GJ)		0.821664	1.1412
	Styrene (t)		0.42863472	0.4382208
	Ethyl benzene (t)			0.04382208
	Pentane (t)		0.0296712	0.0319536
	Cooling water (closed circuit) (t)		7.76016	31.9536
	Process water (t)		0.958608	2.73888
	Nitrogen (t)		0.0045648	0.136944
	Additives (t)		0.0136944	0.0136944

DISCUSSION

Figure 2. (a, b, c, and d) shows a graphic representation of pollutant emissions in (a) air, (b) water, (c) solid waste, and (d) inputs during the production of expanded polystyrene (styrofoam) with a thickness of 10 cm.

During the production of expanded polystyrene, the most pentane is emitted into the air, and we can see that its value is lower than the maximum allowed if the best available technologies are used, which is the case with the production that we have taken into account. Within the considered use of expanded polystyrene, we see that the amount of wastewater is large, but that it does not exceed the European average for similar production and is far less than the allowed maximum values. As far as solid waste is concerned, it is also within the permitted range and can be of a hazardous or non-hazardous nature. In the production of this type of insulation for the analyzed object, there is about 1.99 times more non-hazardous waste than hazardous waste. During the production of the necessary amount of expanded polystyrene for the insulation of this building, it is necessary to invest about 0.82 GJ of energy and 428.6 kg of styrene (Figure 2).

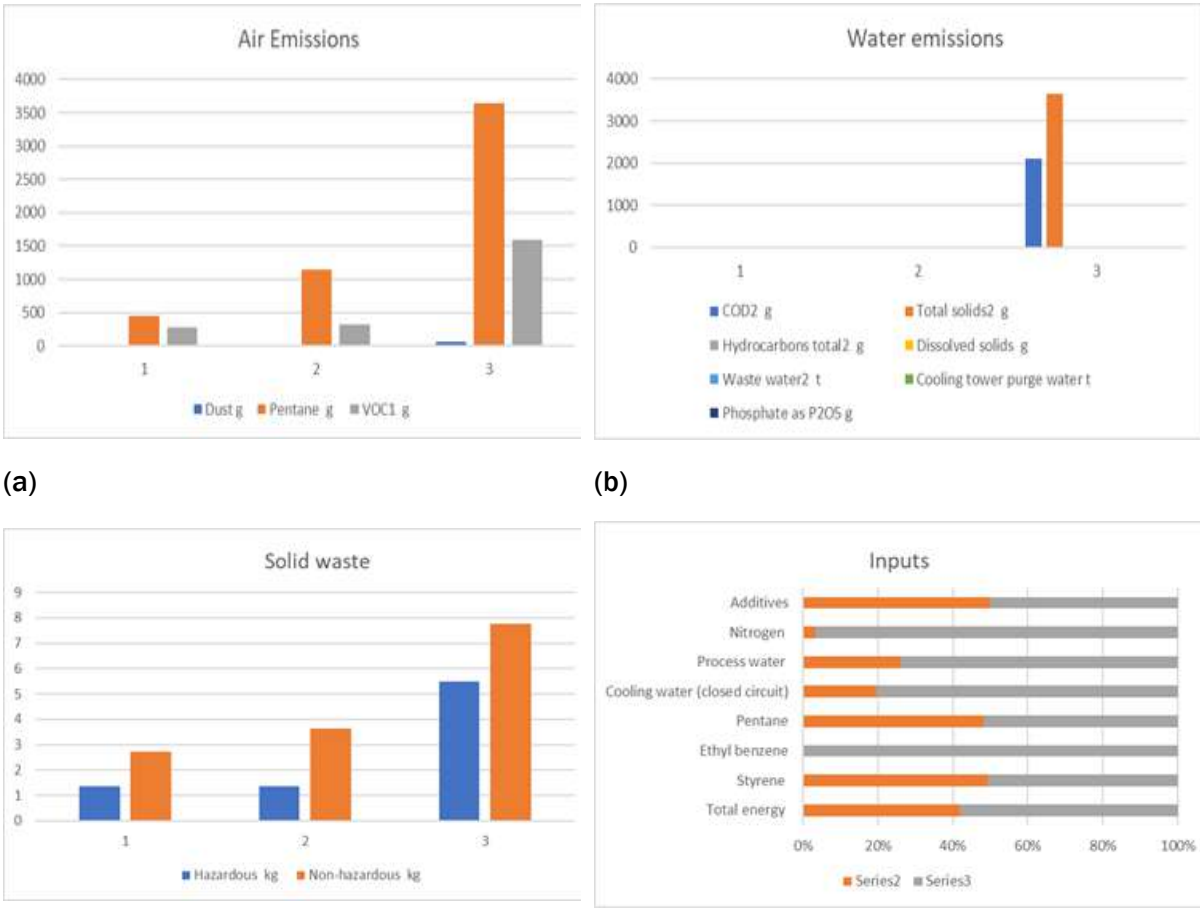

Figure 2. Emissions of pollutants into (a) air, (b) water, (c) solid waste, and (d) inputs during the production of expanded polystyrene

CONCLUSION

We can examine the effects of the EPS insulating panel based on the data provided, accounting for the CO_2 footprint, environmental impact, and cost. In general, EPS panels are the most economical form of insulation. Due to the use of petrochemicals during production, EPS panels have a significant carbon footprint. However, as EPS panels are composed of non-renewable materials and produce a sizable amount of waste, they have a detrimental effect on the environment. When they burn or decay, they may potentially release harmful fumes.

In conclusion, EPS panels have a significant carbon footprint and a detrimental effect on the environment despite being the most cost-effective option on the market.

Additionally, EPS panels are frequently produced in centralized plants and shipped over great distances. The final decision among these materials will be based on the particular requirements of the rural architectural rebuilding project, taking into account elements like cost and availability.

Based on research, it can be said that sustainable reconstructions should be built with sustainable methods, materials, and procedures. Their creation and subsequent use ought to have no negative environmental effects. The LCA technique confirmed that energy reduction is required prior to repair. Another prerequisite is that the rebuilt structure must be energy-efficient. The building's life cycle comes to an end with its demolition, which is the last stage. The materials utilized should be environmentally friendly and simple to recycle.

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REMEDIATION OF ORGANOPHOSPHORUS PESTICIDES USING SPENT COFFEE GROUNDS – KINETICS AND NEUROTOXICITY

Milanković V.[1], Tasić T.[1], Brković S.[1], Lazarević-Pašti T.[1]

[1]VINČA Institute of Nuclear Sciences-National Institute of the Republic of Serbia, University of Belgrade, Mike Petrovića Alasa 12-14, 11000 Belgrade, Serbia (e-mail: vedran.milankovic@vin.bg.ac.rs)

Abstract: Organophosphorus pesticides (OPs) are widely used in agriculture to control pests, but their residues pose significant environmental and health risks. In this study, the potential of spent coffee grounds (SCG) as a sustainable adsorbent for the remediation of organophosphorous pesticides, specifically malathion (MLT) and chlorpyrifos (CHP), was investigated. The kinetics of MLT and CHP adsorption onto SCG were examined using various kinetic models, and the pseudo-second-order model fitted experimental data the best. The adsorption capacities were determined as 3.401 mg g^{-1} for MLT and 2.518 mg g^{-1} for CHP. A higher adsorption rate was observed for MLT, with a k_2 value of 0.191 mg min^{-1} g^{-1}, compared to a k_2 value for CHP of 0.003 mg min^{-1} g^{-1}. The intraparticle diffuson kinetic model revealed three linear stages for MLT and two for CHP, suggesting multiple processes in the adsorption mechanism. Furthermore, the significance of the boundary layer effect was demonstrated by an increasing C value during adsorption. Notably, the neurotoxicity of the adsorbed pesticides was also assessed to evaluate the safety of the remediation process. Overall, this study highlights the efficacy of SCG as a potential eco-friendly and cost-effective adsorbent for the remediation of organophosphorous pesticides from contaminated environments while considering the potential impact on neurotoxicity.

Keywords: *biowaste, organophosphates; adsorption; remediation; spent coffee grounds.*

INTRODUCTION

Organophosphorus pesticides (OPs) are widely employed in agriculture to combat pests, functioning as neurotoxicants by inhibiting the enzyme acetylcholinesterase (AChE). This inhibition leads to the accumulation of the neurotransmitter acetylcholine (ACh) at nerve endings, prolonging its action and causing potential harm (Lazarevic-Pasti, 2017, Milankovic, 2021, Tasić, 2022).

Chlorpyrifos (CHP) is an organophosphate insecticide widely used in agriculture to control various pests on crops such as fruits, vegetables, and grains. It acts as a potent neurotoxin by disrupting the nervous system of insects. However, concerns have been raised about its potential health risks to humans, especially children, as exposure to it led to various neurological, respiratory, and other diseases (Milanković, 2023).

Malathion (MLT) is another organophosphate insecticide commonly used in agriculture and public health programs to control various insect pests. While effective in controlling pests, malathion should be used with caution due to its potentially harmful effects on non-target organisms and the environment (Milanković, 2023).

CHP and MLT can undergo oxidation, forming the more toxic chlorpyrifos-oxon and malaoxon when absorbed or ingested by humans.

The efficient removal of OPs from water is a crucial environmental concern, and adsorption has emerged as a promising and safe method (Tasić, 2023). The search for an adsorbent material with optimal properties and environmentally friendly production techniques continues, with non-treated waste materials garnering attention due to their cost-effectiveness (Anićijević, 2023, Jocić, 2022, Tasić, 2023).

This study investigates the kinetics and effectiveness of adsorbing CHP and MLT using bio-waste material obtained from non-treated, spent coffee grounds. Coffee, being one of the world's most consumed products, generates significant amounts of waste in the form of discarded coffee grounds, presenting an environmental pollution challenge. By exploring the potential of coffee grounds as an adsorbent for OPs, this research aims to contribute to sustainable and eco-friendly solutions for water purification and pesticide removal.

MATERIALS AND METHODS

Spent coffee grounds (SCG) were dried for five days at ambient temperature. The obtained bio-waste material was dispersed in double-distilled water (stock dispersion was 2 mg ml^{-1}). To prepare the mixtures, 1 ml of SCG stock dispersion was combined with specified amounts of CHP and MLT stock solutions (Pestanal, Sigma Aldrich, Søborg, Denmark) prepared in 50 vol.% ethanol in water to achieve the desired concentration of adsorbent and OP. The mixtures were then shaken in a laboratory shaker for a specific duration and centrifuged at 14,500 rpm. The supernatant was filtered through a nylon membrane. Ultra-Performance Liquid Chromatography (UPLC) analysis was carried out using a Waters ACQUITY UPLC system with a photodiode array (PDA) detector and Empower 3 software to determine the concentrations of chlorpyrifos and malathion. The analyses were done using ACQUITY UPLC™ BEH C18 column (1.7 µm, 100 mm × 2.1 mm, Waters GmbH, GER) under isocratic conditions with 10% acetonitrile in water (v/v) for mobile phase A and pure acetonitrile for mobile phase B, with a flow rate of 0.2 mL min−1 and an injection volume of 5 µL. The mobile phase composition for chlorpyrifos was 20% A and 80% B, while for malathion, it was 40% A and 60% B. The retention times for malathion and chlorpyrifos were 3.2 min and 2.7 min, respectively, and both OPs were detected at 200 nm. Control experiments were conducted without an adsorbent following the same procedure.

To determine the kinetic parameters of CHP and MLT adsorption on SCG, the tested adsorbent at a concentration of 1 mg mL^{-1} was incubated with OPs at a concentration of 5×10^{-4} mol dm^{-3} at 25 °C for 1, 10, 30, 60 and 1440 min. The concentration of adsorbed pesticides was calculated as the difference between its initial concentration (C_0) and the equilibrium concentration (C_e) of malathion measured by UPLC after removing the adsorbent. The kinetics of MLT adsorption onto investigated materials were analyzed using the linear pseudo-first (eq. 1), pseudo-second-order (eq. 2), Elovich kinetic model (eq. 3), and intraparticle diffusion model (eq. 4).

$$ln(q_e - q_t) = lnq_e - k_1 t \quad (1)$$

$$\frac{t}{q_t} = \frac{1}{k_2 q_e^2} + \frac{1}{q_e} t \quad (2)$$

$$q_t = \frac{1}{\beta} ln(\alpha\beta) + \frac{1}{\beta} lnt \quad (3)$$

$$q_t = k_{id} t^{0.5} + C \quad (4)$$

Where the parameter q_t (mg g^{-1}) represents the quantity of adsorbed MLT at time t, parameter q_e denotes the quantity of OP adsorbed at equilibrium (mg g^{-1}). The parameter k_1 corresponds to the adsorption rate constant in the pseudo-first-order kinetic model (min^{-1}). On the other hand, k_2 represents the adsorption rate constant in the pseudo-second-order kinetic model (mg g^{-1} min^{-1}). In the Elovich model, α represents the initial adsorption rate (mg g^{-1} min^{-1}), while β represents the desorption constant (g mg^{-1}). Parameter k_{id} represents the adsorption rate constant of the intraparticle diffusion model (mg g^{-1} $min^{-0.5}$), and C is connected to a boundary layer (mg g^{-1}).

The study also assessed the physiological effects of the treated solutions by measuring AChE inhibition by modifying Ellman's assay (Ellman, 1961, Lazarević-Pašti, 2012). A commercially purified AChE from an electric eel (Sigma Aldrich, Taufkirchen, Germany) was exposed to the OP solutions in a 50 mM phosphate buffer with a pH of 8.0, at a temperature of 37 °C, in a final volume of 0.650 mL. The enzymatic reaction was triggered by combining acetylcholine-iodide (AChI, Sigma Aldrich, Taufkirchen, Germany) and DTNB (Sigma Aldrich, Taufkirchen, Germany) as a chromogenic reagent. After an 8-minute reaction time, it was stopped with 10% sodium dodecyl sulfate (SDS), and the optical absorption of the reaction product, 5-thio-2-nitrobenzoate, was measured at 412 nm to quantify the AChE inhibition, with the enzyme concentration held constant to produce an optimal spectrophotometric signal. The physiological effects were quantified as the AChE inhibition, given in eq. 5, where A_0 and A stand for the AChE activity in the absence of OP and the one measured after exposure to a given OP.

$$I = 100 \times \frac{A_0 - A}{A_0} \quad (5)$$

RESULTS AND DISCUSSION

The linear forms of the mentioned kinetic models are presented in Figure 1. The kinetic parameters and corresponding R^2 values are given in Table 1.

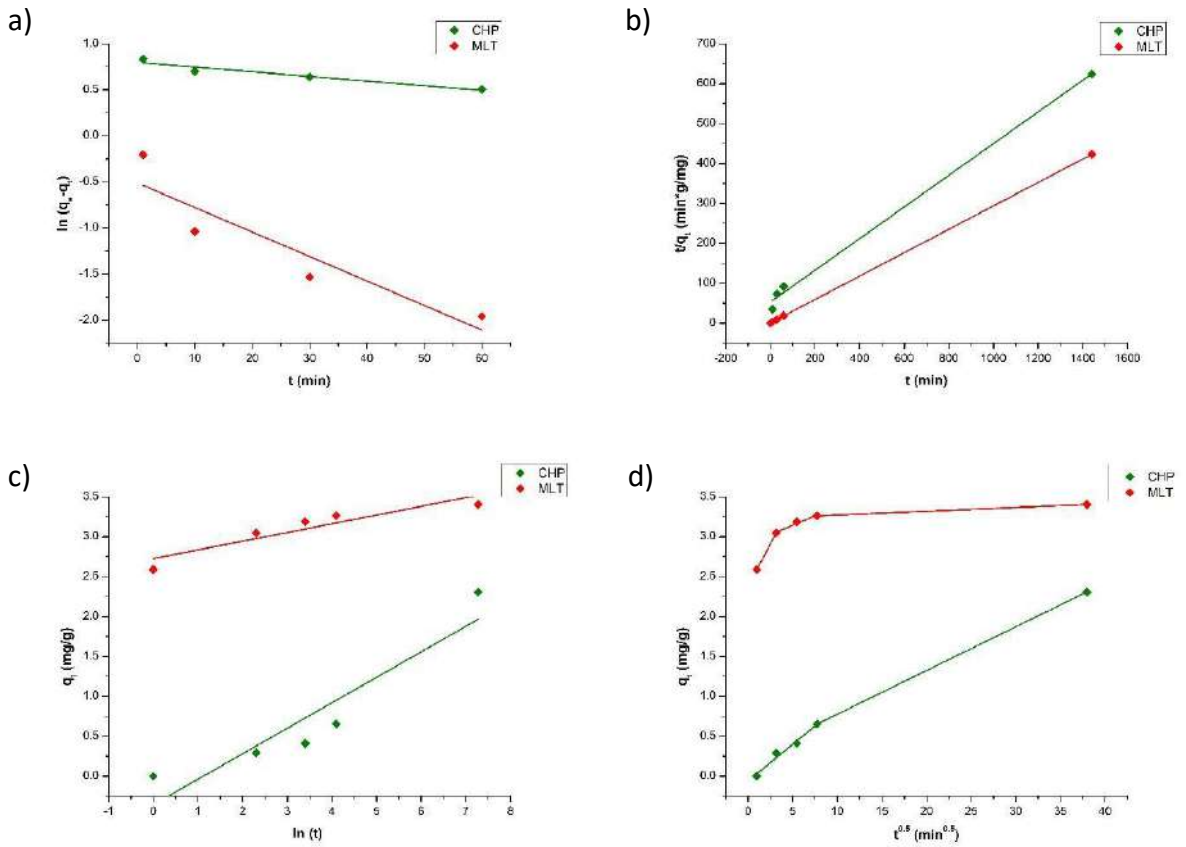

Figure 1. Kinetic models: a) pseudo-first-order; b) pseudo-second-order; c) Elovich; d) intraparticle diffusion

Observing the obtained results, it can be concluded that in the case of both OPs adsorption under given experimental conditions, the pseudo-second-order model fitted experimental data the best, according to R^2 values. The calculated adsorption capacities of SCG are 3.401 mg g^{-1} for MLT and 2.518 mg g^{-1} for CHP. A higher k_2 value for MLT adsorption (0.191 mg min^{-1} g^{-1}) indicates a higher adsorption rate than CHP (0.003 mg min^{-1} g^{-1}). By plotting qt against t0.5, three linear stages for MLT and two linear stages for CHP could be clearly observed in the intraparticle kinetic model (Figure 1d). The C value, representing the boundary layer, increases, suggesting that the boundary layer has a high significance in the adsorption of MLT and CHP onto SCGs. It can be concluded that the three mentioned processes control the rate of molecule adsorption for MLT and two for CHP. Still, for each time range during the adsorption process, one process at a time determines the adsorption kinetics.

Table 1. Kinetics parameters for CHP and MLT (5×10^{-4} mol dm^{-3}) adsorption on SCG (1 mg ml^{-1}).

		CHP	MLT
Pseudo-first order kinetics			
q_e (mg g^{-1})		2.22	0.60
k_1 (min^{-1})		0.005	0.027
R^2		0.890	0.779
Pseudo-second order kinetics			
q_e (mg g^{-1})		2.52	3.41
k_2 (mg min^{-1} g^{-1})		0.003	0.191
R^2		0.995	1
Elovich model kinetics			
α (mg g^{-1} min^{-1})		0.699	15.29
β (g mg^{-1})		3.132	9.163
R^2		0.822	0.817
Intraparticle diffusion model kinetics			
Part I	C (mg g^{-1})	0	2.37
	k_{id} (mg $min^{-0.5}$ g^{-1})	0.092	0.212
	R^2	0.959	–
Part II	C (mg g^{-1})	0.230	2.91
	k_{id} (mg $min^{-0.5}$ g^{-1})	0.055	0.046
	R^2	–	0.947
Part III	C (mg g^{-1})		3.23
	k_{id} (mg $min^{-0.5}$ g^{-1})		0.005
	R^2		–

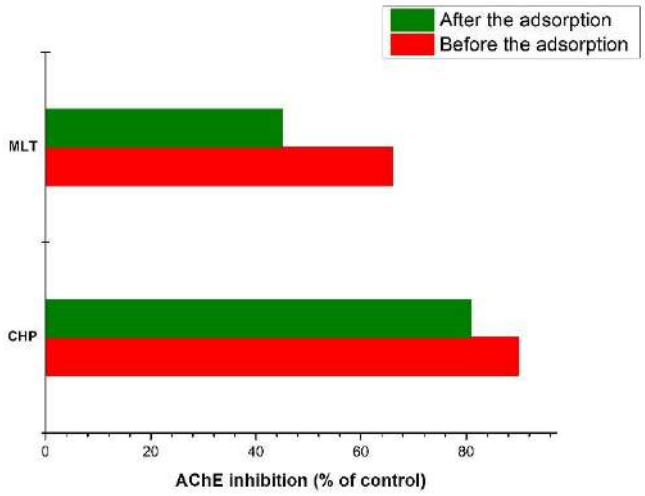

Figure 2. Inhibition of AChE before and after the adsorption of CHP and MLT (5.00×10^{-5} M)

As can be seen on the histogram presented in Figure 2, after the adsorption process of both OPs on SCG, the inhibition of AChE decreased, indicating that during the process, no more toxic products, chlorpyrifos-oxon and malaoxon, were formed.

CONCLUSION

The pseudo-second-order model best fits the experimental data of both OPs (MLT and CHP) under the given experimental conditions. The calculated adsorption capacities of the sorbent (SCG) are 3.40 mg g^{-1} for MLT and 2.52 mg g^{-1} for CHP. This means SCG has a higher affinity for MLT compared to CHP. The k_2 value is higher for MLT (0.191 mg min^{-1} g^{-1}) than for CHP (0.003 mg min^{-1} g^{-1}). This indicates that MLT is adsorbed at a faster rate than CHP onto SCG. The intraparticle diffusion model suggests that multiple processes are involved in the adsorption of MLT and CHP onto SCG. The increasing C value, which represents the boundary layer effect, indicates that the boundary layer plays a significant role in the adsorption of both MLT and CHP onto SCG. Neurotoxicity experiments showed that no more toxic products are formed during the process of adsorption, meaning that SCG is a safe-to-use adsorbent for OP remediation from water.

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OUTBREAK AND PROPAGATION OF SUBSURFACE LANDFILL FIRES

Milošević L.[1], Mihajlović E.[2], Malenović-Nikolić J.[2], Krstić D.[2]

[1]Faculty of Occupational Safety in Niš, Čarnojevića 10a, Niš, Serbia (e-mail: lidija.milosevic@znrfak.ni.ac.rs)

[2] Faculty of Occupational Safety in Niš, Čarnojevića 10a, Niš, Serbia

Abstract: Unlike surface landfill fires, subsurface fires tend to be more complex in terms of their point of origin, duration, amount of engulfed waste, and manner and duration of extinguishment. This paper analyses the combustion of municipal solid waste and flammable components of landfill gas. The manner of heat transfer is important with regard to fire propagation in the landfill body. Another important aspect is the identification of hot spot locations in a landfill, as it ensures a rapid alert to initiate a fire suppression intervention, prevent new hot spots from forming, and properly rehabilitate the landfill.

Keywords: *landfills; municipal solid waste; landfill gas; landfill fires.*

INTRODUCTION

Disposal is the most common option for municipal waste treatment in EU countries as well as in Serbia. Fire is one of the unforeseeable and unwanted events in any landfill, and it can occur on or under the landfill surface. The mechanism of hot spot development in the landfill body directly depends on the amount of deposited waste, which may contain different materials with relatively low ignition points, and on the volume of methane, a constituent of landfill gas (LFG). The age of deposited waste affects the flammability of municipal solid waste (MSW). Ignition and smouldering temperatures decrease as the time after disposal passes, and so does the moisture content in deposited MSW. The presence of air in the landfill body is a necessary condition leading to different exothermic oxidation reactions, which result in uncontrolled combustion. Oxidation at higher temperatures may lead to slow smouldering combustion in the waste, which is typical of subsurface landfill fires, and to flaming combustion, typical of surface landfill fires and high exposure to oxygen.

COMBUSTION OF DEPOSITED MUNICIPAL SOLID WASTE AND LANDFILL GAS

The chemical reaction of combustion requires a collision of reacting molecules, while the energy of the collision needs to be great enough to break the existing bonds and form new ones. Such energy is called activation energy. Experimental analysis of polypropylene pyrolysis has shown that activation energy is between 90 kJ/mol and 250 kJ/mol. In the pyrolysis and combustion of twig biomass, the initial average activation energy is 160 kJ/mol, as opposed to 65 kJ/mol in the case of cardboard (Gunasee, 2016).

Solid materials burn depending on their physicochemical properties. Their combustion may be direct combustion, combustion with phase change, and combustion with decomposition. Thermal decomposition of solid fuel materials in waste, liquid vaporization, and gas and vapour combustion proceed in the combustion zone. Temperature ranges of thermal decomposition for specific materials are as follows: polyvinyl chloride 225 to 690°C; polypropylene 260 to 400°C;

twigs 200 to 520°C; foliage 190 to 550°C; grass 125 to 545°C; packing paper 280 to 715°C; and cardboard 210 to 480°C (Gunasee, 2016). The place of the most intense combustion within and around flammable waste, with a constant supply of oxygen and constant release of heat, is called a hot spot.

Gaseous flammable materials only burn during homogeneous chemical reactions, whereby the chemical energy of combustible LFG components (methane) is converted into thermal energy. For oxidation to be initiated, the bond between atoms or groups of atoms in a molecule needs to become weakened to form new bonds, so the molecules need to be activated by introducing thermal energy. A certain number of gas molecules receive sufficient energy to react with oxygen. Another way of activation is the formation of free atoms or radicals. For a gaseous material to burn, it has to be within its flammable range (Milosević, 2022).

During the combustion of deposited MSW and specific LFG components, certain amounts of heat are released. The calorific value of MSW ranges from 8.5 to 11.0 (MJ/kg), while methane has a calorific value of 53.0 (MJ/kg).

HEAT EXCHANGE DURING A FIRE IN THE LANDFILL BODY

In the thermal effect zone, the exchange of released heat during a landfill fire proceeds through conduction, convection, and radiation. Such exchange is caused by the combustion of flammable waste and methane and it is transferred to other parts of the landfill and the environment.

Heat exchange in the landfill body proceeds via conduction and/or convection. Heat conduction is characteristic of heat transfer through and/or from MSW to other MSW and primarily depends on the physical properties of the waste. Heat conduction in a landfill is limited by waste surface area. Molecules in the warmer layer of a solid are faster and they collide with the molecules from the cooler layer of the same solid, transferring a portion of their kinetic energy (Milošević, 2022).

Heat convection by a fluid occurs when the temperature, and thus density, is different in different layers of the fluid, which causes its convection and heat transfer. During convection, heat is transferred through a fluid, from a fluid to a solid, or from a solid to a fluid. Heat transfer depends on multiple factors, the most notable of which are convection type and mode, the type and physical properties of a fluid, and the shape and dimensions of a solid's surface area. Heat convection in the landfill body occurs via LFG, the gaseous products of combustion as their heat transfer to the MSW.

DEVELOPMENT OF SUBSURFACE LANDFILL FIRES

Subsurface landfill fires break out deep below the landfill surface, inside the waste deposited months or years before. The waste often oxidizes in the immediate vicinity of a gas collection well or near the landfill surface, which allows oxygen to penetrate the landfill body, which in turn results in the rapid oxidation of organic waste. Subsurface fires may also create large gaps inside the landfill body, which can lead to surface cracks and even landfill collapse. They are often referred to as deep-seated fires or hot spots and are more difficult to detect, control, and extinguish. Their presence, which may last for weeks or even months, is best determined through the monitoring of fire indicators – LFG temperature and concentration, landfill subsidence and surface

depressions, emissions of gaseous products of combustion, and appearance of smoke and odours (Milošević, 2022).

The development of deep-seated hot spots may be

- horizontal;

- vertical;

- confined;

- unconfined.

Horizontal hot spot development in the landfill body occurs due to horizontal convection currents of hot gaseous products of MSW combustion and combustible LFG components (Figure 1). Another relevant factor for hot spot development is the atmospheric air, which penetrates the landfill body through gas collection wells and open leachate wells. Considering that the cap made of inert materials is compact and solidly built, such propagation creates a deep-seated hot spot. Cracks and depressions on the landfill surface usually indicate that the hot spot is below them, which can be determined in more detail through the monitoring of other fire indicators (LFG temperature and concentration and appearance of odour and smoke).

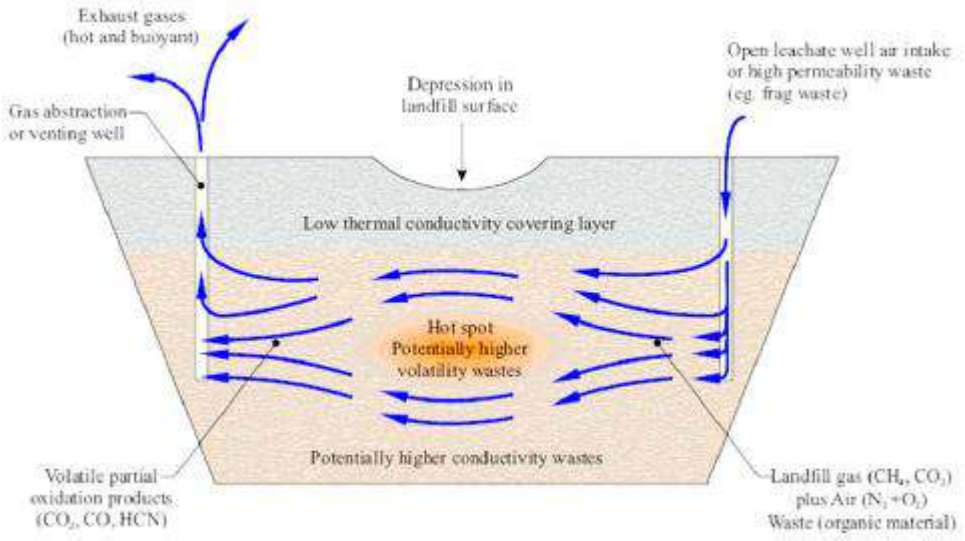

Figure 1. Horizontal hot spot development in the landfill body (Copping, 2007)

Vertical development of landfill fires occurs when a hot spot is formed around gas wells or leachate wells, where the airflow is vertical (Figure 2). This causes depressions to form immediately around the gas or leachate well. The damage to wells due to higher temperatures as well as to the cap made of inert materials allows larger volumes of ambient air to enter the body and affect hot spot development. Visible signs of subsurface fires are present around gas wells and are manifested as emissions of products of combustion and smoke.

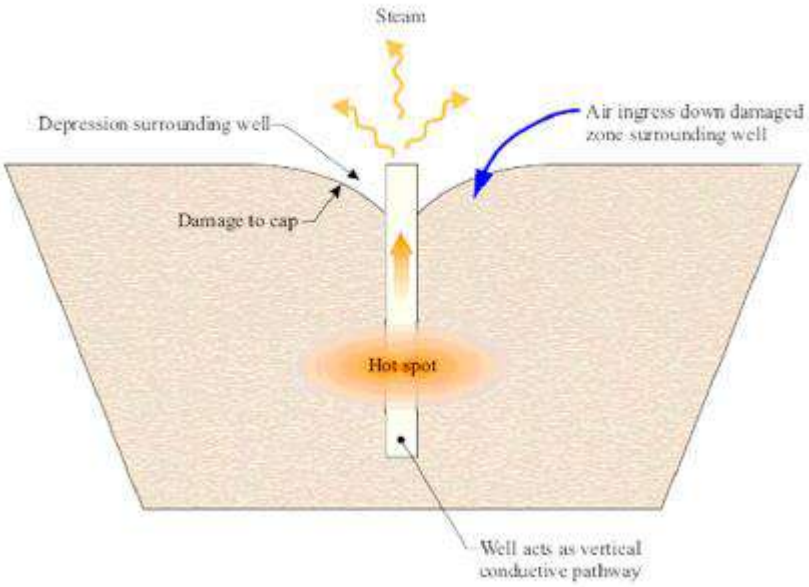

Figure 2. Vertical hot spot development in the landfill body (Copping, 2007)

Confined hot spots are usually difficult to detect as there are no apparent visible signs of their presence (Figure 3). The volume of oxygen is limited by a lack of pathway to the atmosphere, so the uncontrolled combustion is manifested as smouldering. The landfill surface has no visible changes in the form of depressions or emissions of gaseous combustion products. This poses a serious risk when installing new gas collection or leachate wells since the inflow of ambient oxygen into the landfill body can cause the fire to spread.

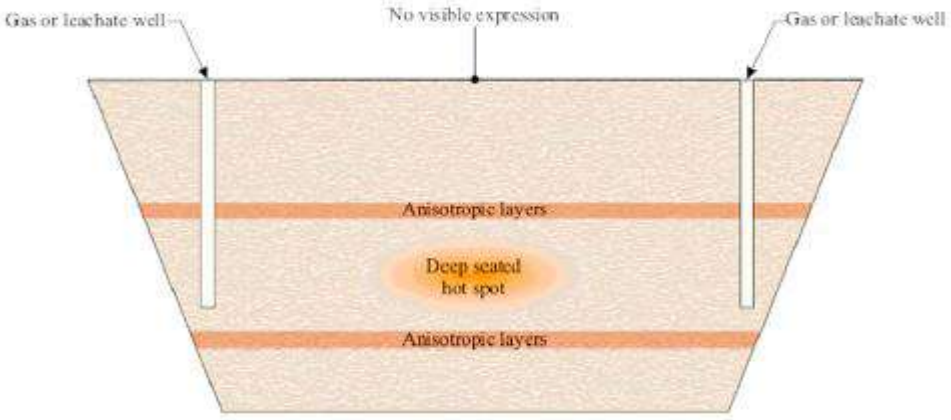

Figure 3. Confined hot spot development in the landfill body (Copping, 2007)

Unconfined hot spot development occurs in the landfill body with low compaction waste and not adequately capped with inert materials (Figure 4). This allows free airflow through the waste mass. Hot gaseous products of combustion are able to migrate in all directions from the hot spot and transfer heat to non-burning waste and LFG, thus spreading the fire. Smoke and products of combustion can be detected inside gas or leachate wells and across the landfill surface. Their presence may be detected sooner than in confined hot spots, but it is more difficult to pinpoint the original hot spot because new hot spots keep emerging as the fire spreads.

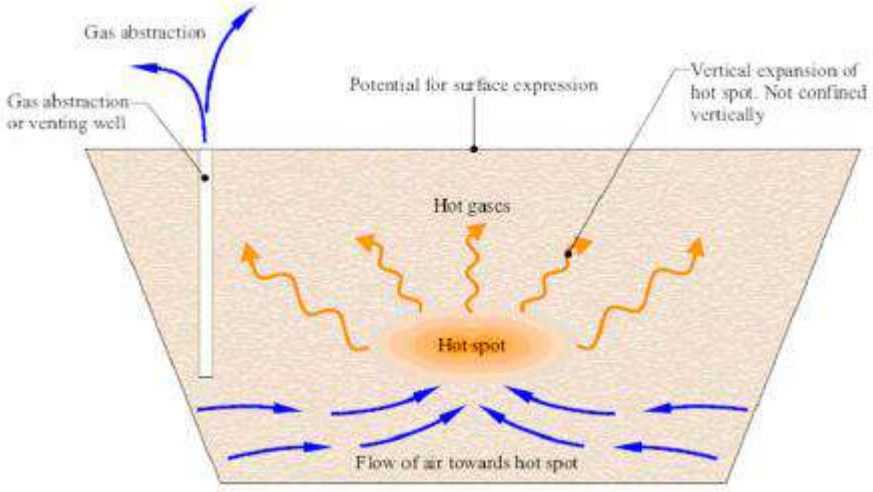

Figure 4. Unconfined hot spot development in the landfill body (Copping, 2007)

CONCLUSION

Fire outbreak in a landfill body depends on the amount and morphological composition of deposited waste, the volume of combustible landfill gas components, and the volume of available air. The diversity of flammable materials in the landfill body, their different combustion activation energies, different ignition and smouldering temperatures, and different thermal energies influence fire outbreaks and duration.

Subsurface landfill fires are more difficult to detect and it is highly complicated to locate the hot spot. Therefore, it is of use to constantly monitor landfill fire indicators (landfill gas temperature and concentration, landfill subsidence and surface depressions, and appearance of smoke and odours). When the circumstances of subsurface landfill fire outbreak and propagation are known, it is easier to identify, locate, and quickly suppress them. It should also be noted that inadequately designed landfills, landfills in which waste is inadequately deposited, and landfills in which fire safety measures are inadequately implemented are at considerably higher risk of a fire.

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CLIMATE CHANGE EFFECTS ON MENTAL HEALTH

Panjičko M.[1], Tarakčija M. [2]

[1]Sustainable Technologies Development Centre, Zagreb, Croatia , Avenija Dubrovnik 151, Paviljon 12/1 (e-mail: mario.panjicko@croteh.eu)

[2]University of Novi Sad, Faculty of Technical Sciences, Novi Sad, Serbia, Trg Dositeja Obradovića 6

Abstract: Climate change can be described as one of the least spoken yet growing health hazards, that has been indigently researched. Rising temperatures, as a result of climate change, can alter weather cycles, negatively impacting global farming systems, human wellness, natural environments, and occupational health and safety conditions. Such climatic shifts are attributable to industrialization, urbanization, and fossil fuel consumption, which have resulted in greenhouse gas build-up in the atmosphere. The impact of these changes can be seen in the proliferation of wildfires, air pollution, extreme weather conditions, and increasing temperatures. Additionally, climate change can also affect the efficacy, longevity, and safety of infrastructure and buildings, thereby raising health and safety hazards like accidents and injuries. All industry sectors, including emergency services, water resources, and agriculture, will experience the repercussions of climate change on their occupational health and safety. The consequences of the changes can be seen through the impacts on the economy and social groups, targeting workers that are bound to their sectors and are prone to the hazards caused by the changes in climate. Even though they are rarely addressed, they are present. Climate change negatively affects mental health through several interconnected pathways, disproportionately affecting vulnerable working populations; effects such as extreme weather events, increased stress, and mental health consequences put certain populations of workers at greater risk of mental illness.

Keywords: *climate change; occupational health; mental health.*

INTRODUCTION TO CLIMATE CHANGE

An important factor of climate change is the presence of greenhouse gases (GHGs). GHGs are those gaseous constituents of the atmosphere that absorb and emit radiation in the thermal infrared range. Traces of GHG, both natural and anthropogenic, are present in the troposphere. Invisible gases present in the atmosphere of the Earth, namely carbon dioxide and methane, function as a cover, ensnaring heat emitted by the sun and enabling our world to maintain a livable temperature.

Human actions, such as the combustion of fossil fuels for energy, transportation, and manufacturing, as well as the alteration of natural landscapes for agriculture and livestock rearing, are causing a rise in the levels of these greenhouse gases on a global scale. (6) Climate changes and variations can result in severe weather conditions and impact the natural surroundings that provide humans with essential elements like clean air, food, water, shelter, and security. Additionally, climate change-related factors can affect individuals and communities unequally.

Climate and weather can impact the quality of water and food in specific regions, which in turn has implications for human health. Over time and in different areas, exposure pathways vary, and climate change-related exposures can affect individuals and communities to varying extents.

Although these threats are often evaluated individually, it is possible for multiple climate change threats to occur concurrently, leading to compounded or cascading health impacts. Additionally, climate change threats can accumulate over time, resulting in long-term changes in resilience and health. The likelihood of being exposed to a health threat or experiencing illness or other adverse health outcomes as a result of that exposure depends on a complex combination of vulnerability factors. Furthermore, the effects of global climate change on mental health and well-being are significant components of the overall impact on human health related to climate (USGCRP, 2016).

There are numerous and substantial effects of weather and environment on human health. They vary from linkages that might appear less obvious to the obvious hazards of temperature extremes and powerful storms. The frequency, severity, and even the location of some weather and climate phenomena, such as extremely high temperatures, prolonged dry spells, and other severe weather events, are already changing, and these changes are expected to increase. This implies that regions already experiencing weather and climatic phenomena that pose a health danger, such as intense heat waves or hurricanes, are likely to see things get worse. For example, temperatures may rise even further, storm strength, rainfall rates, and storm surge may increase, and there may be more intense storms.

Additionally, it implies that some regions would face fresh health risks brought on by the climate. For instance, regions that were historically immune to toxic algal blooms or waterborne infections due to colder water temperatures may do so in the future as rising water temperatures encourage the growth of the organisms that pose these health threats. The timing of the seasons that represent the greatest risk to human health could change, even in locations that already suffer these health risks.

Therefore, climate change can have a negative impact on human health in two ways: first, by altering the severity or frequency of health issues already impacted by climatic or meteorological factors; and second, by posing new, unexpected health risks or threats in areas where they have never existed before (Ansah, 2021).

Effect on occupational health and people

Climate change also has an influence on Occupational Safety and Health (OSH) due to higher temperatures, both indoors and outdoors, air pollution, exposure to ultraviolet radiation, and the effects of extreme weather events, among others. These factors can lead to health issues such as heat-related disorders, diseases transmitted by vectors and water, accidents, cancer, and production losses. Mental health problems related to heat are also noted with several contributing factors as reviewed by Cianconi et al. (2020): exposure to the outside during the summer increases the chance of conflicts, and psychological and physical fatigue which occur with seasons as well as the consumption of alcohol which increases aggression. Understanding the risks climate change poses to safety and health in the workplace is crucial for evaluating and managing these risks.

The effects of climate change on OSH have received minimal attention in countries with a temperate climate, specifically in northern industrialized nations. However, some research has been done on this topic in tropical countries (Adam-Pupart, 2013). European Agency for Safety and Health at work, academics, advocacy groups, and medical professionals have acknowledged climate change as a health crisis. However, the emphasis so far has primarily been on physical

health. This has led to a disregard for the impact of climate change on mental illness and emotional well-being, which is often considered the most neglected aspect of human health.

Exposure to high temperatures can lead to heat-related ailments, as well as stress and exhaustion, thereby endangering workers by increasing the likelihood of hostility or violent behavior, aggression, anxiety disorders, and, in some cases, confusion. The impacts of climate change on health vary depending on variations in the fundamental factors that influence physical, physiological, and mental well-being in developing economies, particularly among low- and middle-income workers. Additionally, the effects differ based on the specific groups of workers affected, such as those who work outdoors versus those who work indoors (Charlson, 2021b). Because of the nature of regional microclimates, as well as socio-economic aspects, OSH impact may be uneven to the population groups, depending on how these aspects would respond to climate change (Charlson, 2021a).

MENTAL HEALTH AND CLIMATE CHANGE

Mental health is a broad term, much like physical health. It varies in quality for everyone at different periods of time. This term includes a person's thoughts, feelings, and capability to manage life's demands. Having good mental health is not merely about being free from sickness or disorders, but it's about possessing a state of positive wellness that encourages resilience and prosperity. Terminologies like emotional well-being are gaining popularity to avoid stigmatizing the whole spectrum of human feelings and experiences. Within this framework, mental health implies both mental and emotional wellness. According to the literature review written by Cianconi et al. (2020), environmental factors can induce congenital defects, impair neurodevelopment, and trigger endogenous mental disorders as well as psychosomatic and neurological disorders.

"Psychological responses" is a term utilized to cover various thoughts and emotions, including diverse feelings, worries, or uneasiness that people may experience in reaction to climate change (USGCRP, 2016). Climate change poses the most significant health risk in the twenty-first century (Charlson, 2021a). It has adverse effects on the mental well-being of populations and is predicted to affect mental health through various direct and indirect means (Charlson, 2021a). From modest stress and distress sensations to clinical disorders like anxiety, depression, post-traumatic stress disorder, and suicidal ideation, climate change has a negative impact on mental health (Figure 1). Direct impacts involve exposure to distressing incidents like wildfires and extreme weather events. Indirect effects primarily occur through social, political, and economic factors that influence mental health, such as poverty, unemployment, and inadequate housing (Charlson, 2021a). The mental health effects of climate change have not received as much research attention as other health areas. The literature on climate change and mental health is rapidly expanding but has several limitations and research gaps. According to the research conducted by Klassen and Galway (2023), youth climate champions that participated conveyed the following emotions concerning climate change: powerlessness, fear, anger, sadness, hopelessness, anxiety, and worry, and an emerging sense of grief was also noted among the participants.

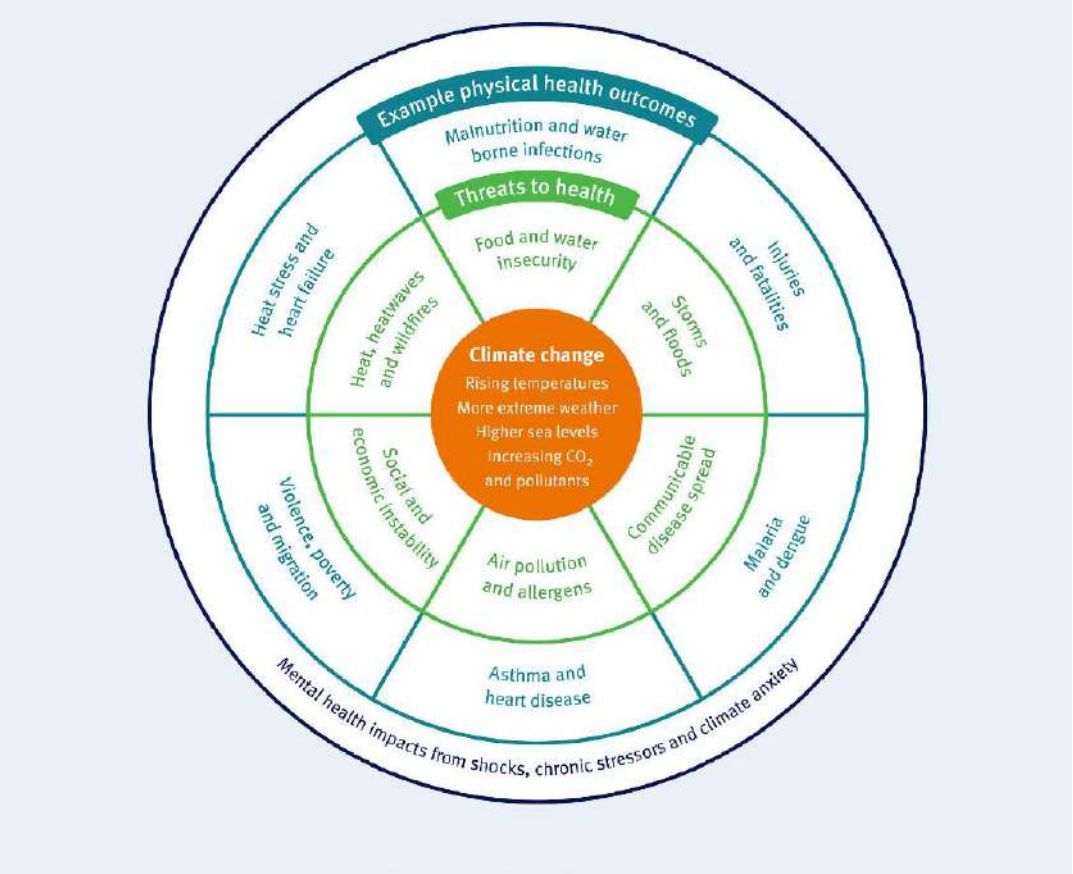

Figure 1. The potential risks to health arising from the existing and expected consequences of climate change (Lawrance, 2021)

Negative emotions in regards to eco-anxiety in youth climate champions are noted to be triggered by collective inaction, systems of oppression, tangible reminders, and climate information and messaging, while identified coping strategies among the participants were empowering thoughts, orienting towards solutions, connecting with community and engagement in creative and physical activities (Klassen, 2023).

Emotions, moods, and feelings that occur about climate change and climate injustice are often referred to as climate emotions, with eco-anxiety as one of its most interesting concepts (Klassen, 2023). Ecoanxiety implies troublesome emotions that arise as a result of climate change and environmental crises (Klassen, 2023). Functional impairments that can be tied to environmental concerns and eco-anxiety are often related to sleep and concentration (Klassen, 2023). High levels of concern over climate change are also exhibited in children (Burke, 2018). Furthermore, climate grief is a term that expresses grief in experienced or anticipated ecological losses (Lawrance, 2021). Also, solastalgia is a term that describes the type of loss regarding landscape modification and is among the risks for mental health (Cianconi, 2020)

The evidence that connects climate change to harmful health effects is now overwhelming. Rising temperatures, more frequent and severe extreme weather events, and air pollution are all associated with worsened physical health, including respiratory conditions and infectious diseases (Charlson, 2021b). Particularly vulnerable individuals and regions, especially those in low-income nations, are expected to experience significant negative consequences (Charlson,

2021a). Cianconi et al. (2020) in their literature review noted that women, young people, and people with low socioeconomic status are more vulnerable to anxiety and mood disorders. Children are particularly more at risk not only regarding mental health but also of other climate-related stressors due to their sensitivity and other factors (Burke, 2018). Also, according to the study performed by Dumcke et al. (2020), a group of children living near the waste recycling sites had a higher prevalence of emotional and behavioral problems in comparison to children who lived further away. Air pollution can contribute to mental illnesses since pollutants such as diesel, carbon monoxide, nitrogen oxides, sulfur dioxide, ozone, and particulate matter can alter neurotransmitter functions (Crane, 2022).

However, the mental health impacts of climate change have not been studied as extensively as other health areas (Adam-Pupart, 2013). The global health challenge of unmet mental health needs and cases of mental illness in people worldwide is on the rise. As mentioned, the negative effects of climate change on physical health also have a significant impact on mental health. This correlation is not surprising, given the close connection between mental and physical well-being. At a population level, good physical health and good mental health are strongly linked (USGCRP, 2016).

What can we do?

The absence of mental health integration in the wider climate and health research agenda highlights a substantial void that needs to be addressed (Charlson, 2021b). Climate change is widely regarded as the primary danger to global mental health in the next century. However, addressing this threat could present an exceptional chance to positively impact our mental well-being for centuries to follow. This is due to the potential health benefits that can arise from transitioning to sustainable practices. Researching the effects of climate change on mental health and related systems will aid policymakers in creating effective and evidence-based strategies for both mitigation and adaptation.

Notably, these strategies have the capacity to yield extensive advantages for society and the environment. Advancing this research agenda will necessitate a collaborative and global effort, which should incorporate innovative methodologies derived from other disciplines' experiences (Charlson, 2021b). Combating climate change will also have the added benefit of improving mental health. In making policy choices, this influence should be carefully considered. Among the survivors of climate or weather-related natural disasters reduced daily life activities and the loss of their „sense of place“ were noted which could have an impact and exacerbate mental health risks (Cianconi, 2020). Displacement to shelters that follow natural disasters can result in separation from social support networks which disrupts familiarity, attachment, and identity (Cianconi, 2020). The negative consequences of such catastrophes on mental health can be reduced by taking proactive steps to increase the resilience of people, communities, and support systems to climate change-related crises as well as by offering early and appropriate care. According to the literature overview (Cianconi, 2020), psychological stress that emerges after hurricanes increases the rate of cardiovascular diseases, prenatal maternal stress and depression, and infant anxiety, fear, and sadness, while floods impact mental health in a way that they bring mourning, displacement, and psychosocial stress due to the loss of lives and belongings which can trigger PTSD, depression, and anxiety. The likelihood of adverse mental health consequences can be decreased in the short and long terms by efficiently responding to emergencies like extreme weather disasters.

It is crucial to involve both workers' and employers' organizations in the creation and execution of climate change mitigation and adaptation policies. Employers and workers are in the best position to identify the challenges and risks that climate change consequences present in their workplaces. They can then take appropriate action, such as ensuring compliance with health and safety standards and finding practical solutions to cope with high temperatures and humidity. It is important for them to be part of the design and implementation of adaptation policies at all levels, with a particular focus on working conditions. Employers' and workers' organizations can develop and implement detailed policies, such as those addressing heat stress in the workplace, through social dialogue and collective bargaining agreements.

Social dialogue is also essential for the development of national OSH policies. These policies should be created in consultation with the most representative organizations of employers and workers. The establishment, maintenance, progressive development, and periodic review of the implementing infrastructure for national OSH policies should also involve these organizations. Furthermore, social dialogue can contribute to making climate change governance more labor-friendly by advocating for policies that consider both environmental and labor concerns (Adam-Pupart, 2013).

Most people who experience a traumatic event, such as a climate-related disaster, will gradually recover over time. Post-traumatic growth refers to the positive changes that can occur in an individual as a result of coping with or going through a traumatic event. Mental health practitioners utilize various intervention approaches to mitigate the negative impact of traumatic events. In the aftermath of a disaster, children may exhibit a range of challenging emotional and behavioral responses, including depression, clinginess, aggressiveness, and social withdrawal. While some of these reactions are normal and expected, they will typically be resolved with appropriate support. Nevertheless, children may be more susceptible than adults to experiencing long-term symptoms (Lawrance, 2021).

Several suggestions have been made to guide the management of changes and the actions that individuals can take in response to them. It is important to incorporate the perspectives of those who are especially susceptible to climate change impacts, such as individuals affected by flooding, in the planning and implementation of services aimed at addressing climate change and related mental health issues. Additionally, it is crucial to enhance public awareness of the mental health consequences of climate change through government and healthcare messaging, such as public health campaigns focused on heat vulnerability (higher risks of mental disorders in correlation to warmer temperatures are observed, especially when mania among the elderly is concerned (Ciansoni, 2020)). These efforts will help individuals recognize and effectively cope with the impacts of climate change on both personal well-being and community health (Lawrance, 2021). Evaluations of past responses to extreme weather, climate events, and environmental disasters have highlighted the importance of establishing collaborations and plans that involve governments, the private sector, and local organizations ahead of time. This ensures that emergency responses are well-organized, efficient, and comprehensive. Providing comprehensive support to mitigate the additional stress of a disaster, such as insurance or financial difficulties, will help reduce the mental health impact of disasters and forced migration. Drawing on expertise from various sectors and fields, including knowledge of grief and loss support, adaptation to uncertainty and change, secondary trauma, and resilience, will greatly enhance the development of interventions and support (Lawrance, 2021).

CONCLUSION

It is crucial to enhance our knowledge of the effects of climate change on mental health, find ways to prevent mental health issues and foster mental well-being amidst climate change. This will require concerted efforts in clinical, social, and political spheres at the individual, communal, and societal levels. Conducting research on the effects of climate change on mental health and related systems will aid policymakers in creating effective and evidence-based strategies for both mitigation and adaptation.

The objective of this paper is to analyze different approaches to the hazards that are around us. It is imperative to take into account the subtle changes that may progress into something far more devastating if we do not take action in time. Climate change is something that surrounds people and dictates the possibilities of work and life. Mental health plays a vital role in employee's well-being, influencing safer and more efficient environments. Ensuring occupational health and safety from the effects of climate change can boost both professional and individual progress, reducing stress and other negative effects on their mental health.

Future research into the environment and public health should focus more on how they are affected by the impacts of climate change. It is essential to further recognize and invest in these fields, as they involve more than just safety hazards, including subjects such as economics, social justice, and natural resources. Because this is a topic that affects the globe, the consequences may become irreversible if it is neglected.

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THE CROSS-SECTION OF LEGAL AND THE ISO 45001 STANDARD REQUIREMENTS IN THE MANAGEMENT OF HEALTH AND SAFETY AT WORK

Perović M.[1], *Todorović M.*[1]

[1]Jaroslav Černi Water Institute, Jaroslava Černog 80, Belgrade, Serbia, (e-mail: marija.perovic@jcerni.rs)

Abstract: The protection of health and safety at work, the avoidance of illnesses and accidents at work, and the promotion of a positive and long-lasting work environment are the main purposes of occupational health and safety. Occupational health and safety are regulated by laws and by-laws, by implementing prescribed safety procedures and by meeting the *ISO 45001* requirements.

This paper discusses the crucial intersection between the application of *ISO 45001*, an internationally recognized standard for occupational health and safety management systems, and the legal framework governing safety and health at work (Law on Safety and Health at Work "Official Gazette of RS", No. 35/2023). *ISO 45001* provides organizations with a structured approach to managing occupational risks and promoting a safe working environment, while legislation on safety and health at work sets forth mandatory requirements for workplace safety compliance. The paper presents a useful tool for incorporating the ISO45001 standard requirements into the business environment. It points out that the fulfilment of legal requirements corresponds to the fulfilment of individual ISO45001 standard clause requirements.

The paper also explores the impact of *ISO 45001*'s proactive approach to risk management on reducing workplace accidents, enhancing worker well-being, and improving overall productivity. It presents real-world examples to show how implementing *ISO 45001* can help organizations stay compliant with the law and promote a culture of safety. The importance of harmonizing *ISO 45001*'s principles with the legal framework on safety and health at work is emphasized within the paper. Organizations can create a robust safety management system that not only enhances compliance but also improves overall safety standards, promoting a healthier and more secure work environment for employees. The research provides valuable insights for organizations seeking to optimize their safety management practices, foster legal compliance, and prioritize the well-being of their workforce.

Keywords: *ISO 4500; legal requirements; work safety measures implementation.*

INTRODUCTION

ISO (International Organization for Standardization) is a worldwide federation of national standard bodies. Preparation of international standards takes place in ISO technical committees. ISO works closely with the International Electrotechnical Commission (IEC) on all matters of standardization in the field of electrical engineering. All international standards (ISO) are developed in accordance with the rules given in the ISO and IEC directives.

The Law on Safety and Health at Work governs the development and application of safety and health measures at work for individuals taking part in work processes as well as individuals who are present in the workplace. The objective of enforcing the law is to prevent injuries at work, occupational diseases, and work-related diseases. The law, among other things, defines the general principles of prevention, the rights of special groups of employees, the employer's obligations, the rights and obligations of employees, information, consultation, cooperation, and training of employees and employee representatives for safety and health at work.

ISO 45001 is a global standard for occupational safety and health management systems that provide companies with practical solutions to improve worker safety and prevent occupational illnesses, injuries, or fatalities. The aim of the research is to emphasize the relation and importance of the interconnection of legal requirements and standard requirements for managing occupational safety and health.

The adoption of the *ISO 45001* standard was of particular importance for Occupational Health and Safety (OH&S) management systems. The standard's development rendered the Occupational Health and Safety Assessment Series (OH&S AS) 18001 outdated (Neag et al., 2019). Legal entities are not legally compelled to implement *ISO 45001* or other equivalent management standards. Despite this, implementing this standard can assist in providing a formal framework for the company to protect the safety of all its employees. Implementing *ISO 45001* recommendations into regular operations also enhances hazard detection and risk assessment, at the same time decreasing the overall cost of workplace incidents, and the total amount of insurance premium payments.

For successful standard implementation, it is essential to conduct an objective assessment of the organization's current functioning in relation to the standard's requirements. The process of comparing the present core processes practices, and documentation with the *ISO 45001* requirements is called gap analysis. As a result of the analysis, the recognized gaps and flaws can be corrected.

Within the implementation of *ISO 45001,* each of the employees (including the top management) can acquire additional responsibilities related to occupational health and safety, which enables everyone to feel a sense of ownership in the safety management system.

Following the establishment of the company's safety goals, it's necessary to correlate the standards requirements with these goals. This alignment should be quantified creating the unique metrics. The metrics will assess the efficacy of the OH&S management system and identify the need for alterations as well as long-term improvements.

How to identify and comply with legal requirements with *ISO 45001* requirements

Considering the human health and safety concerns, compliance of legal requirements with *ISO 45001* requirements is one of the most important tasks. The standard quotes legal requirements in several places, demanding the inclusion of at least a commitment to comply with applicable legal requirements, and with other requirements to which the organization declares to relate when writing the Policy. This compliance must be considered through the whole Plan-Do-Check-Act (PDCA) cycle within the OH&S management system, from the OH&S Policy and definition of OH&S Objectives to management review. Legal requirements that apply to a certain company should be selected, listed, and kept up to date.

When the company is setting its OH&S Objectives (Clause 6, *ISO 45001*) and planning to achieve them, applicable legal requirements should be considered. Periodic evaluation of compliance with legal and other requirements is a mandatory activity, and evidence of the implementation must be kept.

Management System Approach

The *ISO 45001* standard focuses on adopting a systematic approach to manage occupational health and safety risks and opportunities. Organizations need to implement processes for hazard

identification, risk assessment, and risk control, as well as establish clear health and safety objectives and performance indicators.

While the Law on Safety and Health at Work in Serbia may require organizations/companies to take similar measures to ensure safety and health, it may not prescribe specific management system requirements like *ISO 45001*. The law sets out general guidelines and minimum safety and health requirements that organizations must follow.

Continuous Improvement and Certification

Organizations can seek certification from accredited certification bodies to demonstrate compliance with the *ISO 45001* standard. The certification process involves external audits to assess the organization's health and safety management system's effectiveness and adherence to the standard's requirements.

Compliance with the Law on Safety and Health at Work in Serbia is determined through inspections and assessments carried out by relevant authorities. Organizations must adhere to its requirements to avoid legal consequences.

Interconnection of legal requirements and standard requirements in managing occupational safety and health

ISO 45001 provides a framework that can be adapted to comply with relevant laws and regulations. Here are some key areas where *ISO 45001* requirements may intersect with legal requirements:

Hazard identification and risk assessment:

ISO 45001 requires organizations to identify and assess health and safety risks and hazards associated with their activities. Similarly, laws prescribe risk assessment and the implementation of appropriate control measures to protect workers from workplace hazards. Organizations must comply with both *ISO 45001*'s risk assessment requirements and the specific legal requirements in their respective jurisdictions.

Legal compliance:

ISO 45001 expects organizations to identify and have access to relevant legal and regulatory requirements related to occupational health and safety. This includes understanding how these requirements apply to their operations and ensuring compliance. Integrating legal compliance into the health and safety management system is crucial for both *ISO 45001* and the law.

Incident reporting and investigation:

ISO 45001 emphasizes the need for organizations to establish procedures for reporting, investigating, and recording work-related incidents and safety non-conformities. The law requires employers to report certain types of workplace incidents to the relevant authorities, such as injuries at work. The intersection here involves complying with *ISO 45001*'s incident reporting requirements while also adhering to legal obligations regarding incident reporting.

Employee participation and consultation:

ISO 45001 emphasizes the importance of engaging workers and their representatives in the development and implementation of the health and safety management system. The law requires employee participation and consultation on health and safety matters. Organizations must ensure

they meet both *ISO 45001*'s requirements for worker involvement and any additional legal obligations related to employee participation.

Emergency preparedness and response:

ISO 45001 requires organizations to plan and implement emergency preparedness and response procedures to address potential accidents and emergency situations. These procedures must be aligned with legal requirements related to emergency response.

Training and competency:

Both *ISO 45001* and the law stipulate the importance of providing adequate health and safety training to employees to perform their work safely and competently. Organizations must ensure they meet the specific training requirements of both *ISO 45001* and applicable legal regulations.

It's important to note that the intersection between *ISO 45001* and legal requirements will vary depending on the country and industry. Organizations seeking *ISO 45001* certification should carefully evaluate their health and safety management system to ensure it meets the standard's requirements while also complying with relevant laws and regulations on safety and health at work. Consulting with legal experts and *ISO 45001* consultants can help organizations navigate this intersection effectively.

Differences between legal requirements and standard requirements in managing occupational safety and health

The management of occupational safety and health involves adhering to both legal requirements and standard requirements. These requirements serve distinct purposes and can have differences in their scope and level of detail.

Legal requirements are enforceable by law, and organizations are obliged to comply with them. Failure to meet these obligations can result in legal consequences, such as fines, penalties, or legal action. Legal requirements are established by governmental or regulatory authorities at the local, national, or international levels, depending on the jurisdiction.

Standard Requirements are voluntary and not legally binding. Organizations can choose to adopt and implement standards based on their needs and objectives. Standards are developed by independent organizations with the aim of promoting best practices in a specific area, such as occupational health and safety. Standards outline best practices, methodologies, and guidelines to achieve optimal safety and health performance in the workplace. Unlike legal requirements, standards are designed to be applicable globally, providing a consistent approach to managing safety and health regardless of the jurisdiction.

Concrete examples in practice

Within 10 clauses of the standard, for clauses 1- 3 documented information is not required. The *ISO 45001 standard* requirements within clause 6 are OH&S objectives and planning to achieve them.

Examples of OH&S objectives might include - increasing employees' awareness of OH&S; reducing the number of injuries at work; and maintaining constant compliance with the appropriate legal and other requirements.

To increase OH&S awareness several things should be done: OH&S training, education, and informing employees about the importance of use of personal protective equipment (PPE) and obligatory OH&S informing of employees.

Reduction of the number of injuries at work could be achieved through OH&S training; procurement of adequate PPE, mandatory medical examinations of employees, especially at workplaces with increased risk, and full implementation of OH&S measures.

Maintaining constant compliance with the appropriate legal and other requirements is achieved through regular compliance review followed by keeping records of the conducted review.

The examples above demonstrate how meeting standards requirements in practice means meeting legal requirements, whereby instead of competing, they effectively complement each other.

Within Clause 8, of *ISO 45001*, Operational Planning and Control, for Emergency Preparedness and Response an adequate number of visible and well-marked first aid kits should be available. An adequate record of the contents and expiration date of the supplies in the first aid kit must be kept up to date. The legal requirement is that the employer must provide first aid to employees, as well as train the appropriate number of employees to provide first aid.

The legal obligation of the employer is to appoint an advisor, i.e., an associate for safety and health at work, by acting in writing. The appointment of employee representatives for safety and health at work is a recommendation of the law and a requirement of ISO 45001. The Risk Assessment Act (RAA) is a legal requirement, and among other things predicts the use of personal protective equipment for certain workplaces. The prescribed by RAA becomes the obligation of the company. Otherwise, the compliance with Clause 7 of the ISO 45001 standard and working environment conditions, is proven by RAA.

Key Performance Indicators (KPI), Clause 9 of *ISO 45001*, present a tool for determining whether the organization is meeting the requirements of *ISO 45001*. Organizations are required to have a systematic approach for measuring and monitoring of KPI of their OH&S management system performance. Defined KPIs are quantifiable measurements of a certain type of activity that a company conducts.

These KPIs usually consider quantifying the data whose monitoring is a legal requirement: The number of held training - training employees for safe and healthy work; The number of periodic inspections of the correctness of the hydrant network and mobile fire extinguishers, the number of days spent on sick leave due to an injury at work.

The listed intersections and differences are summarised and presented in Figure 1.

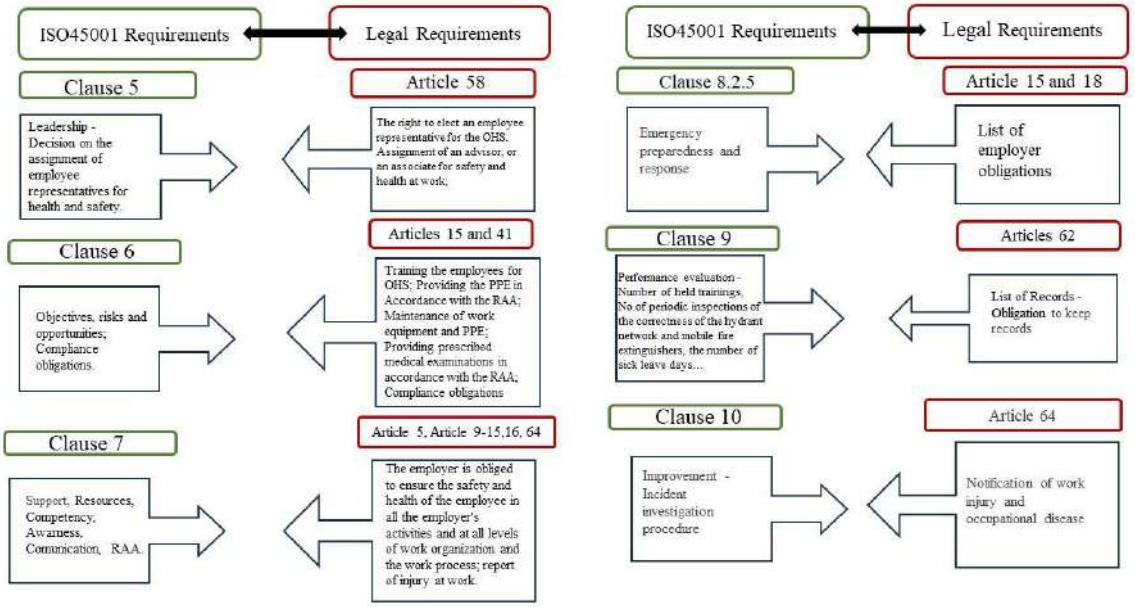

Figure 1. The intersection of ISO 45001 standard requirements and Legal Requirements

CONCLUSION

Being an international standard, *ISO 45001* is not legally binding by itself. Organizations choose to implement it voluntarily to demonstrate their commitment to ensuring a safe and healthy work environment and to comply with relevant legal and regulatory requirements.

Law on Safety and Health at Work in Serbia is a mandatory legal document for organizations operating within Serbia. It is enforceable by the relevant authorities, and non-compliance may lead to penalties or legal consequences.

The certification of an OH&S management system against the requirements of *ISO 45001* is not a guarantee of legal compliance, but it is a proven and efficient tool to achieve and maintain such legal compliance. Compliance with legal and other requirements disables organizations from unintentionally violating the legislation and results in the improvement of the health and safety of employees at the workplace. The findings of Mohammadfam et al., 2017, show that certified companies perform much better than uncertified companies in terms of occupational health and safety management practices.

ACKNOWLEDGMENT

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ASSESSMENT OF AQUATIC ENVIRONMENTAL PARAMETERS AND IDENTIFICATION OF SOURCES OF POLLUTION

Perović M.[1], *Obradović V.*[1], *Milovanović M.*[1], *Sretenović Ž.*[1]

[1] Jaroslav Černi Water Institute, Jaroslava Černog 80, 11 226 Belgrade, Republic of Serbia (e-mail: marija.perovic@jcerni.rs)

Abstract: Water quality is a complex issue impacted by natural conditions and anthropogenic activities. It is usually reported based on simultaneous chemical, physical, and biological analysis of results. The utilization of water and environmental protection of this valuable resource will greatly depend on water composition. Presented research included monthly measurements of 19 physicochemical parameters of water quality, during a 5-year period, from an official state monitoring program, for two profiles on the Danube in Serbia. The aim of the research was determination of the relations between examined parameters, and their analysis in the light of tracing the potential signature of anthropogenic impact on water quality. The analysis of the results confirmed that the distance from the pollution source and the accompanying dilution have a significant influence on the concentration levels of the observed parameters. Without measured significant variations in parameter concentrations only an indication of the pollution origin can be designated.

Keywords: *water quality; PCA analysis; sewage.*

INTRODUCTION

Surface water quality is influenced by atmospheric precipitation (water level), deposition, soil erosion (geology), population, industrialization in the basin area, seasonal change in temperature, and mixing of different types of water (Matijević et al., 2015). Point pollution sources are characterized by an exact location of wastewater discharge, while diffuse or nonpoint sources are generated spatially and are harder to control. Population connected to sewage and industrial plants represent the most significant point sources of pollution. Diffuse pollution sources include all surface and underground polluting substances loads that directly or indirectly reach watercourses, originating from the population that is not connected to the sewage system, inadequate land cultivation and leaching from forest and soil surfaces (due to inadequate soil management), livestock, non-sanitary landfills, and others human activities (WMS, 2017). According to the WMS, 2017, the current state of water quality protection in Serbia is primarily the result of a lack of funding, specifically for the construction and ongoing maintenance of wastewater treatment plants for settlements as well as for industrial and other consumers. Almost 75% of the population of the Republic of Serbia lives in settlements larger than 2,000 inhabitants, in which the average connection to public sewage systems is about 72%, and on individual (septic tanks) about 27%. In settlements with less than 2,000 inhabitants, the connection to the sewage system is less than 5% (WMS, 2017).

More than 50 wastewater treatment facilities, 32 of which are now in use, have been built in settlements with more than 2,000 residents in the Republic of Serbia over the previous few decades. Few operate in accordance with project requirements, while the majority perform with productivity significantly below projected. Although most of the City of Belgrade's sewage infrastructure has been constructed, the problem of wastewater evacuation and treatment has

not yet been properly solved. The Belgrade Sewerage System is partitioned into five distinct catchment areas, and systems: Central, Batajnica, Banat, Ostružnica, and Boleč. Among these, the largest is the Belgrade Central Sewerage System, covering approximately 85% of the entire Belgrade Sewerage System (Mitrinović et al., 2022). This system serves around 1,250,000 residents who are connected to the sewage network. Through more than 40 direct sewage outfalls, all effluent is released without treatment into the Sava River and Danube River (Mitrinović et al., 2022).

The largest sewage outfalls are: „Sajam", „Ušće", „Lasta", „Dorćol", „Istovarište", „Ada Huja 1", „Ada Huja 2", "Mirijevski potok" „Višnjica" and "Karađorđev Trg". Wastewater quantity and quality data obtained from measurements conducted at these outfalls are presented in Table 1 (2010-2019) (JCWI, 2020). There is no recorded measurement data at the outfall location "Mirijevski Potok".

Table 1. Average wastewater quantity and quality values in the period from 2010 to 2019 (JCWI, 2020)

Outfall	$Q_{avg.dly}$	BOD_5	COD	TSS	TN	TP	PE	PE
	l/s	mg/L	mg/L	mg/L	mg/L	mg/L	(BOD_5)	(COD)
Sajam	1480	240	361	200	31	4	511 084	384 410
Ušće	667	224	348	257	42	5	215 097	166 963
Lasta	280	195	296	165	28	6	78 700	59 581
Dorćol	152	147	239.5	107	25	5	32 150	26 216
Istovarište	530	173	268	142	31	7	131 752	102 211
Ada Huja 1	35	182	285	309	24	3	9 179	7 172
Ada Huja 2	28	157	255	191	22	5	5 202	4 226
Višnjica	117	212	316	228	36	7	53 969	40 231
Karađorđev Trg	305	215	323	165	40	7	94 544	71 022

According to the construction of the sewage infrastructure, the Republic of Serbia belongs to the group of medium-developed countries, while in terms of wastewater treatment, the very back. The sewage network covers about 55% of the population, while less than 10% of the population is covered by some level of wastewater treatment (WMS, 2017). The few industries have pretreatment of technological wastewater, before entering the sewage network or other recipients. In addition to the above, the water quality of major watercourses on the territory of the Republic of Serbia is threatened by most parameters of water quality (WMS, 2017).

Figure 1 shows the spatial distribution of hydrological stations, sanitary and combined sewer outfalls, and analyzed (sampled) profiles in the area of interest.

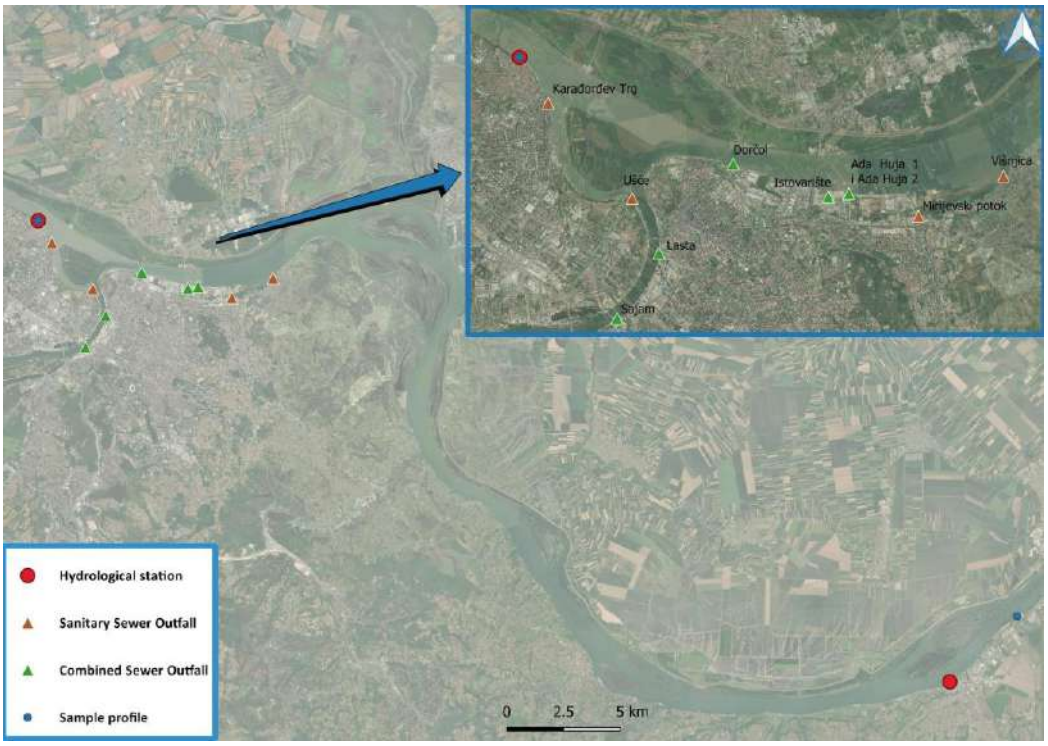

Figure 1. Spatial distribution of hydrological stations, sanitary and combined sewer outfalls, and analyzed (sampled) profiles in the area of interest

According to the quality of surface water bodies from the WMS, 2017, the largest number of water bodies in Serbia belong to the II and III quality class (over 80% of monitored water bodies), while less than 20% of water bodies belong to IV and V quality classes. It is also stated that water bodies on large watercourses, Danube, Tisza, Sava, and Drina, meet the criteria for class II quality, except for the content of orthophosphate in the exit sector of the Danube, which belongs to class III (WMS, 2017). In general, it can be concluded that surface water quality is relatively good, given the fact that less than 10% of wastewater is treated in an adequate way. It is particularly significant that the water quality of the Danube River at the exit from the Republic of Serbia is significantly better than the quality at the entrance, indicating the quality improvement throughout its course throughout the country (WMS, 2017).

MATERIALS AND METHOD

The results of the quality of the surface water body in the territory of AP Vojvodina Danube - Zemun (water body D6 - Accumulation of HPP Đerdap 1 - from the mouth of the Sava to the mouth of the Tisa) were compared with the water quality in the profile Danube near Smederevo (water body D5-Accumulation of HPP Đerdap 1 - from the mouth of the Velika Morava to the mouth of the Sava), analyzed and interpreted. The first sampled profile Zemun is located on the Danube, roughly 1 km upstream of the first bigger outfall of the Belgrade Sewer System, - "Karađorđev trg. The second analyzed profile is located near Smederevo, about 45 km downstream from the last major outfall of the Belgrade Sewage System into the Danube River - "Višnjica". It is also important to note that water levels have been used for the following analysis since the downstream

hydropower plant Iron Gate 1 has a great impact on the reliability of the daily flow measurements. The average flow of the Danube River during the 5-year period of interest at profile Zemun was around 3250 m^3/s and at profile Smederevo was around 4600 m^3/s.

The application of statistical processing methods is common for large data sets of monitoring results. The statistical data processing of selected water quality parameters was conducted with the aim of revealing the hidden relations, which might indicate possible pollution sources. Analyzed data originate from annual surface and groundwater quality monitoring reports, created by the Ministry of Environmental Protection for the period 2017-2021. The applied principal component analysis (PCA) is a statistical technique for reducing the dimensionality of a dataset while increasing the interpretability of data and preserving the maximum amount of information. It is important to emphasize that PCA results depend on parameters included in the analysis. The basic descriptive statistics for profile Zemun are presented in Table 2.

Table 2. Descriptive statistic of selected parameters for profile Zemun

		pH	Ec	NH_4^+	NO_2^-	NO_3^-	BOD	TOC
N	Valid	60	60	60	60	60	59	44
	Missing	8	8	8	8	8	9	24
Unit		/	µS/cm	mgN/l	mgN/l	mgN/l	mg/l	mg/l
Mean		8.04	393.4	0.17	0.014	0.98	2.38	4.08
Median		8.04	390.5	0.16	0.011	0.90	2.30	3.90
Std. Deviation		0.21	51.5	0.08	0.01	0.33	0.77	1.21
Minimum		7.58	305.0	<0.02	0.01	0.50	1.10	2.10
Maximum		8.45	516.0	0.31	0.07	1.90	5.30	6.60
Percentiles	25	7.91	348.0	0.12	0.010	0.70	2.00	3.03
	50	8.04	390.5	0.16	0.011	0.90	2.30	3.90
	75	8.17	435.5	0.23	0.016	1.20	2.80	5.07

The basic descriptive statistics for profile Smederevo are presented in Table 3.

The analyzed parameters were chosen because their correlations can indicate the origin of the pollution or indicate the unfolding of the transformation process. The parameters processed by statistical data processing included water level, turbidity, suspended solids, pH value, electrical conductivity (Ec), ammonium ion (NH_4), nitrites (NO_2), nitrates (NO_3), organic nitrogen (ON), total nitrogen (TN), orthophosphates (OP), total phosphorous (P), sodium (Na), chloride (Cl), sulfates (SO_4), boron (B), chemical oxygen demand (COD), biological oxygen demand (BOD) and total organic carbon (TOC). The program IBM SPSS Statistics v.23 was applied. The Rotation Method Varimax with Kaiser Normalization was implemented and the obtained value for Bartlett's test of sphericity $p < 0.01$ indicates that factor analysis can provide significant information for data interpretation. Based on eigenvalues greater than 1, PCA analysis revealed four factors in the Zemun profile (Principal components - PCs) which explain 82.75% of the total variance, and four factors in the Smederevo profile that explain 93.52% of total variance.

Table 3. Descriptive statistics of selected parameters for profile Smederevo

		pH	Ec	NH_4^+	NO_2^-	NO_3^-	BOD	TOC
N	Valid	60	60	60	60	60	57	31
	Missing	5	5	5	5	5	8	34
Unit		/	µS/cm	mgN/l	mgN/l	mgN/l	mg/l	mg/l
Mean		7.99	390.7	0.16	0.012	0.83	2.12	3.59
Median		8.01	385.0	0.15	0.011	0.80	2.00	3.60
Std. Deviation		0.19	38.2	0.07	0.005	0.21	0.62	0.79
Minimum		7.51	328.0	<0.02	0.004	0.40	1.00	1.90
Maximum		8.46	499.0	0.30	0.03	1.40	3.90	5.20
Percentiles	25	7.86	360.3	0.12	0.009	0.70	1.70	2.90
	50	8.01	385.0	0.15	0.011	0.80	2.00	3.60
	75	8.10	412.8	0.22	0.015	0.98	2.55	4.00

RESULTS AND DISCUSSION

Zemun profile

For the first examined profile Zemun, the PCA revealed four principal components, which explain 82.75 % of the total variance (Table 4.). Because of their significance, the first two components are further analyzed. The hydrochemical factors of point pollution (phosphorous, ammonium ion, and conductivity) are in inverse correlation with the water level, pH value, BOD, and TOC. PC2 explains 22.44% of the total variance and shows that in examined samples increase in turbidity is followed by an increase of suspended solids, nitrite, nitrate, organic, and total nitrogen content. At the same time, within the same PC2, the decrease of sodium and chloride (municipal pollution indicators) is noted. Observed positive correlation of nitrogen component with turbidity and suspended solids, and at the same time inverse correlation with sodium and chlorides, indicate that at Zemun profile nitrogen component load is also related to diffuse pollution sources probably originating from agriculture. Ammonia decrease can be induced by the nitrification process, where generated nitrates, along with phosphorous, could be assimilated by the aquatic plant component (macrophyte vegetation and algal production-organic production) whose indirect indicator is the increased pH value and increased organic carbon content. The confirmation of the mentioned can be inferred from the ammonia and phosphorous simultaneous decrease, followed by pH, TOC, and BOD increase, observed within the PC1 on the Zemun profile.

Smederevo profile

For the second profile Smederevo downstream from Belgrade, the PCA revealed four factors that explained 93.52% of the total variance (Table 4). Because of their significance, PC1 and PC2 are further discussed. The PC1 explains 34.18% of the variance and shows a significant relation between water level, turbidity, suspended solids, pH, and TOC. Within the same factor (PC1) the decrease of conductivity, nitrates, sodium, chloride, and sulfate concentration is noticed.

The influence of hydrological conditions (water level) on water quality can be observed from PC1, as well as an indication that organic pollution (probably of autochthonous origin - algae biomass)

near Smederevo depends on the water level of the river, which can be indicated by measured pH values. The indicators of communal pollution (sodium, chlorides, sulfates, and nitrates), at this profile, are in negative correlation with the river water level indicating dilution influence. The second factor (PC2) explained 26.08% of the total variance and showed a significant relationship between ammonium, nitrites, organic nitrogen, total nitrogen, and orthophosphate. Within the same factor, the inverse correlation with organic pollution (chemical and biological oxygen demand) is observed, which indicates that the nitrogen component probably originates from mineral fertilizers, erosion, or surface runoff.

Table 4. Component matrix for examined profiles

	Principal Components Zemun					Principal Components Smederevo			
	PC1	PC2	PC3	PC4		PC1	PC2	PC3	PC4
Water level	0.758				Water level	0.791			
Turbidity		0.769			Turbidity	0.744			
Suspended solids		0.597	-0.625		Suspended solids	0.863			
pH	0.823				pH	0.534			-0.837
Ec	-0.742				Ec	-0.763			0.537
NH_4	-0.720				NH_4		0.548	-0.763	
NO_2		0.612			NO_2		0.926		
NO_3		0.504	0.588		NO_3	-0.597			-0.518
ON		0.638			ON		0.760		
TN		0.826	0.511		TN		0.880		
OP				0.592	OP		0.916		
P	-0.702		0.533		P			-0.842	
Na	0.646	-0.706			Na	-0.752			
Cl		-0.671			Cl	-0.831			
SO_4	-0.847				SO_4	-0.765		-0.546	
B	0.620				B			0.985	
COD				0.693	COD		-0.766		
BOD	0.579			0.636	BOD		-0.579	0.758	
TOC	0.731				TOC	0.961			

CONCLUSION

Surface water monitoring is an important tool for maintaining ecosystems, protecting public health, ensuring sustainable resource management, and responding to environmental challenges. It enables making adequate decisions and taking appropriate actions to safeguard

water resources for current and future generations. When it comes to monitoring programs that are carried out on an annual basis, statistical methods are most often used to process such a large set of data with the aim of identifying possible factors/sources responsible for water quality variability. The location and distance of pollution sources from the measuring point, as well as the identification of the other pressures on the water quality, must be considered in the water quality results interpretation.

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APPLICATION OF THE AHP METHOD TO ASSESS THE CONSEQUENCES OF THE FIRE IN VINČA IN 2021

Petrović N.[1], *Krstić I.*[2], *Stojičić S.*[3], *Petrović M.*[4]

[1]Ministry of Interior, Kneza Miloša 101, Belgrade, Serbia (e-mail: natasa.petrovic@mup.gov.rs)

[2]Faculty of Occupational Safety, University of Niš, Čarnojevića 10a, Niš, Serbia

Abstract: System analysis and risk assessment of undesired events, such as fires, are conducted from the perspective of risk management and overall security provision. As risk represents the degree of probability that a specific event will occur, knowledge of materials and conditions that could lead to its occurrence, along with knowledge and preparedness to respond to undesired events and hazards, might help in the planning and implementation of measures and activities for timely reduce the probability of occurrence or mitigate the consequences of the risk. System analysis and risk assessment might serve as the foundation for building fire protection systems, confirmed through events examined in this study. The results of system analysis contribute to deriving recommendations whose implementation enhances the safety of individuals, objects, and other material goods. This article shows the results of applying systems analysis to the example of a fire in Vinča, which occurred on August 3, 2021, based on data retrieved from the national system for automatic air quality monitoring stations.

Keywords: *risk; system analysis; AHP method; forensics; fires; explosions; pollutants*.

INTRODUCTION

The presence of risk exists in all human activities and systems. Risk is an inevitable part of business and in many fields. The confirmation of implementing appropriate processes of systems analysis and risk management is essential, especially considering the volume of data that is provided and processed in business processes.

Risk assessment refers to the ability to predict the probability of the occurrence of undesired events with the aim of timely identifying the need for preventive actions or assessing the responses taken in the events already happened. The results can be directed towards preventive action, identifying individuals or circumstances that could lead to undesired events such as fires, and/or uncovering the causes of undesired events and the activities taken to reduce their consequences. This involves the implementation of strategies to minimize harmful consequences for individuals, material assets, and the environment.

Furthermore, it can contribute to the planning and provision of necessary minimum resources for efficient and effective protection of the work and living environment. The identification of static and dynamic risk factors and corresponding responses for their prevention is included in the risk assessment process (Brown et al., 2014).

METHODS OF IDENTIFICATION, ANALYSIS AND RISK ASSESSMENT

Risk identification is the process of identifying and documenting potential risks, hazards, or threats that can result in the occurrence of undesired events (Stojičić et al., 2023). This identification involves the application of appropriate methods to identify risks and the preparation of information about all identified risks, which forms the basis for evaluating the problem/risk.

Based on risk identification, all sources of hazards need to be discovered and precisely described. The results of risk identification include: recognizing undesired events; describing sources of hazards, risk factors, conditions of occurrence, and the way they develop, as well as the consequences of undesired events; and preliminary hazard and risk assessments (Mlađan et al., 2013).

ANALYTICAL HIERARCHY PROCESS METHOD

The Analytical Hierarchy Process (AHP) method, developed by Thomas Saaty (Saaty, 1980), is a multi-criteria analysis method used for group or individual decision-making. The central part of the AHP involves comparing elements in pairs in the hierarchy and forming corresponding local reciprocal numerical matrices from which the weights of the compared elements are determined using certain mathematical procedures. The analytical part of this method represents the hierarchical division of the problem. The problem is decomposed into multiple levels of decision factors, between which there is an established hierarchy. The method starts with defining the goal, determining criteria related to the goal, and if necessary, sub-criteria. After defining the hierarchy, the decision-maker compares the element criteria in pairs at the same level to establish mutual priorities, i.e. determine the rank of criteria. The comparison is made using Saaty's scale given in Table 1.

Table 1. Saaty's Scale (Saaty, 1980)

Definition	Numeric value
Equal importance	1
Weak importance of one over the other	3
Essential or strong importance	5
Demonstrated importance	7
Absolute importance	9
Intermediate values between the two adjacent judgments	2,4,6,8

Comparisons in pairs are made based on Saaty's scale of importance (Table 1), by assigning values from the set {1/9, 1/8, 1/7, 1/6, 1/5, 1/4, 1/3, 1/2, 1, 2, 3, 4, 5, 6, 7, 8, 9}. In this scale, 1 means that both factors (being compared) are equally important, while 9 indicates that the first factor in the pair is more important than the second factor. Pairs are compared relatively to each other, not in relation to a defined or imagined quality or quantity (Saaty, 1980).

After the pairwise comparisons, the decision-maker calculates their relative weights with respect to the goal. They compare alternatives (in pairs) for each criterion and assign relative weights, thus creating a database of compared pairs (Saaty, 1980).

The computational part of the AHP method is based on a reciprocal matrix, in which the elements of the upper triangle of the matrix are reciprocals of the corresponding elements in the lower triangle with respect to the diagonal, which is always 1. The general matrix for comparing n

decision elements at a specific level of the hierarchy is expressed as ($a_{ij}=1/a_{ji}$, for each i and j; $a_{ii}=1$ for each i, detA≠0) (Saaty, 1980).

$$A=[a_{11} \cdots a_{1n} \vdots \ddots \vdots a_{n1} \cdots a_{nn}]$$

AHP compares pairs, taking into account the goal, criteria, and alternatives. The analysis of individual decision-maker consistency can be performed based on the calculated values for CR and ED (Eigenvector Discordance) for each comparison matrix. The vector weight of each criterion is derived from this comparison. The CR is calculated during the standard AHP procedure. First, the Consistency Index (CI) is calculated:

$$CI=\frac{(\lambda max-n)}{(n-1)} \quad (1)$$

where λmax is the maximum eigenvalue of the comparison matrix. Using this index and the Random Index (RI), which depends on the order of the matrix, the consistency ratio (CR) is obtained.

$$CR=\frac{CI}{RI} \quad (2)$$

The RI is determined from Table 2, where n is the rank of the matrix:

Table 2. Values of random indexes (Saaty, 1980)

n	1	2	3	4	5	6	7	8
RI	0	0	0.52	0.89	1.11	1.25	1.35	1.4

If the CR for the comparison matrix is found to be CR < 0.10, the decision-maker is considered to be satisfactorily consistent. In some cases, this statement may also hold if CR > 0.10 (Saaty, 1980).

The AHP method allows the decomposition of any complex problem into multiple sub-problems, and each level represents a set of criteria elements significant for that sub-problem. In this way, might be defined the cause of unwanted events as a series of criteria with the same or different importance or a series of influences that led to the undesired state, using engineering knowledge.

EVALUATION OF THE CONSEQUENCES OF A FIRE AS AN AIR POLLUTION RISK IN VINČA ON 03.08.2021 USING THE AHP METHOD

To demonstrate the use of AHP and system analysis of risks, we will consider the example of the consequences of the fire in Vinča on August 3, 2021, which directly impacted air pollution with particles of SO2, PM10, O3, NO2, and NOX. According to the report of the Republic of Serbia ("Official Gazette RS", no., 11/2010, 75/2010, and 63/2013), the conditions regarding

monitoring and requirements of air quality were regulated. Air pollutant emission comes from almost every economic and public activity (Rašić et al., 2013).

Through the AHP method, we will determine the location where the polluting particles have the greatest impact on the environment and work conditions. According to the location of the event chosen data from stations for automatic air quality measurement which are relevant, pollution parameters were measured on stations in the area of interest: Belgrade Vinča, Belgrade Vračar, Belgrade Zeleno brdo, and Pančevo Starčevo (Table 3, 4, 5, 6) (data obtained from http://www.amskv.sepa.gov.rs/mob/). The established hierarchy is shown in Figure 1.

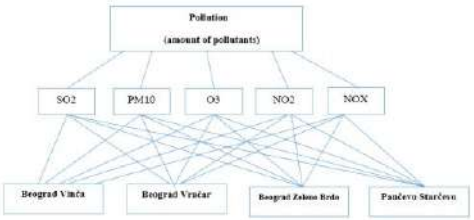

Figure 1. Hierarchical representation of the pollution problem

Table 3. Values of pollutant particles at the location Belgrade Vinča

Time	SO2 [ug.m-3]	PM10 [ug.m-3]	O3 [ug.m-3]	NO2 [ug.m-3]	NOX [ug.m-3]
Place			Belgrade Vinča		
3.8.2021 14:00	12.61	14.65	172.56	7.66	10.43
3.8.2021 15:00	15.17	13.59	168.73	5.95	8.52
3.8.2021 16:00	18.61	13.94	153.73	5.68	8.48
3.8.2021 17:00	19.29	13.97	146.28	3.59	5.99

Table 4. Values of pollutant particles at the location Belgrade Vračar

Time	SO2 [ug.m-3]	PM10 [ug.m-3]	O3 [ug.m-3]	NO2 [ug.m-3]	NOX [ug.m-3]
Place			Belgrade Vračar		
3.8.2021 14:00	37.63	15.03	127.23	7.08	11.19
3.8.2021 15:00	34.27	16.1	147.93	7.48	10.02
3.8.2021 16:00	31.65	15.43	151.62	7.85	10.06
3.8.2021 17:00	32.27	15.21	142.91	8.63	11.7

Table 5. Values of pollutant particles at the location Belgrade Zeleno brdo

Time	SO2 [ug.m-3]	PM10 [ug.m-3]	O3 [ug.m-3]	NO2 [ug.m-3]	NOX [ug.m-3]
Place			Belgrade Zeleno brdo		
3.8.2021 14:00	27.01	14.87	86.74	27.04	44.46
3.8.2021 15:00	20.46	21.79	105.89	29.45	43.87
3.8.2021 16:00	20.84	19.11	106.47	27.13	39.93
3.8.2021 17:00	21.6	16.55	94.38	24.65	37.53

Table 6. Values of pollutant particles at the location Pančevo Starčevo

Time	SO2 [ug.m-3]	PM10 [ug.m-3]	O3 [ug.m-3]	NO2 [ug.m-3]	NOX [ug.m-3]
Place			Pančevo Starčevo		
3.8.2021 14:00	7.63	1.72	126.86	8.37	13.8
3.8.2021 15:00	9.04	6.17	114.08	9.82	16.39
3.8.2021 16:00	10.43	6.76	114.29	12.55	17.61
3.8.2021 17:00	12.71	5.11	112.67	11.89	18.5

Comparison of pollutant particles significance and assessment and priorities in relation to SO2, PM10, O3, NO2, and NOX are shown in Table 7, 8, 9, 10, 11, and 12.

In Table 13 and Table 14 determining the normalized attribute vectors are shown.

Table 7. Comparing the significance of pollutant particles on the "nine-point" scale

	SO2	PM10	O3	NO2	NOX
SO2	1	5	(5)	2	3
PM10		1	(3)	(5)	(5)
O3			1	3	4
NO2				1	2
NOX					1

Table 8. Assessments and priorities in relation to SO2

	Belgrade Vinča	Belgrade Vračar	Belgrade Zeleno brdo	Pančevo Starčevo
Belgrade Vinča	1	2	2	5
Belgrade Vračar		1	(2)	(6)
Belgrade Zeleno brdo			1	(3)
Pančevo Starčevo				1

Table 9. Assessments and priorities in relation to PM10

	Belgrade Vinča	Belgrade Vračar	Belgrade Zeleno brdo	Pančevo Starčevo
Belgrade Vinča	1	7	4	5
Belgrade Vračar		1	(3)	3
Belgrade Zeleno brdo			1	(3)
Pančevo Starčevo				1

Table 10. Assessments and priorities in relation to O3

	Belgrade Vinča	Belgrade Vračar	Belgrade Zeleno brdo	Pančevo Starčevo
Belgrade Vinča	1	3	(2)	5
Belgrade Vračar		1	5	3
Belgrade Zeleno brdo			1	(3)
Pančevo Starčevo				1

Table 11. Assessments and priorities in relation to NO2

	Belgrade Vinča	Belgrade Vračar	Belgrade Zeleno brdo	Pančevo Starčevo
Belgrade Vinča	1	5	(3)	4
Belgrade Vračar		1	4	2
Belgrade Zeleno brdo			1	(2)
Pančevo Starčevo				1

Table 12. Assessments and priorities in relation to NOX

	Belgrade Vinča	Belgrade Vračar	Belgrade Zeleno brdo	Pančevo Starčevo
Belgrade Vinča	1	3	3	4
Belgrade Vračar		1	(5)	(7)
Belgrade Zeleno brdo			1	(8)
Pančevo Starčevo				1

Table 13. Determining the normalized attribute vector (pollutant particles)

	SO2	PM10	O3	NO2	NOX
SO2	1	5	0.2	2	3
PM10	0.2	1	0.33	0.2	0.2
O3	5	3	1	3	4
NO2	0.5	5	0.33	1	2
NOX	0.33	5	0.25	0.5	1
Σ	**7.03**	**19**	**2.11**	**6.7**	**10.2**

Table 14. Determining the normalized attribute vector (pollutant particles) - each element in the table is divided by the sum of the elements in the corresponding column

	SO2	PM10	O3	NO2	NOX	$\sum attribute\ /5$
SO2	0.14	0.26	0.09	0.30	0.29	**0.22**
PM10	0.03	0.05	0.16	0.03	0.02	**0.06**
O3	0.71	0.16	0.47	0.45	0.39	**0.44**
NO2	0.07	0.26	0.16	0.15	0.20	**0.17**
NOX	0.05	0.26	0.12	0.07	0.10	**0.12**

In Table 15 and Table 16, the determination of the normalized vector in relation to SO2 is shown.

Table 15. Determining the normalized vector in relation to SO2

	Belgrade Vinča	Belgrade Vračar	Belgrade Zeleno brdo	Pančevo Starčevo
Belgrade Vinča	1	2	2	5
Belgrade Vračar	0.5	1	0.5	0.17
Belgrade Zeleno brdo	0.5	2	1	0.33
Pančevo Starčevo	0.2	6	3	1
∑	**2.2**	**11**	**6.5**	**6.5**

Table 16. Determining the normalized vector in relation to SO2 - each element in the table is divided by the sum of the elements in the corresponding column

	Belgrade Vinča	Belgrade Vračar	Belgrade Zeleno brdo	Pančevo Starčevo	$\sum attribute\ /4$
Belgrade Vinča	0.45	0.45	0.18	0.31	**0.77**
Belgrade Vračar	0.23	0.23	0.09	0.08	**0.03**
Belgrade Zeleno brdo	0.23	0.23	0.18	0.15	**0.05**
Pančevo Starčevo	0.09	0.09	0.55	0.46	**0.15**

We repeat the same procedure for other pollutants (Tables 17 and 18).

Table 17. Normalized pollutant vector

SO2	PM10	O3	NO2	NOX
0.22	0.06	0.44	0.17	0.12

Table 18. Normalized pollutant vector by location

	SO2	PM10	O3	NO2	NOX
Belgrade Vinča	0.77	0.57	0.38	0.39	0.43
Belgrade Vračar	0.03	0.13	0.29	0.25	0.07
Belgrade Zeleno brdo	0.05	0.14	0.19	0.23	0.15
Pančevo Starčevo	0.15	0.16	0.14	0.13	0.35

Table 19. Determination of composite normalized vector

	SO2	PM10	O3	NO2	NOX	∑ attribute
Belgrade Vinča	0.17	0.03	0.17	0.07	0.05	**0.49**
Belgrade Vračar	0.01	0.01	0.13	0.04	0.01	**0.19**
Belgrade Zeleno brdo	0.01	0.01	0.08	0.04	0.02	**0.16**
Pančevo Starčevo	0.03	0.01	0.06	0.02	0.04	**0.17**

Based on the values of the weights of the composite normalized vector, the order of exposure to pollutant substances is Beograd Vinča: 0.49; Beograd Vračar: 0.19; Pančevo Starčevo: 0.17; and Beograd Zeleno brdo: 0.16 (Table 19).

The pollution results in the examined areas are expected, considering that the center of the fire was in Vinča. Vračar has additional pollution along with its "usual" pollution. Pančevo, located opposite Vinča, across the Danube, shows higher pollution levels. Zeleno brdo is the least polluted area due to its higher altitude.

CONCLUSION

For conducting a systemic risk analysis of undesired events, a systematic and structured approach is applied. This analysis, progressing through phases and adhering to the goals of systemic risk analysis, involves identifying the mechanisms of potential occurrence. In the event of an occurrence, it encompasses the development of harmful consequences or effects on health and human lives, material goods, and the environment, especially critical infrastructure elements. The results of applying the systemic risk analysis method, as presented in this article, confirm its applicability for analyzing potential scenarios of fire development and processes, along with the temporal component, while considering measures and activities for responding to the occurrence of undesired events, taking into account all the effects that fire processes can lead to. Furthermore, analysis using the APH method can be applied to risk assessment and the selection of optimal security systems in technological systems in the observed environment.

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ASSESSMENT OF FIRE RISK IN THE COMPANY "ESSEX FURUKAWA MAGNET WIRE BALKAN" DOO ZRENJANIN

Radosavljević V. [1], *Krstić I.* [2], *Stojković A.*[2]

[1] Essex Furukawa Magnet Wire Balkan DOO Zrenjanin, Industrijska zona Jugoistok I, Zrenjanin, Serbia
[2] University of Niš, Faculty of Occupational Safety, Čarnojevića 10a, Niš, Serbia

Abstract: Fire protection as a set of organizational and technical measures for fire prevention is applied in all branches of industry to the extent that depends on the categorization of fire risk. Due to the specifics of the technological process of enameled copper wire production from the aspect of fire protection in the company "Essex Furukawa Magnet Wire Balkan" DOO Zrenjanin, a complex fire protection system was established in accordance with the Fire Protection Plan. Accordingly, the paper analyzes specific protection measures based on the estimated fire risk.

Keywords: *fire protection measures; fire risk; fire protection plan; production of enameled copper wire.*

INTRODUCTION

Fire and explosion protection is a set of measures and activities of a preventive and repressive nature, with the aim of preventing the outbreak and spread of fire, reducing the consequences to the smallest possible extent, effective fire extinguishing, determining the manner and cause of fire and explosions, possible liability due to non-observance of prescribed or of prescribed fire and explosion protection measures, as well as the detection of possible elements of criminal acts, aims to protect people's lives and material goods (Erić, 2003). Fire safety refers to measures taken to reduce the possibility of damage to material assets or injury to employees (Pheng, 2006; Khorram-Manesh, 2017; Alexander, 2019; Sawalha, 2020). Preventive measures are of essential importance in the possibility of fire occurrence and minimizing the consequences caused by fires (Martinson, 2003; Piñol, 2007; Higgins, 2012). Due to the concept of prevention, the global paradigm of fire management is shifting from remediating consequences to proactive action (MPSS, 2016). Accordingly, fire protection system management can be divided into four phases: prevention (mitigation), preparedness, response, and recovery (Shoaf, 2000). Prevention methods include continuous education of all stakeholders, fire risk assessment, and improvement of fire response infrastructure (Wuschke, 2013; Jonsson, 2016; Taylor, 2019). On the other hand, fire risk assessment implies the determination of prevention plans taking into account the probability and effects of fire occurrence, the costs of prevention, as well as the efficiency and availability of resources (Eric Dickson, 2012).

Based on the Fire Protection Plan and fire risk in the technological process of enameled copper wire production, protection measures were analyzed in order to proactively improve the fire protection system.

TECHNOLOGICAL PROCESS OF PRODUCTION OF ENAMELED COPPER WIRE

Enamel wire or magnetic wire is a copper wire wrapped with a very thin layer of insulation. It is used in making transformers, motors, speakers, potentiometers, electromagnets, electrical conductors, etc. Modern lacquered wires typically use one to four layers of polymer insulation,

often of different compositions, to provide a resistant and continuous layer. As an insulating film, wire varnish is used: polyester-polyamide, amides, and polyimide.

The raw material for the production of varnished wire is copper wire with a diameter of 8 mm, placed on large pallets (about 4 to 5 tons). The purity of the copper is the main criterion, as only a few percent of another metal, even silver, would preclude the ability to further extract and temper it. Due to the large number of different requirements related to the dimensions of lacquered wire, the production process has a linear character with the following technological stages: drawing, hardening, enameling, and grafting.

All copper lacquer wires, thicker or thinner, even as thin as a hair, are made from an 8 mm bar, which is then reduced to the desired dimension by drawing through diamond drawing dies and/or heavy metal dies, a process called cold forming drawing. Further, copper is tempered by heating due to recrystallization (optimization of grain size).

Figure 1. The process of applying enamel to copper wire

Enameling is done in applicators (Figure 1). Inside the production facility, varnishes are stored in a hazardous materials warehouse and then sent by pump to the enamel furnace in closed pipe systems. The number of different enamel formulations is large and largely depends on the size of the wire and the user's application (15 - 20 different types). All enameling machines operate with their own sealed enamel tanks, up to 5 different types of enamel, filled through a tube.

Enameling aims to put a layer of liquid enamel on the wire and is based on the following procedures:

- The wire passes through the enamel coating, with excess liquid, and through the drawing die to obtain the appropriate thickness;
- On entering the furnace, the wire is first heated to evaporate the solvents and then to cross-link the polymer. The thickness is reduced approximately 3 times by drying, to a dry film size of several microns;
- As this thickness is very small, the process should be repeated up to 25 times, in order to obtain the appropriate dimensions. The wire is cooled before being drawn through the liquid enamel again.

Finally, it is necessary to cover the wire with a layer of wax, in order to wind it on the support and deliver it to the end user. The wire passes through the enamel and the matrix at a speed of 300 m/min. The carrier fills spools up to 800 kg, and the main spools are usually between 80 and 200 kg. The final procedure is grafting on the delivery reels. All available enameling furnaces use BAT (*Best Available Technique*).

During the enameling process, the (enamel) solvents are mixed with oxygen from the air and taken in a closed/encapsulated pipe system to the catalytic system. Here, their catalytic oxidation is carried out (efficiency level of about 97%).

Emissions from the process are strictly controlled and comply with the European Industrial Emission Regulation: NO_X < 350 mg/m³, CO < 500 mg/m³, C total < 50 mg/m³, and CMR < 1 mg/m³.

ASSESSMENT OF FIRE RISK OF HAZARDOUS MATERIAL STORAGE

Enamels, that is, enamels used in the technological process are stored in a hazardous materials warehouse and then pumped to the enamel furnace in closed pipe systems. In accordance with that, the calculation of the fire risk of the warehouse of hazardous materials was carried out depending on the intensity and duration of the fire, as well as on the structural characteristics of the load-bearing elements of the building, according to the form:

$$Ro = \frac{(Po \times C + Pk) \times B \times L \times \check{S}}{W \times Ri} \quad (1)$$

Clarification of form:

Ro - warehouse fire risk;

Po - coefficient of fire load of warehouse contents;

C - coefficient of combustibility of the contents of the warehouse;

Pk - coefficient of fire load from materials incorporated in the construction of the warehouse;

B - coefficient of the size and position of the fire sector;

L - coefficient of delay of the start of extinguishing;

W - fire sector width coefficient;

V - coefficient of resistance of the bearing structure of the warehouse to fire;

Ri - risk reduction coefficient.

The fire load coefficient of the warehouse contents (Po) is determined according to the heat value of all combustible materials in the warehouse MJ/m², as shown in the following Table 1.

Table 1. Fire load coefficient of warehouse contents (Po)

MJ/m²	0 - 251	252 - 502	503 - 1004	1005 -2009	2010 -4019	4020 -8038	8039 - 16077	16078 - 32154	32155- 64309	≥64310
Po	1	1.2	1.4	1.6	2.0	2.4	2.8	3.4	3.9	4.0

The calculated total heat value of all combustible materials in the warehouse is 2500 MJ/m². It follows from Table 1 that the Po coefficient is 2.

The combustibility coefficient (C) is determined according to the fire hazard class, Table 2.

Table 2. Combustibility coefficient (C)

Fire hazard class	VI	V	IV	III	II	I
Combustibility coefficient (C)	1.0	1.0	1.0	1.2	1.4	1.6

The warehouse of hazardous materials belongs to class III fire hazard. It follows from Table 2 that the coefficient C is 1.2.

The coefficient of fire load of the warehouse structure (Pk) is determined according to the heat value of all combustible materials in the building MJ/m², as shown in Table 3.

Table 3. Fire load coefficient of the warehouse structure (Pk)

MJ/m²	0-419	420-837	838-1675	1676-4187	≥ 4188
Pk	0	0.2	0.4	0.6	0.8

The calculated total heat value of all combustible materials in the warehouse is 2500 MJ/m². Table 3 shows that the Pk coefficient is 0.6.

The coefficient of the size and position of the fire sector (B) is determined according to the descriptive characteristics of the warehouse, as shown in Table 4.

Table 4. Coefficient of size and position of the fire sector (B)

Characteristics of the object	Fire sector up to 1500 m², room height up to 10 m, maximum 3 floors	Fire sector up to 1500-3000 m², room height up to 10-25 m, one floor in the basement	Fire sector up to 3000-10000 m², room height over 25 m, 2 or more floors in the basement	Fire sector over 10000 m²
B	1.0	1.3	1.6	2.0

According to the description of the characteristics of the warehouse from Table 4, it follows that the coefficient B is 1.

The intervention delay coefficient (L) depends on the equipment and type of the firefighting unit that intervenes, as well as on its distance from the object, as shown in Table 5.

Based on the optimal time until the start of extinguishing and the distance of the firefighting unit from the object, it follows from Table 5 that the coefficient L is 1.

Table 5. Coefficient of intervention start delay (L)

Time until the start of shutdown/ The distance of the fire department		10' / 1 km	10'-20' / 1-6 km	20'-30' / 1 km	≥ 30' / 1-6 km
Species fire department units	Professional industrial unit	1.0	1.1	1.3	1.5
	Voluntary industrial unit	1.1	1.2	1.4	1.6
	Territorial professional unit	1.0	1.1	1.2	1.4
	Territorial voluntary unit with permanent duty	1.1	1.2	1.3	1.5
	Territorial voluntary unit without permanent duty	1.3	1.4	1.6	1.8

The coefficient of the width of the fire sector (W) depends on the width of the fire sector, as shown in Table 6.

Table 6. Fire sector width coefficient (W)

The smallest width of the fire sector [m]	do 20	20-40	40-60	≥60
W	1	1.1	1.2	1.3

Based on the width of the fire sector, it follows from Table 6 that the W coefficient is 1.

The fire resistance coefficient (V) of the load-bearing structure depends on the structural characteristics of the building, as shown in Table 7.

Table 7. Fire resistance coefficient (V)

Fire resistance in minutes	manje od 30	30	60	90	120	180	240
Fire resistance coefficient (V)	1.0	1.3	1.5	1.6	1.8	1.9	2.0

Based on the constructive characteristics of the building, it follows from the table that the coefficient V is 1.6.

The coefficient of circumstances affecting the risk assessment (Ri) is calculated taking into account the type of fuel material, storage method, speed of its burning, and other influencing factors, the fire risk of the object can be reduced depending on the coefficient of circumstances affecting the risk assessment, the values of which are given in Table 8.

Table 8. Coefficient of circumstances affecting risk assessment (Ri)

Risk	Circumstances affecting risk assessment	Ri
MAX	high flammability of materials and storage with larger distances; the rapid spread of fire is expected; in the technical process itself or during storage, there is a greater number of possible ignitions	1.0
Normal	flammability is not so pronounced, and storage is with spaces sufficient for manipulation; a normal rate of fire spread is expected; there are normal sources of ignition in the technological process itself or during storage	1.3
Smaller than normal	lower flammability due to partial storage (20-25%) of flammable goods in non-combustible packaging; storage of flammable goods without intermediate spaces; the fire is not expected to spread quickly; for ground-floor halls whose area is less than 3000 m²; for facilities where the issue of smoke and heat removal has been resolved	1.6
Insignificant	low probability of ignition due to goods in tin boxes or other, similar materials, as well as due to very dense storage; very slow fire development is expected.	2.0

Based on the type, storage method, and burning rate of combustible materials, it follows from Table 8 that the Ri coefficient is 1.3.

Based on the displayed parameters, the calculation of the fire risk of the hazardous materials warehouse amounts to:

$$Ro = \frac{(2\times1,2+0,6)\times1\times1\times1}{1,6\times1,3} = 1.44 \qquad (2)$$

Given that the maximum value of fire risk is 5, it is considered that the fire risk in the warehouse of hazardous materials is acceptable, but certainly, due to the nature of the materials stored in the warehouse of hazardous materials, it is necessary to install stable fire alarm and extinguishing systems, in the EX version, and it is especially necessary to apply technical and technological protection measures.

CONCLUSION

The basic principle of fire protection prevention is ensured by planning and implementing preventive measures and actions so that the outbreak of fire is prevented as effectively as possible, and in the event of a fire, the risk to life and health of people and endangering material goods as well as endangering the environment is reduced to the minimum possible. measure and limit the fire to the place of the outbreak itself. In accordance with that, in the company "ESSEX FURUKAWA MAGNET WIRE BALKAN" DOO ZRENJANIN, preventive fire protection measures prescribed by the Fire Protection Plan were applied. The company has established an effective fire protection system that is continuously improved through training, education, and consistent application of legal and standardization regulations.

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HARMONIZING ENVIRONMENTAL, OCCUPATIONAL HEALTH AND SAFETY, AND LABOR RELATIONS REGULATIONS WITH EUROPEAN EXCELLENCE: A COMPREHENSIVE PROJECT OVERVIEW FOR SCHOOL PREPARATION AND ROUND TABLE DISCUSSION

Španik I[1], Mučenski V[2], Petrović M[2],

[1]Slovak University of Technology, Faculty of Chemical and Food Technology, Institute of Analytical Chemistry, Radlinskeho 9, SK-812 37 Bratislava, Slovakia

[2]University of Novi Sad, Faculty of Technical Sciences, Department of Environmental Engineering and Occupational Safety and Health, Trg Dositeja Obradovića 6, Novi Sad 21000, Serbia (e-mail: majadjogo@uns.ac.rs)

Abstract: The paper presents a comprehensive project overview aimed at harmonizing environmental, occupational health and safety (OHS), and labour relations regulations with European excellence. The project, titled "ENROL" (Erasmus Module on European Studies in Challenges and Opportunities for implementation of regulations on environment, occupational health and safety, and labour relations), addresses the pressing need to bridge the gap between the academic curriculum of Serbian universities, the demands of the labour market, and the EU objectives. Motivated by the EU's Strategy Europe 2020, which encourages innovation in the education system, the project is designed to develop a summer school comprising three modules: Environmental Protection, Occupational Safety and Health, and Labor Relations. These modules will equip students, professionals, and policymakers with in-depth knowledge of EU regulations and best practices in these critical areas. Collaboration and dialogue with government agencies, industry representatives, labour unions, and civil society are integral to the project's success and are planned to be achieved through round tables which will be organised during the project's lifetime. The ENROL project embodies a multidisciplinary approach, bringing together a consortium of seven educators dedicated to harmonizing environmental, occupational health and safety (OHS), and labour relations regulations with European excellence. This consortium comprises six experts from the Faculty of Technical Sciences (FTS) and one from the Faculty of Medicine (MF). Within the FTS team, a diverse and collaborative group of professors and researchers hailing from three distinct departments—Environmental Engineering and Occupational Safety and Health, Civil Engineering and Geodesy, and Computing and Control Engineering collaborates seamlessly. This multidisciplinary composition leverages a wealth of knowledge, skills, and extensive experience, creating a dynamic synergy that addresses EU subjects and issues concerning environmental protection and OHS comprehensively.

Keywords: *EU regulation; environmental protection; occupational safety and health; european excellence.*

INTRODUCTION

In recent years, the global landscape has witnessed a heightened emphasis on environmental sustainability, occupational health and safety (OHS), and labour relations. These paramount concerns are integral components of Europe's ambitious agenda for growth and prosperity. The European Union (EU) has embarked on a journey to establish a comprehensive regulatory framework that champions environmental protection, safeguards the well-being of workers, and fosters harmonious labour relations (European Union, 2020). As part of this endeavour, the EU

has initiated a series of measures, directives, and policies aimed at setting the gold standard for these crucial domains (European Commission, 2021).

The Republic of Serbia, a nation aspiring to EU membership, recognizes the pivotal role of aligning its own regulations and practices with European standards (European Integration Office of the Government of the Republic of Serbia, 2020). To facilitate this harmonization process and equip its academic, professional, and policymaking communities with the necessary knowledge and competencies, the ENROL project emerges as a pioneering initiative. ENROL, short for "Harmonizing Environmental, Occupational Health and Safety, and Labor Relations Regulations with European Excellence," is a comprehensive project that endeavours to bridge the knowledge gap and address the absence of Euro-integrative subjects in the academic curriculum of Serbian universities. The importance of initiatives like ENROL cannot be overstated. They serve as vital conduits for achieving several critical objectives, each intertwined with the broader context of European integration and sustainable development.

The EU's commitment to environmental sustainability, OHS, and fair labour practices is enshrined in its fundamental values. As Serbia seeks closer ties with the EU, it is imperative that the nation aligns its own values and regulations with those of its European counterparts. Initiatives like ENROL play a pivotal role in ensuring that Serbia can effectively integrate into the European community and uphold shared principles (European Commission, 2021).

In today's globalized world, competitiveness hinges on a skilled and knowledgeable workforce. ENROL Summer schools offer participants a unique opportunity to enhance their understanding of EU regulations and best practices. This knowledge not only bolsters their employability but also equips them to contribute meaningfully to the European region's growth and development.

ENROL's emphasis on innovative and context-based learning reflects the evolving landscape of education in the 21st century. It introduces academic staff and students to cutting-edge ideas and pedagogical approaches that prepare them to thrive in a rapidly changing world.

The round table discussions and stakeholder engagement facilitated by ENROL promote meaningful dialogue between academia, industry, and policymakers. Such interactions are instrumental in shaping informed, effective, and collaborative strategies for the future (European Commission, 2021).

SWOT ANALYSIS FOR THE IMPLEMENTATION OF THE ENROL

The ENROL project demonstrates significant strengths, primarily stemming from its alignment with the strategic objectives of the European Union (EU). By closely adhering to the EU's priorities in environmental sustainability, occupational health and safety, and labor relations, ENROL positions itself as a catalyst for Serbia's integration into the EU. This alignment underscores the project's relevance and importance in the context of Serbia's European aspirations. Furthermore, ENROL adopts a comprehensive approach to address the existing knowledge gaps and curriculum deficiencies within Serbian universities. This holistic approach spans multiple critical domains, creating a well-rounded educational foundation in key areas. Additionally, the project places a strong emphasis on innovative and context-based learning methods, equipping participants with skills highly relevant to the demands of the 21st-century workforce. Moreover, ENROL actively engages stakeholders, facilitating meaningful dialogues between academia, industry, and

policymakers. This commitment to stakeholder engagement ensures that the project remains attuned to the real-world needs and challenges of the relevant sectors.

While ENROL boasts several strengths, it is not without its challenges. One notable weakness lies in its resource intensity. Implementing a comprehensive project like ENROL demands significant financial and human resources. While these resources are essential for its success, their magnitude could potentially strain available budgets and personnel, posing a challenge that requires meticulous management. Additionally, traditional academic institutions may exhibit resistance to incorporating new, innovative learning methods. This resistance could potentially slow down the project's progress as it endeavors to introduce and establish modern pedagogical approaches.

ENROL is presented with several promising opportunities that can contribute significantly to its success. Serbia's ambition to join the EU represents a remarkable opportunity for the project. By aligning itself with EU standards and regulations, ENROL can play a pivotal role in facilitating the nation's integration process, ultimately strengthening Serbia's position on the European stage. Moreover, in today's globalized world, a nation's competitiveness heavily relies on the presence of a skilled and knowledgeable workforce. ENROL is well-positioned to contribute to the development of such a workforce in Serbia, thereby enhancing the country's competitiveness. Furthermore, there is a growing global awareness of the critical importance of environmental sustainability, OHS, and labor relations. ENROL can capitalize on this increasing awareness to attract participants and support, aligning itself with the global trend toward sustainable practices.

ENROL is not immune to threats that could impact its implementation. One significant threat is political instability, whether within Serbia or the EU. Such instability has the potential to disrupt the project's continuity and funding. To mitigate this threat, it is imperative to have robust contingency plans in place to address uncertainties stemming from political instability. Additionally, the presence of other initiatives or projects with similar goals may lead to competition for limited resources and potential participants. ENROL must navigate this competitive landscape carefully and differentiate itself to maximize its impact. Moreover, economic challenges, such as economic downturns or budget constraints at the national or regional level, could impose limitations on the funding available for educational initiatives like ENROL. This necessitates prudent financial planning and adaptability to ensure project sustainability in the face of economic challenges.

ENHANCING ACADEMIC CAPACITY AND FOSTERING EUROPEAN VALUES

One of the primary objectives of the ENROL Project is to bolster the academic prowess of UNS faculty members, enabling them to effectively impart knowledge on EU-related topics. Through the development of specialized modules and courses for the ENROL Summer School, faculty members are empowered with the expertise required to deliver high-quality education on EU matters. This initiative not only enriches the academic landscape at UNS but also enhances the educational experiences of students, positioning them to comprehend the intricacies of European integration more comprehensively.

ENROL operates in alignment with core European values and principles, thus contributing to the promotion of the European way of life. By disseminating knowledge about EU regulations, policies, and principles, the project fosters a deeper understanding of European values among the

academic community and students. This alignment is of particular significance as it strengthens Serbia's commitment to EU integration and harmonization with EU standards, reflecting the shared values that underpin the EU project.

An instrumental outcome of the ENROL Project is the infusion of additional financial resources into UNS for the purpose of teaching EU subjects. The organization of the ENROL Summer School serves as a means to diversify the financial base dedicated to EU education. Consequently, this influx of resources not only enhances the university's capacity to provide EU-focused education but also raises awareness regarding the relevance and significance of EU-related subjects among students and professionals.

While ENROL is cantered at UNS, its impact extends well beyond the borders of Serbia. The project resonates with students, academic staff, professionals, and policymakers in neighbouring non-EU Member States, particularly in Western Balkan countries. Through ENROL, Serbian students, professionals, and policymakers can collaborate and engage with their international counterparts, thereby strengthening their professional networks and enriching their understanding of EU subjects.

ENROL leverages the knowledge and experience of distinguished guest speakers, including experts from EU Member States. These guest speakers contribute significantly to the promotion and elucidation of EU regulations and requirements. Their contributions, often presented through case studies and good practices, facilitate a comprehensive comprehension of EU mandates. Consequently, ENROL serves as a conduit for the dissemination of EU expertise and best practices.

ENROL's unique educational approach enhances UNS's capacity to attract high-caliber students and a broader spectrum of professionals. The project's multidisciplinary and holistic approach to EU education, combined with opportunities for cross-border collaboration, appeals to a diverse audience. In doing so, it reinforces UNS's position as a hub for EU-related expertise. Furthermore, ENROL cultivates international cooperation among its team members, resulting in strengthened professional networks. This international collaboration allows for the identification of crucial future needs related to EU issues and provides a foundation for future project proposals.

ENROL'S ALIGNMENT WITH SUSTAINABLE DEVELOPMENT GOALS

ENROL's commitment to enhancing the quality of education in Serbia aligns directly with sustainable development goal (SDGS) 4, which aims to ensure inclusive and equitable quality education and promote lifelong learning opportunities for all. By addressing knowledge gaps and curriculum deficiencies within Serbian universities, ENROL empowers participants with valuable skills and knowledge related to environmental sustainability, occupational health and safety, and labor relations.

ENROL's emphasis on labor relations and the development of a skilled workforce directly support SDG 8, which focuses on promoting sustained, inclusive, and sustainable economic growth, full and productive employment, and decent work for all. By equipping individuals with the expertise needed for a rapidly evolving job market, ENROL contributes to creating decent work opportunities and fostering economic growth in Serbia.

In alignment with SDG 9, which seeks to build resilient infrastructure, promote inclusive and sustainable industrialization, and foster innovation, ENROL embraces innovative and context-

based learning methods. These methods not only prepare participants for the demands of the 21st-century workforce but also promote innovation in education and pedagogical approaches.

ENROL's focus on environmental sustainability directly corresponds to SDG 12, which calls for responsible consumption and production patterns. By educating individuals about environmental protection and sustainability practices, the project contributes to reducing resource consumption and promoting more sustainable production processes, aligning with

Lastly, ENROL embodies the spirit of SDG 17, which underscores the importance of global partnerships for sustainable development. The project facilitates meaningful dialogues and collaboration between academia, industry, and policymakers, creating a platform for stakeholders to collectively address the challenges related to environmental sustainability, OHS, and labor relations. This collaborative approach aligns with SDG 17's call for partnerships to achieve the SDGs.

CONCLUSION

The ENROL project's strengths lie in its alignment with EU objectives, comprehensive approach, innovative learning methods, and stakeholder engagement. However, it faces challenges in terms of resource intensity and potential resistance to change. Nevertheless, it can leverage opportunities related to EU integration, the need for a skilled workforce, and growing awareness of its focus areas. To mitigate threats, it must remain adaptable in the face of political instability, competition, and economic challenges. Overall, ENROL holds great potential for contributing to Serbia's European integration and sustainable development.

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THE IMPACT OF WORK ENVIRONMENT FACTORS ON BURNOUT AT WORK

Stojilković P.[1], *Malenović-Nikolić J.*[2]

[1]Institut VIP centar d.o.o, Obrena Kovacevica 21, Leskovac 16000, Serbia (e-mail: vip.agencija@yahoo.com)

[2]University of Nis, Faculty of Occupational Safety, Carnojevića 10a, Nis 18000, Serbia

Abstract: The paper examines the impact of work environment factors on burnout at work among medical nurses employed in high-risk workplaces. Additionally, it investigates the influence of personal characteristics in reducing this impact. The findings show that job workload has the greatest impact on burnout at work, while work experience has the greatest influence in mitigating this impact. The results indicate that it is necessary to redefine the scope and requirements of the job for medical nurses employed in high-risk workplaces. Additionally, when assigning them to specific positions, work experience should be taken into consideration.

Keywords: *burnout at work; work environment factors; personal characteristics; nurses; healthcare institutions.*

INTRODUCTION

It is a well-known fact that satisfied employees are usually motivated employees who perform well in their jobs and demonstrate a strong psychological connection to the organization (Stander & Rothmann, 2010). Numerous authors have shown that high levels of job satisfaction correlate with a positive attitude towards the job and a willingness to fully engage in achieving organizational goals, while low levels indicate employee dissatisfaction with their job (Evans et al., 2011; Stauffer et al., 2016), which increases the likelihood of suboptimal performance at work. Furthermore, employees with a strong sense of satisfaction display high levels of loyalty and commitment to the organization (Stefanovic et al., 2019; Kwon & Kim, 2013), which, in the context of achieving organizational objectives, means they exhibit behavior that supports improved business efficiency. Hence, job satisfaction, organizational commitment, and motivation can be considered significant factors in business efficiency. A large body of research indicates that factors within the work environment play a crucial role in motivating and providing satisfaction to employees. However, empirical studies also point out that work environment factors can negatively impact employees' well-being. Analyzing empirical research published in scientific journals from 1993 until now reveals that all work environment factors can be grouped into two main categories: physical characteristics of the work environment and workplace design, and these factors significantly influence the physical, mental, and social well-being of employees. Specifically, these work environment factors affect employees' musculoskeletal system, burnout at work, stress levels, as well as their social life and perception of support received from the organization. Additionally, occupational illnesses and injuries place a significant financial burden on organizations (Clements-Croome, 2018; Vasovic et al., 2018). For this reason, studying their impact and the ability to predict their occurrence becomes essential for preventive action. One common form of occupational illness is job burnout, particularly prevalent among employees in healthcare institutions. Ivanovic et al. (2020) identified job burnout as the leading cause of job dissatisfaction among employees in the Republic of Serbia.

Therefore, the aim of this paper is to examine the impact of work environment factors on burnout among employees in healthcare institutions in the Republic of Serbia.

THEORETICAL FOUNDATIONS OF THE RESEARCH

Starting from the model presented by Christen et al. (2006), which establishes a direct two-way causal relationship between employees' efficiency in performing work tasks and job satisfaction, there is a need to predict the risk of negative influences of work environment factors on employees' health. The question arises as to which work environment factors have a dominant impact on employees' mental health and consequently, their performance. This question becomes particularly relevant in professions with high levels of emotional and physical stress, as is the case in healthcare and medicine. It is well-known that healthcare workers are exposed to significant levels of stress, putting them at high risk of burnout (Ladstätter et al., 2010), which is a specific form of occupational stress resulting from psychologically and emotionally demanding relationships between healthcare workers and their patients (Elfering et al., 2006). Burnout is manifested through one or more dimensions: exhaustion, depersonalization, and a reduced sense of personal accomplishment at work (a belief that one is no longer capable of effectively performing their job). According to the theoretical foundations of the concept of high-performance work systems (HPWS), job characteristics and physical work conditions, i.e., the opportunities that an organization provides to its employees to express their maximum work potential, represent a key determinant in achieving extraordinary performance among employees in the workplace. In this context, job characteristics (the complexity and significance of work tasks, the degree of autonomy and independence in work and decision-making) and work conditions (opportunities for advancement, income security, physical characteristics of the work environment, possession of protective equipment, etc.) are treated as a certain form of reward that the organization delivers to its employees as recognition of their efforts in achieving organizational goals. By offering such benefits, the organization influences employees to feel obliged to engage more and be more committed to the company's objectives. In other words, by providing them with a well-designed work environment and favorable work conditions, the organization influences increased organizational commitment and job satisfaction among employees. However, specific work conditions in healthcare, particularly in high-risk work settings, have an impact on employees' perceptions and feelings. The pressure of exposure to heightened health risks and the occurrence of occupational illnesses due to radiation exposure undoubtedly constitute additional factors that contribute to employee stress. The specifics of the job lead to the consideration of work design and conditions through dimensions such as job demands, conflict resolution, empathy, and a clear understanding of work tasks and obligations (Ladstätter et al., 2010). It is well-known that personal characteristics, such as resilience (Kobasa, 1979; Kobasa-Ouellette & di Placido, 2001; Maddi et al., 2006), contribute to reducing burnout at work. However, what remains unknown is the extent to which socio-economic and cultural specificities of employees impact the exacerbation or reduction of the risk of burnout in healthcare workers. Research (Danzen, 2019; Bodescu et al., 2022) related to the impact of employee satisfaction on work performance suggests that a low standard of living, low average wages, and fear of job loss influence presenteeism among employees, i.e., the readiness to work even when not feeling well, which has been identified as a significant cause of job dissatisfaction (Lohaus & Habermann, 2019).

Studies by Radivojevic et al. (2023) have shown that these factors influence employees to value reward and compensation systems over other work conditions, such as opportunities for

advancement, fair and equitable treatment for all, etc. Additionally, numerous studies indicate that factors such as gender (Milijić et al., 2014; Čábelková et al., 2015), position within the organization (Milijić et al., 2014), educational level (Kavalic et al., 2020), and social status (Danzer, 2020) influence employees' attitudes and motives, but there is no knowledge of how these characteristics impact resilience as a personality trait that affects the reduction of burnout at work. Considering the aforementioned, there is an imperative need to seek answers to the posed questions. As healthcare workers have been exposed to significant physical and mental burdens in recent years, investigating the issue of burnout among medical workers becomes a priority, especially in those workplaces that face higher risks, such as positions in the field of radiology, where medical staff are under additional pressure due to exposure to higher levels of radiation. Hence, the focus of this paper is on studying the factors of burnout among healthcare workers in workplaces exposed to higher levels of risk.

Variables and Research Methodology

The research was conducted on a sample of 137 medical workers employed in 16 healthcare institutions in the territory of Central Serbia. The sample size was determined by considering the population size, the desired level of confidence, and the allowable sampling error. Employees filled out the questionnaire during the year 2023. All questionnaires are validly completed. The total sample included 137 nurses who were employed in high-risk workplaces. The research included employees with more than 10 years of work experience. The data were collected based on a structured questionnaire, which was compiled based on relevant statements proposed in the scientific literature. More precisely, The Nursing Burnout Scale (Moreno-Jimenez et al., 2000; Garrosa et al., 2008) was used to evaluate the process of burnout. This measure includes specific job stressors in nursing as antecedents and also hardy personality. The NBS for this research contains 78 items. The burnout block has 24 items and is consistent with the classical dimensions in human services—emotional exhaustion, depersonalization, and personal accomplishment—proposed by Maslach and Jackson (1986). The dimension of personal accomplishment was substituted in the NBS by its opposite, lack of personal accomplishment, to facilitate the interpretation of profiles and the computation of an overall burnout index for each nurse, established from the mean of all three dimensions. The validity of the questionnaire was tested by applying principal component analysis (PCA) since a high Cronbach's alpha value does not indicate a high reliability as it can simply be the result of a large number of items included in the analysis. The respondents assessed the statements from the questionnaire using the five-point Likert scale, with ratings from (1), "completely disagree", to (5), "completely agree". The adequacy of the sample is tested using the Kaiser-Meier-Okin sample adequacy test (test value = 0.821). Also, Bartlett's test of sphericity ($\chi 2(3003) = 4181.3$) was conducted. Since the application of the Likert scale leads to difficulties in the application of PCA, in order to alleviate the limitations of PCA analysis in the design and validation of the questionnaire, an assumption is made with interval data (Cavic et al., 2023). Namely, the data from the questionnaire are ordinal, so it is difficult to determine whether they are normally distributed or not. On the other hand, in order to generalize the results of PCA, strict compliance with these assumptions is required. Otherwise, acceptance of this assumption is common practice when working with ordinal data. The results of the questionnaire validity test are not presented in the paper due to its length, with the note that an oblique Promax rotation was used. The results of the PCA analysis indicate that the questions are grouped according to expectations, respectively, so that the questionnaire can be confidently used in further analysis. The collected data were processed using the statistical package for social sciences (Gretl) and the statistical software AMOS for modeling structural

equations (SEM). Two hypotheses were defined based on the theoretical foundations and tested: *H1: Work environment factors workload, conflict resolution, empathy, and a clear understanding of work tasks and obligations have a significant impact on the burnout at work for healthcare workers in high-risk areas; H2: Personal characteristics of employees play a significant role in reducing burnout at work for healthcare workers in places with increased risk.*

Analysis and discussion of the obtained results

Before the AMOS model parameters were assessed, a correlation analysis of the indicators was conducted. The first condition for the valid application of factor and structural analysis is that indicators are highly correlated and mutually replaceable. Table 1 shows the correlation matrix of indicators (variables that are measured in the model), the average variance extracted (AVE), Cronbach's alpha for estimating the reliability of the multi-item sections, and the goodness-of-fit indices for the SEM model.

Table 1. Correlation Matrix (squared correlation), AVE (average variance extracted), reliability, and the goodness-of-fit indices

	WL	CI	Em	RA	WE	JS	HP	EX	De	LPA
WL	1									
CI	0.501	1								
Em	0.521	0.561	1							
RA	0.611	0.501	0.503	1						
WE	0.562	0.403	0.502	0.511	1					
JS	0.529	0.539	0.592	0.487	0.509	1				
HP	0.514	0.344	0.453	0.493	0.494	0.452	1			
EX	0.499	0.458	0.514	0.432	0.479	0.541	0.503	1		
De	0.468	0.522	0.529	0.521	0.506	0.476	0.477	0.512	1	
LPA	0.505	0.553	0.585	0.619	1	0.513	0.449	0.561	0.459	1
AVE	0.65	0.61	0.631	0.667	0.688	0.664	0.629	0.634	0.631	0.628
Reliability	0.771	0.701	0.751	0.901	0.842	0.772	0.777	0.729	0.742	0.767
RMSEA (root mean square error of approximation)					0.044					
RMSR (root mean square residual)					0.052					

All correlations are significant at p<.05. WL – Workload, CI – Conflictive interaction, Em – Empathy, RA – Role ambiguity, WE – Work experience, JS – Job status, HP – Hardly personality, EX – Emotional exhaustion, De – Depersonalization, LPA – Lack a personal accomplishment

The correlation matrix analysis indicates that the variables are highly correlated with each other. The AVE for each construct was greater than the square of the correlation coefficient for the corresponding inter-constructs, which confirms discriminant validity, while the results of convergent validity of measures also contribute to convergent validity. Values of Cronbach's alpha

in all cases are above 0.7, indicating an acceptable level of reliability for each construct. Additionally, construct reliability was further supported by the fact that all AVEs exceeded .50. According to the goodness-of-fit indices, the proposed structural model was found to fit the data well. The results presented in Tables 2 and 3 indicate that the stated hypotheses can be accepted as confirmed, as all regression coefficients are statistically significant at a confidence level of 0.05.

Table 2. The regression coefficients

	WL	CI	Em	RA	Impact on Emotional exhaustion
Regres.	0.233	0.102	-0.058	0.392	
P-value	0.001	0.003	0.002	0.001	
	WL	CI	Em	RA	Impact on Depersonalization
Regres. coef.	0.101	0.011	-0.028	0.023	
P-value	0.011	0.013	0.031	0.001	
	WL	CI	Em	RA	Impact on Lack of Personal Accomplishment
Regres. coef.	0.318	0.082	-0.017	0.281	
P-value	0	0	0.02	0.01	

More precisely, Table 2 shows regression coefficients that describe the influence of work environment factors on each of the three dimensions of burnout at work. As each work environment factor significantly impacts each dimension, it can be concluded that hypothesis H1 is supported. The results in Table 2 demonstrate that the greatest influence on job burnout is work overload, which significantly affects all three dimensions of job burnout. This finding indicates the necessity to reduce the workload of healthcare workers. Following work overload is role ambiguity, then conflictive interaction. This points to the importance of clearly defining what is expected of employees. Often, nurses do not understand what is required of them in the workplace, particularly in certain circumstances. Since empathy is measured through questions that refer to experiences with the suffering of others and encountering death cases, it is not unexpected that the regression coefficient for this factor has a negative sign, which indicates that such experiences help alleviate burnout on the job.

Table 3. The regression coefficients for personal characteristics

	WE	JS	HP	Impact on Emotional exhaustion
Regres.	- 0.301	-0.022	- 0.298	
P-value	0	0.003	0.023	
	WE	JS	HP	Impact on Depersonalization
Regres. coef.	- 0.101	-0.011	-0.028	
P-value	0.01	0	0.016	
	WE	JS	HP	Impact on Lack of Personal Accomplishment
Regres. coef.	- 0.021	-0.038	-0.073	
P-value	0.017	0.028	0.043	

The Sobel test was used to test the indirect effect, and the coefficient of the indirect effect is 0.701 ($Z = 6.882$, $SE = 0.102$, $p < 0.05$), indicating that personal characteristics influence the reduction of burnout on the job. More precisely, the results in Table 3 show that work experience and a hardy personality have an impact on reducing burnout at work. Work experience turned out

to be the most important factor, as it has the greatest influence on all three dimensions of job burnout. Also, job status has a negative influence on all three dimensions. The obtained results indicate that in high-risk workplaces, nurses should be selected based on their work experience. Additionally, when hiring, personal characteristics, such as a hardy personality, should also be taken into account.

CONCLUSION

The paper examines the impact of work environment factors on burnout at work, as well as the influence of personal characteristics in mitigating this impact. More precisely, the focus of the study was on the effects of workload, conflictive interaction, empathy, and role ambiguity on three dimensions of burnout at work: emotional exhaustion, depersonalization, and lack of personal accomplishment. Additionally, the study investigated the significance of personal characteristics in reducing this impact. The research was conducted on a sample of medical nurses working in healthcare institutions in Central Serbia, specifically in high-risk workplaces. The study was carried out during the year 2023. The research results indicate that workload is the main driver of burnout at work. This suggests the necessity of redefining the scope of work. Additionally, role ambiguity has a significant impact, implying the need to redefine job tasks more precisely through various measures, such as job descriptions and similar documents, like job classification systems. Empathy has a negative impact. When accepting this finding, it should be borne in mind that it was measured through experiences with death cases and encounters with the suffering of others. The findings indicate that personal characteristics significantly influence the reduction of the impact of work environment factors on burnout at work. The key characteristics are work experience, as well as a hardy personality.

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QUALITATIVE ANALYSIS OF WASTE MATERIALS FROM THE TECHNOLOGICAL PROCESS OF CHROMING IN THE FUNCTION OF STABILIZING TOXIC METALS

Stojković A.[1], *Stanisavljević M.* [2], *Krstić N.* [3], *Đorđević D.* [3], *Krstić I.*[1]

[1]University of Niš, Faculty of Occupational Safety, Čarnojevića 10a, Niš, Serbia (e-mail: ana.stojkovic@znrfak.ni.ac.rs)
[2]The Academy of Applied Technical Studies, Department Applied Engineering Sciences, Dunavska 5, Požarevac, Serbia
[3]University of Niš, Faculty of Sciences and Mathematics, Višegradska 33, Niš, Serbia

Abstract: The galvanic sludge produced in the technological process of chrome plating, in accordance with international and national legislation, is declared as hazardous waste due to the high concentration of toxic metal ions. A physical-chemical characterization and qualitative analysis of galvanic sludge was performed in this paper. The analysis was done according to the legislation of the Republic of Serbia, which confirmed increased concentrations of toxic metals Ni^{2+}, $Cd^{2+,}$ and Cu^{2+}.

Keywords: *galvanic sludge; toxic metals; qualitative analysis*.

INTRODUCTION

The technological process of chrome plating, one of the most common in the metalworking industry, results in the creation of waste in the form of sludge containing high concentrations of Cr^{6+}, Ni^{2+}, Zn^{2+}, Cu^{2+} (Aziz et al., 2008; Wang et al., 2018; Kul et al., 2015). In the research of Ozdemir et al. (2012), an assessment of the ecological risk of galvanic sludge was carried out using rainwater as a solvent, where galvanic sludge was classified as a pollutant in real conditions. Szakov et al. (2016) point out that galvanic sludge plays a significant role in soil contamination due to the mobility of toxic metal ions, which makes the remediation process ineffective.

The concentration of toxic metals in galvanic sludge is determined by the volume of production, process characteristics, as well as the concentration in electrolytes and washing waters. In order to inactivate toxic metal ions, it is first necessary to carry out a qualitative analysis of the galvanic sludge. In previous research, different extraction solutions were used for the characterization of galvanic sludge and the extraction of metals. The most common extraction liquids are: sulfuric (Silva et al., 2005), organophosphoric (Kongolo et al., 2003), nitric, hydrochloric, and hypochlorous acid (Vuković et al., 2019).

In this paper, the physical-chemical analysis of galvanic sludge was performed by extraction with hydrochloric acid. FTIR and ICP-OES techniques were used in the experimental part. FTIR analysis indicates the presence of characteristic functional groups, while ICP-OES analysis determines the qualitative and quantitative composition of the sample.

MATERIALS AND METHODS

Chemical preparation of the galvanic sludge sample was performed by dissolving it with hydrochloric acid. Dissolution by hydrochloric acid was initiated by weighing the dried sample. Sludge weighing 1 g was treated with 25 ml of 6 M HCl. It was then heated and mixed for 8 hours

with a magnetic stirrer at a temperature of up to 100 °C. Then, the samples were centrifuged in 3 phases. The first stage lasted 3 minutes at 2000 revolutions, the second 5 minutes at 3000 revolutions, and the third 5 minutes at 3500 thousand revolutions. Then the solution was filtered because decanting was not successful. After filtering, the undissolved residue of the tested galvanic sludge samples was dried to a constant mass, i.e. 0.0455 g, which means that the sample's level of desiccation is about 95% (Stojković et al., 2023). Figure 1 shows the reference galvanic sludge from the chrome plating process.

Figure 1. Reference galvanic sludge

The determination of the concentration of toxic metals in the waste galvanic sludge was carried out by the method of Inductively Coupled Plasma - Optical Emission Spectrometry (ICP-OES) on the ICP-optical emission spectrometer iCAP 6000 Thermo scientific. FT-IR spectra were recorded on a BOMEM Michelson Hartman & Braun Series MB in the area 4000-400 cm^{-1} at a resolution of 2 cm^{-1}. The preparation of samples for recording was done by the "potassium bromide" method.

RESULTS AND DISCUSSION

The FT-IR spectrum of the reference galvanic sludge from the chroming technological process is shown in Figure 2.

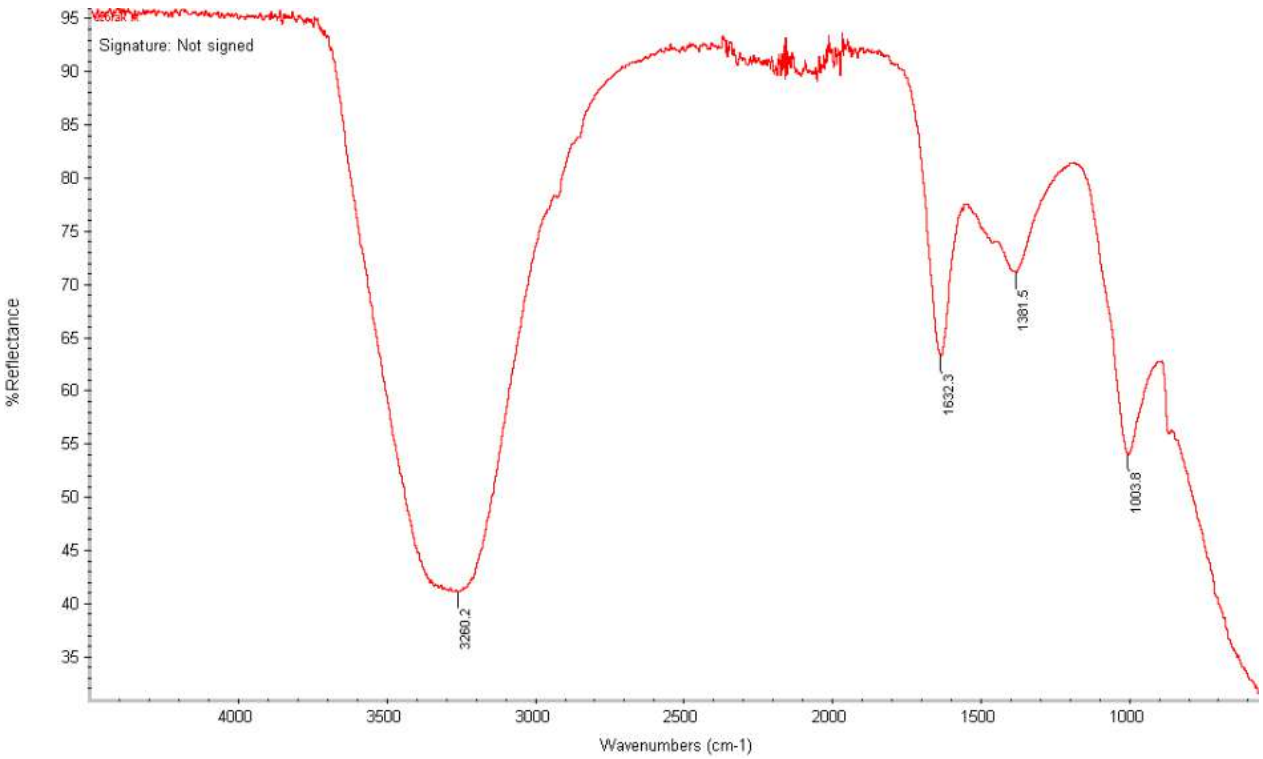

Figure 2. FT-IR spectrum of reference galvanic sludge

In the FT-IR spectrum of the galvanic sludge, shown in Figure 2, a broad band at 3200 to 3600 cm^{-1} is observed, indicating the presence of water. A peak at 1632 cm^{-1} is also observed, indicating the presence of an OH group, which is consistent with the elemental composition of the reference sample (Święch et al., 2018). In this sample, a broad band at about 1000 cm^{-1} confirms the presence of an oxide, that is, a M=O group (Margenot et al., 2017).

The graphic in Figure 3 shows the concentrations of the elements detected in the galvanic sludge, obtained by the ICP-OES method with prior dissolution in HCl.

The obtained values were compared with the maximum allowed concentrations (abbreviated: MAC) defined by the Rulebook on categories, testing, and classification of waste („Official Gazette RS“, no. 56/2010, 93/2019, and 39/2021). Based on MAC, limit values of concentrations of hazardous components in waste were determined, according to which waste characterization is carried out.

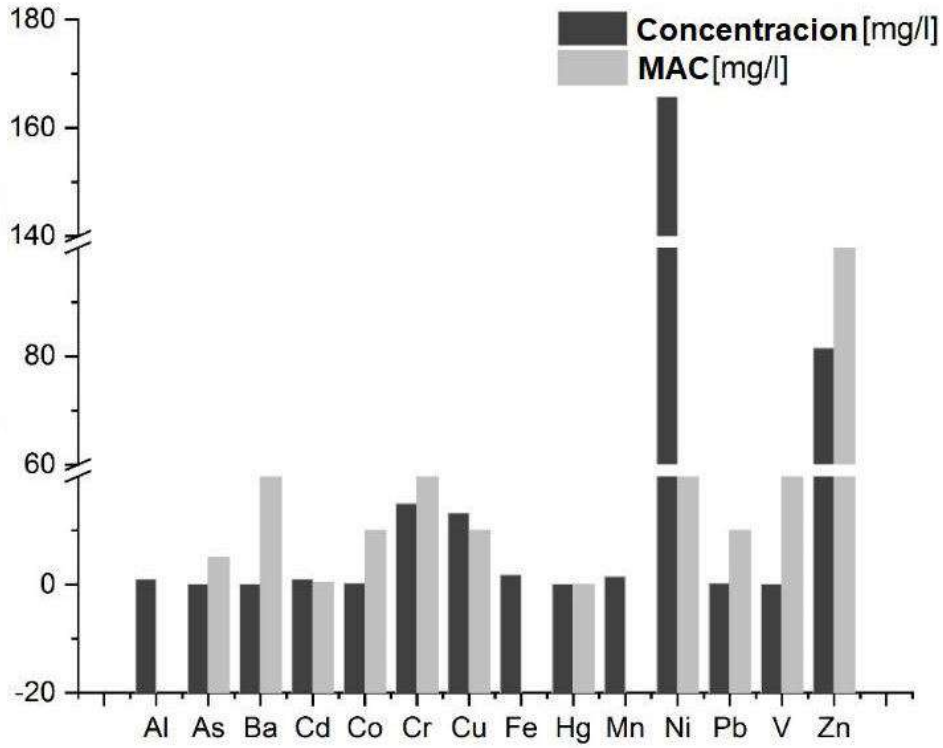

Figure 3. Metal concentration in galvanic sludge (±5%)

The concentrations of cadmium (1.0 mg/l), copper (13.2 mg/l), and nickel (165.8 mg/l) in the treated sample are higher than the permitted values, which declares this sample of galvanic sludge as hazardous waste according to the national legal regulations.

CONCLUSION

Testing of galvanic sludge by dissolution with hydrochloric acid proved to be extremely effective considering the high degree of dissolution of the sample. On the other hand, high concentrations of toxic metals Cd^{2+}, $Cu^{2+,}$ and Ni^{2+}, which are above the maximum allowed according to national legislation, were also confirmed by physical-chemical characterization. Based on the qualitative analysis, the hypothesis that galvanic sludge represents a dangerous waste was confirmed, so future research will be based on their inactivation by stabilization into a useful eco-sintered product.

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ASSESSMENT OF PROFESSIONAL RISK FOR RAMP-TRANSPORT WORKER

Strugar A.[1], Krstić D.[2], Stanisavljević M.[3]

[1]Institute for Development and Research in the Field of Occupational Safety, Džordža Vašingtona, Podgorica, Montenegro (e-mail: andja.strugar@iti.co.me)

[2]University of Niš, Faculty of Occupational Safety, Čarnojevića 10a, Niš, Serbia

[3]The Academy of Applied Technical Studies, Department - Applied Engineering Sciences, Dunavska 5, Požarevac, Serbia

Abstract: The paper presents the assessment of occupational risk for ramp-transport workers performing their work activities in the company "Port of Adria" in Bar. The method used for risk assessment is a modified version of the AUVA (*Allgemeine Unfall versicherungs anstalt* - Austrian Pulp and Paper Industry Association method) and BG (*Die gewerblichen Berufs genossenschaften* - German Professional Associations method) methodologies. Based on this methodology, it was determined that the analyzed workplace has an elevated risk.

Keywords: *ramp-transport worker; assessment of professional risk*.

INTRODUCTION

The goal of the occupational risk assessment is to identify critical locations and procedures, as well as conditions and processes in which there might be a compromise to the safety and health of workers in the workplace and its surroundings. This aims to take appropriate measures to eliminate or reduce them to an acceptable level (Krstić, 2011). Risk assessment is conducted based on available information, observations of the current state, experience, and intuition (Elms, 1992). The risk assessment process is necessary for three reasons: moral principle - it is inherent in human nature to act preventively and prevent potential undesirable events, legal obligation - legal regulations mandate the mandatory implementation of risk assessment, good management - minimizing the number of undesirable events results in increased productivity and a better work atmosphere (Đapan, 2014). An organization should recognize all sources of risk, their areas of operation, events resulting from them, as well as their causes and potential consequences. This is a critical step because risks that are not identified in this phase will not be included in further analysis (SRPS ISO 31000:2019). Risk assessment is carried out for each recognized hazard or harm, by comparing it to permissible values in relevant safety and health at work regulations, technical regulations, standards, and recommendations (Krstić, 2013). If, after applying workplace protection measures, the workplace still poses a risk, then, by issuing a Risk Assessment Act, that specific place is designated as a high-risk workplace. Risk assessors must provide justification for this categorization, explaining the reasons for designating it as a high-risk workplace (Jocić, 2008).

In accordance with that, an assessment of occupational risk was conducted for the position of a ramp transport worker (Figure 1). Ramp transport tasks are carried out in the Operations Sector and encompass the following activities:

- Loading, unloading, and transshipment of general cargo;

- Weighing, measuring, sorting, sampling, marking, packaging refurbishment, and other forms of enhancing goods in foreign trade activities;
- Preparing the workplace for various handling operations;
- Preparing containers for loading/unloading manipulations and similar tasks;
- Preparing ships for work or navigation by opening or closing ship holds, removing and stacking wooden flooring, installing protective nets, and other tasks;
- Cleaning and washing ship holds, as well as the workplace before and after cargo handling;
- Responsible for any damage to the ship, goods, and storage caused by careless, unskilled, or negligent work;
- Properly handling equipment and arranging cargo;
- Required to visually inspect the tools upon receipt. If faulty, they are obligated to return them;
- Performs repairs on cargo packaging as needed and as instructed, secures cargo on the ship and land transportation vehicles, etc.

Figure 1. Ramp-transport worker

All tasks are carried out outdoors in areas known as GATs (General Cargo and Container Terminals), including container terminals and general cargo terminals. Cargo handling during loading and unloading onto ships is performed using vertical mechanization (crane lifting systems) and horizontal mechanization (trucks, tractors, and forklifts).

The average equipment lifespan for work has not been determined. Employees receive their work assignments in the form of work orders.

METHOD OF RISK ASSESSMENT

The elements for assessing and evaluating risk according to the AUVA/BG method are the probability of the occurrence of hazards or harm and the severity of possible consequences. Accordingly, in (1) the risk level (NR) is defined as the product of the probability rank of an undesirable event (RV) and the rank of possible injury severity (RP):

$$NR=RV\times RP \quad (1)$$

The probability of hazards or harm occurring depends on the employee's exposure to hazards and harm, as well as the condition of the working environment (the existing state of occupational health and safety). The rank of the probability of hazards and/or harm occurring is determined as the product of the rank of exposure and the rank of the working environment's condition. The rank of severity of possible consequences is categorized from a very minor injury, minor injury, moderate-severe injury, severe injury, to fatal injury. The risk rank is determined for each identified or potential hazard and/or harm in the workplace and its environment.

When establishing data about hazards and harm in the workplace and its environment, hazards and harm were grouped according to the Regulation on the Method and Procedure of Risk Assessment in the Workplace. The workplace's risk rank is determined by the highest risk rank from individual hazards or harm. Workplaces with risk ranks I and II are considered to have an acceptable risk. Workplaces with elevated risk are those with risk ranks III, IV, and V.

Based on the assessed risks in the workplace and its environment, methods and measures for their elimination, reduction, or prevention are determined, as well as specific health requirements that employees must follow in workplaces with increased risk, as well as employees handling specific work equipment.

IDENTIFICATION OF HAZARDS AND RISK ASSESSMENT

Mechanical hazards that arise from the use of work equipment include:

- Insufficient safety due to moving parts (work activities involving the movement of hooks and hanging accessories);
- Unprotected moving parts of the crane (shaft sleeves, electric motors, rigid couplings, ropes, sprockets, gears, levers, etc.) constantly pose a risk of catching the clothing or body parts of the worker;
- Unrestrained movement of parts or materials that can cause injury to employees (activities that can lead to the fall of loads from vertical mechanization due to improper or unsafe hanging of the load; activities that can cause the snapping of load securing devices, snapping of load-bearing ropes due to excessive loads; work activities that can cause the fall of materials during loading, hanging, and lifting by vertical mechanization;

- Working near internal transport vehicles (working in the maneuvering space of overhead cranes, hoists, forklifts, and other machines);
- Working with vertical mechanization equipment that can tip over can lead to the inability or restriction to timely evacuate the work area, exposure to closure, mechanical impact, collision, and similar risks;
- Mechanical sources of hazards (using port tools, securing loads with sharp edges that can cause superficial injuries to the employee's skin and subcutaneous tissue (cuts, scratches, punctures, etc.)).

Hazards related to workplace characteristics include:

- Working at heights when working on ships;
- Possibility of slipping or tripping (wet or slippery surfaces) - tasks during loading and unloading of general cargo and containers on oily and greasy floors, in the vicinity of buried objects or protruding installations, openings, hatch channels, and other objects.

Hazards arising from the use of electrical energy:

- Risk of indirect contact when working with electrical devices.

Physical harm:

- Noise occurs during the loading and unloading of general cargo and containers. Adverse climatic influences:
- Work outdoors during the loading and unloading of general cargo and containers.

Harm arising from psychophysiological efforts:

- Efforts or physical exertions - manual handling of loads during the loading and unloading of general cargo and containers;
- Prolonged physical activities involve heavy physical tasks that require appropriate physical strength and fitness from workers;
- Unphysiological body posture - prolonged standing, bending, squatting, and kneeling during tasks such as loading, unloading, and transshipment involving general cargo, weighing, measuring, sorting, sampling, marking, packaging, and more.

Harms arising from mental efforts:

- Psychological burdens - stress - mental strain caused by work conditions and the responsibility to prevent accidents, resulting from work conditions;
- Conflicting situations and others.

Harms related to work organization:

- Working beyond regular working hours (overtime work);
- Shift work;
- Night work.

Other harms:

- Working near water during the loading and unloading of general cargo and containers;
- Participation in traffic - commuting to work and during working hours, performing work activities.

Based on the conducted procedure of work organization assessment, implemented occupational health and safety measures, identification of hazards and harm in the workplace and its environment, as well as risk ranking, it has been assessed that the analyzed workplace has an increased risk (Table 1).

The increased risk has been assessed based on the following hazards and harm:

- Working at heights (08);
- Adverse climatic influences - work outdoors (27);
- Prolonged physical activities (30).

Table 1. Identification of hazards and harm in the workplace and risk ranking

Code	Hazards and/or harm	Possible consequences	RI	RO	RV	RP	NR	Risk ranking
Hazards related to workplace characteristics								
08	**Working at height** LTR tasks	Multiple fractures, polytrauma with potentially fatal outcome	2	2	2	5	10	III
Harmful climatic influences								
27	**Working outdoors** LTR tasks during the loading and unloading of general cargo and containers	Sunstroke, dehydration, cold	4	2	3	4	12	III
Harms arising from psychophysiological efforts								
30	**Prolonged physical activities** LTR tasks for forklift operators involve heavy physical tasks that require appropriate physical strength and fitness from workers	Injuries to specific body parts (tendon strains and other disorders of the musculoskeletal and connective tissue system, degenerative spondylosis, etc.)	4	2	3	4	12	III

Based on the risk assessment, the following characteristic protective measures have been defined:

- Careful manipulation when hooking and hanging loads;

- Giving an audible signal to clear employees from the maneuvering area of vertical mechanization;
- Using signs/signals for communication, in accordance with the Instruction for working with vertical mechanization;
- Using specialized tools with appropriate load-bearing capacity for grasping and securing loads on the load hook of vertical mechanization, ensuring load balance;
- Placing the load in a safe manner to ensure stability and prevent falling onto nearby individuals;
- Before transporting a load, ensure that it is securely fastened, hung, and balanced by slightly lifting it from the ground. Only after confirming that the load is securely fastened, hung, and balanced, proceed with lifting and transporting;
- Place larger items on supports and smaller objects on wooden pallets. If larger objects have designated gripping points, use auxiliary load-bearing devices that enable safe gripping;
- Exercise caution when ascending and descending while working at heights;
- Maintain climbing surfaces to equipment in a clean and tidy condition;
- Wear non-slip footwear;
- Wear personal protective equipment for working at heights;
- Use prescribed personal protective equipment for protection against climatic influences;
- Implement measures for safe and healthy lifting and carrying of loads, taking frequent short breaks during work;
- While lifting loads, maintain a straight back and lift not only with the muscles of the back but also with the legs and other body parts.

Pre-employment medical examinations are mandatory as workers must meet specific health requirements in line with the job's demands and conditions. Periodic examinations are required every 12 months. Worker health protection should be continuous and include:

- Targeted and control examinations (conclusion from Occupational Medicine) with individual assessment of work capacity;
- Continuous monitoring of employees' psychophysical abilities;
- Health-promotion work;
- Special training programs to enhance psychophysical endurance and stress tolerance (through various recreational programs, training, etc.).

CONCLUSION

Through the assessment of occupational risk using the modified AUVA/BG method, it has been determined that the job of a port transport worker carries an increased risk. Based on the identified hazards and harmful factors, protective measures at work, medical examinations, and personal protective equipment have been defined. By considering the risks, specific protective measures have been prescribed to minimize the risk to the lowest possible level. By reducing the

risk, the number of workplace injuries and the number of days an employee is absent are also reduced, leading to the psychological well-being of the employee through secure and safe task execution and the preservation of physical health.

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SRPS ISO 31000:2019 Menadžment rizikom-principi i smernice (in Serbian)

PM EXPOSURE RISK ASSESSMENT OF CONSTRUCTION WORKERS IN THE CITY OF NOVI SAD

Šunjević M.[1], Vojinović Miloradov M.[1], Tošić N.[1], Nedučin D.[1], Šunjević M.[2]

[1]Faculty of Technical Sciences, University of Novi Sad, Trg Dositeja Obradovica 6, 21000 Novi Sad, Serbia, (e-mail: msunjevic@uns.ac.rs)

[2]Faculty of Medicine, University of Novi Sad, Hajduk Veljkova 3, 21000 Novi Sad, Serbia

Abstract: The Particulate Matter emission on construction sites is a serious and unattended environmental and health problem. The emitted pollution consists of tiny particles of dust, soot, and other pollutants generated during construction activities. PM emissions not only pose health risks to construction workers but also contribute to air pollution, affecting nearby communities and the environment. The fine airborne particles, generated from activities such as excavation, demolition, and material handling, can lead to serious health issues when inhaled. Construction workers are at a heightened risk of respiratory problems, including bronchitis and asthma, due to prolonged exposure to PM pollution. Moreover, fine dust can contain hazardous materials like asbestos and silica, which can cause severe lung diseases when workers are exposed without proper protection.

The study presents a comprehensive risk assessment of construction workers' exposure to particulate matter (PM) on a selected building site in Novi Sad. The assessment focused on two specific PM size fractions: PM10 and PM2.5. The research follows the exposition of construction workers on the building site. Real-time monitoring was conducted on the selected construction site in Novi Sad. The assessment involved the calculation of Time-Weighted Average exposure levels and a comparison of these levels to relevant health guidelines and occupational exposure limits.

The assessment underscores the importance of PM size fraction differentiation in risk assessment, as PM2.5, with its smaller particle size, is associated with more significant health risks. Recommendations for mitigating PM exposure on the construction site include the implementation of dust control measures, engineering controls, and the promotion of strict occupational health and safety practices. The assessment highlights the need for ongoing monitoring, adherence to health guidelines, and proactive measures to safeguard the health and well-being of construction workers in Novi Sad and similar construction sites.

Keywords: *particulate matter; construction site; risk assessment.*

INTRODUCTION

Particulate Matter (PM) emissions arising from construction activities represent a complex and multifaceted environmental challenge with far-reaching implications. Construction sites are prolific sources of PM pollution, releasing a diverse mixture of fine particles and aerosols into the atmosphere (Azarmi and Kumar 2016a; Sinesi, Petracchini, and Allegrini 2008; Kim and Tae 2021; Holman et al. 2014). The PM pollutant emission is the result of numerous processes, including excavation, material handling, and combustion of fossil fuels in construction machinery (Sunjevic et al. 2023; 2022; Ahmed and Arocho 2019). PM emissions not only deteriorate ambient air quality but also impact the health and well-being of both construction workers and nearby communities. Furthermore, the composition of construction-related PM can encompass a wide range of chemical constituents, some of which may carry toxic properties (US EPA 2010; Kchih, Perrino, and Cherif 2015; Araújo, Costa, and de Moraes 2014). Understanding the sources,

dynamics, and composition of PM emissions on construction sites is essential for developing effective mitigation strategies and safeguarding public health, making it a subject of increasing scientific inquiry and environmental concern (Yadav et al. 2022; Hassan, Tsiouri, and Kakosimos 2015; Yang, Tae, and Kim 2021).

Particulate Matter emissions from construction activities in urban environments, such as the city of Novi Sad, represent a critical area of scientific investigation due to their significant impact on air quality, public health, and the broader ecosystem. The city of Novi Sad, as a growing urban center, has witnessed an upsurge in construction projects, which has consequently led to heightened levels of PM pollution (Statistical Office of the Republic of Serbia 2023). The emerging concern necessitates a comprehensive scientific inquiry to assess the extent and nature of PM emissions specific to Novi Sad's construction landscape. Understanding the sources, chemical composition, dispersion patterns, and potential health implications of PM emission is vital for formulating effective regulatory measures and sustainable urban development strategies.

Construction sites are notable sources of PM pollution, exposing workers to a complex mixture of fine particle matter (Sunjevic et al. 2023; 2022). Prolonged exposure to these emissions can lead to adverse health effects, including respiratory conditions such as bronchitis and exacerbation of pre-existing asthma (WHO 2016; Cohen et al. 2017; Rojas-Rueda and Morales-Zamora 2021; Li et al. 2019). Moreover, PM from construction activities can contain hazardous materials such as silica and asbestos, which pose heightened risks of severe lung diseases among workers (Azarmi and Kumar 2016b; Beelen et al. 2014; Raaschou-Nielsen et al. 2016). Scientific studies aim to elucidate the relationship between PM exposure levels, health outcomes, and the effectiveness of protective measures, providing critical insights for formulating occupational safety guidelines and interventions to mitigate the health risks faced by construction workers.

Ensuring the safety of construction workers regarding Particulate Matter (PM) exposure requires a comprehensive approach that includes the following safety measures: Respiratory Protection, Personal Protective Equipment, Training and Education, Worksite Ventilation, Hand Hygiene and Personal Cleanliness, Regular Health Monitoring, Workplace Hygiene, Control Measures, Work Scheduling and Regular Site Monitoring (HSE 2015; Azarmi et al. 2016; Xing et al. 2018). The mentioned safety measures, when effectively implemented and enforced, can significantly reduce the risk of PM exposure for construction workers, ensuring their health and well-being in demanding and potentially hazardous work environments.

The issue of inadequate safety equipment usage among construction site workers in Serbia presents a significant concern from both occupational health and regulatory compliance perspectives. The failure to use proper safety equipment, including respiratory protection, helmets, and other personal protective gear, exposes workers to heightened risks of injuries, respiratory ailments, and long-term health complications. Furthermore, this non-compliance challenges the effectiveness of existing regulatory frameworks designed to ensure safe working conditions in the construction sector. Addressing this issue necessitates comprehensive strategies encompassing increased enforcement of safety regulations, enhanced worker education and awareness, and fostering a culture of safety within the construction industry. Such measures are essential for safeguarding the health and safety of construction workers in Serbia and for achieving a more secure and sustainable construction sector.

MATERIALS AND METHODS

Site Selection

The research was conducted at a construction site situated in Novi Sad, Serbia (45°15'37.45"N 19°48'7.87"E). The selection of this site was based on its representativeness of typical construction environments in the region. The site characteristics, such as construction activities and location, were considered for their suitability for the study. The selected construction site was a typical residential building with excavation activities during the monitoring processes (Figure 1).

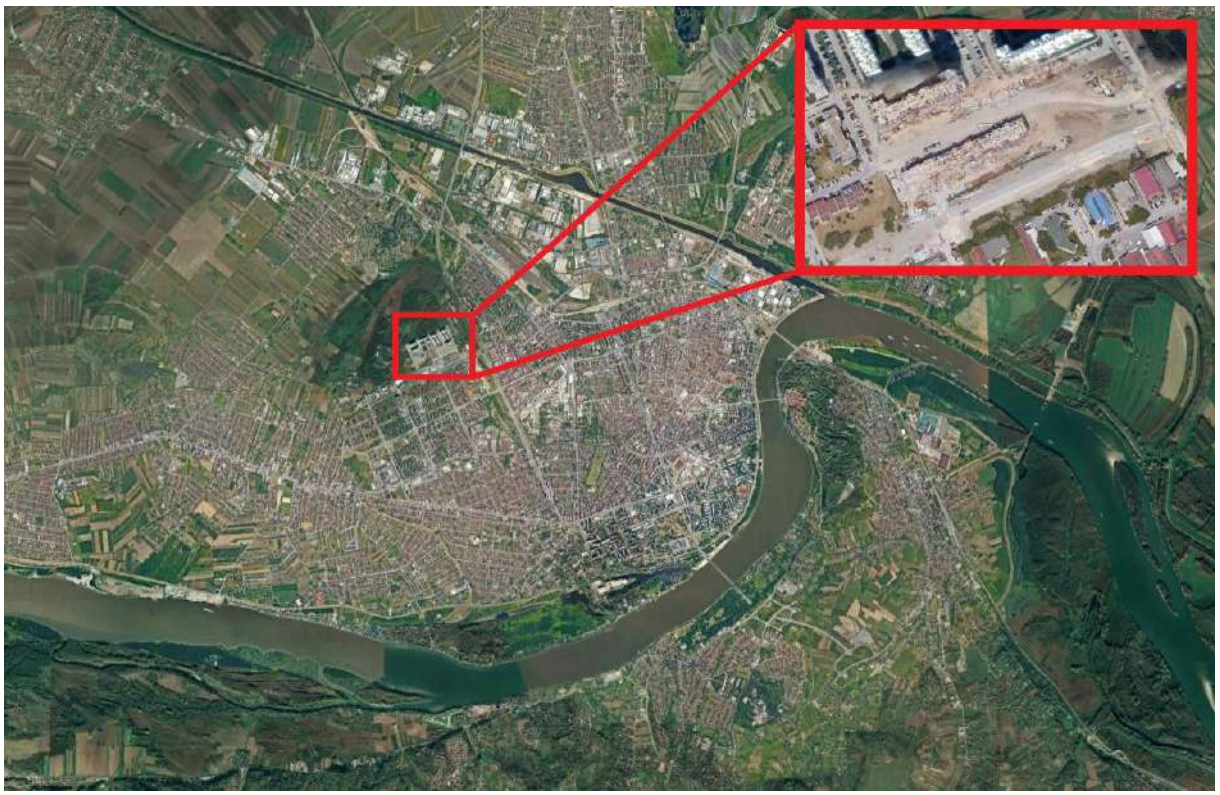

Figure 1. Selected construction site.

PM Monitoring

PM concentrations were continuously monitored during 6 work days (19-24.08.2019.) using a specially developed sensor in the project "Development of methods, sensors, and systems for monitoring of water, air and soil quality" with the AlphaSense OPC-N2 (Optical Particle Counter) as a base (Alphasense 2015). The sensor was strategically placed at locations on the construction site where worker exposure was anticipated to be significant. The OPC-N2 is a portable and precise PM monitor known for its ability to measure PM2.5 and PM10 concentrations with high accuracy and real-time data collection. The instrument provided particle count data, which was converted to mass concentrations ($\mu g/m^3$) based on particle size and density.

Worker Exposure

The exposure of a representative construction worker on the site was assessed. The worker's activities and exposure duration were closely monitored and documented. Personal exposure data were collected to ensure an accurate assessment of individual exposure levels.

Risk assessment

The Time-Weighted Average (TWA) exposure for both PM2.5 and PM10 was calculated using the formula:

$$TWA = (C1 * T1 + C2 * T2 + ... + Cn * Tn) / \text{Total Time} \quad (1)$$

Where:

- C1, C2, ..., Cn are the PM concentrations measured by the AlphaSense OPC-N2 at different locations or time intervals.
- T1, T2, ..., Tn are the corresponding time durations.
- Total Time represents the total duration of exposure during the worker's shift.

The calculated TWA exposure levels for PM2.5 and PM10 were compared to relevant occupational exposure limits (OELs) and health guidelines. Applicable guidelines were sourced from regulatory authorities or international health organizations.

RESULTS AND DISCUSSION

The obtained monitoring data is presented in Table 1. The results indicate alarmingly increased concentration values of PM on the construction sites. With Average values of 252.69 and 82.16 respectively for PM10 and PM2.5.

Table 1. Monitoring values for PM10 and PM2.5

Day	19.08.	20.08.	21.08.	22.08.	23.08.	24.08.	Average	OEL
PM10	258.16	263.74	243.90	249.55	252.41	248.36	252.69	10
PM2.5	84.68	85.11	78.29	79.40	83.86	81.65	82.16	25

PM10 Exposure Assessment

The TWA exposure assessment for PM10 indicated that the construction worker on the Novi Sad site was on average exposed to a concentration of 252.69 $\mu g/m^3$ for 10 hours. This resulted in a calculated TWA exposure of 2,526.9 $\mu g/m^3 \cdot$hours.

In order to compare the total dose of PM10 to relevant health guidelines and European standards, the indicative OEL for PM10 was calculated. The PM10 OEL is typically set at 10 mg/m^3 as an 8-hour TWA. To be able to compare, milligrams were converted to micrograms (1 mg = 1,000 µg), defining indicative OEL (EU) = 10 mg/m^3 = 10,000 $\mu g/m^3$.

The calculated TWA exposure for PM10 did not exceed the European Union's indicative Occupational Exposure Limit (OEL) of 10 mg/m^3 as an 8-hour time-weighted average (10,000 $\mu g/m^3$). This suggests that, from a regulatory perspective, the worker's exposure to PM10 on the construction site is within acceptable limits.

However, it is essential to acknowledge that while the regulatory limit was not exceeded, PM10 exposure can still have health implications, especially with prolonged exposure. Workers exposed

to high levels of PM10 may experience respiratory irritations, reduced lung function, and other health effects over time. Therefore, even when regulatory limits are met, it is crucial to implement measures to minimize PM levels and protect worker health.

PM2.5 Exposure Assessment

The TWA exposure assessment for PM2.5 revealed that the worker was exposed to a concentration of 82.16 μg/m³ for 10 hours, resulting in a calculated TWA exposure of 821.6 μg/m³·hours.

In contrast to the PM10 assessment, the TWA exposure for PM2.5 exceeded the World Health Organization's (WHO) 24-hour guideline of 25 μg/m³. The finding highlights the elevated health risk associated with PM2.5 exposure on the construction site. PM2.5, being finer and more respirable than PM10, poses a greater health risk. Prolonged exposure to PM2.5 is linked to respiratory problems, cardiovascular issues, and a range of adverse health outcomes. Therefore, even though regulatory OELs may not exist for PM2.5 in this context, exceeding WHO guidelines emphasizes the need for immediate measures to reduce PM2.5 levels.

CONCLUSION

The assessment of construction workers' exposure to particulate matter (PM) on the building site in Novi Sad has provided valuable insights into the potential health risks associated with this occupational environment. The study focused on two specific PM size fractions: PM10 and PM2.5, using the AlphaSense OPC-N2 monitoring instrument.

The TWA exposure assessment for PM10 indicated that the construction worker was exposed to a concentration not exceeding the European Union's indicative Occupational Exposure Limit. It is essential to recognize that PM10 exposure, even within regulatory limits, may still pose health risks over extended periods.

In contrast, the TWA exposure for PM2.5 exceeded the World Health Organization's guidelines. The calculated TWA exposure of PM2.5 emphasized the elevated health risk associated with this particulate matter. PM2.5 exposure has been linked to respiratory and cardiovascular health problems, warranting immediate attention and mitigation measures.

Ongoing monitoring of PM levels on the construction site is crucial to track exposure trends and ensure the effectiveness of mitigation measures. Consideration of individual worker health assessments is also recommended, as some individuals may be more susceptible to PM-related health effects.

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KINETICS OF MALATHION REMOVAL USING CARBON MATERIAL DERIVED FROM VISCOSE FIBERS

Tasić T.[1], Milanković V.[1], Breitenbach S.[2,3], Unterweger C.[2], Fürst C.[2], Pašti I.[4], Lazarević-Pašti T.[1]

[1] VINČA Institute of Nuclear Sciences-National Institute of the Republic of Serbia, University of Belgrade, Mike Petrovića Alasa 12-14, 11000 Belgrade, Serbia (e-mail: tamara.tasic@vin.bg.ac.rs)

[2] Wood K Plus —Kompetenzzentrum Holz GmbH, Altenberger Strasse 69, 4040 Linz, Austria

[3] Institute of Chemical Technology of Inorganic Materials (TIM), Johannes Kepler University Linz, Altenberger Strasse 69, 4040 Linz, Austria

[4] Faculty of Physical Chemistry, University of Belgrade, Studentski Trg 12-16, 11158 Belgrade, Serbia

Abstract: Widespread use of toxic organophosphate malathion raises the need to develop efficient procedures for its elimination from the environment. The acute neurotoxicity of malathion is associated with the irreversible inhibition of acetylcholinesterase, the enzyme involved in signal transduction in the nervous system. Its inhibition leads to different neurological disorders. Various methods have been applied to remove malathion from water, but one of the most promising is adsorption. We used carbon materials derived from viscose fibers as an adsorbent for malathion. It was shown that 1 g of carbon material could adsorb 42.5, 22.0, and 161.0 mg of malathion, respectively, at 25 °C. The kinetics of the batch adsorption removal of malathion from water solutions was also investigated. Results showed that malathion adsorption onto carbon materials followed the pseudo-second-order kinetics model most appropriately under the given experimental conditions, with the constant rate value of 0.002, 0.043, and 0.010 mg g^{-1} min^{-1}.

Keywords: *organophosphates; adsorption; remediation; viscose fibers; carbon material.*

INTRODUCTION

Pesticides are chemical substances, either synthetic or natural, used to control insects, weeds, and other factors that affect plant growth (Milanković, 2023, Tasić, 2023). Different types of chemical pesticides include carbamates, organophosphates, organochlorines, and pyrethroids, with organophosphates being widely used and effective for pest control (Gong, 2022, Tudi, 2021). However, excessive use and slow biodegradation of organophosphates can lead to contamination of the ecosystem and food chain, causing various health disorders due to their inhibitory effect on the enzyme acetylcholinesterase, which is essential for neurotransmission (Gong, 2022, Milanković, 2023, Tasić, 2023).

Among different types of pesticides, malathion is commonly used to control mosquitoes and insects attacking fruits, vegetables, and plants, as well as for pet care to manage ticks, fleas, and ants (Kermani, 2021, Milanković, 2023). However, malathion's slow decomposition in water and soil, as a result, has increased concentration in discharge and application areas (Vasseghian, 2022). It can lead to neurological, hepatorenal, metabolic, reproductive, and developmental dysfunctions in aquatic organisms and cause genotoxicity and cancer in humans (Bharti, 2021).

The removal of organophosphates has become a significant area of research, and various methods have been explored, including biodegradation, photocatalysis, electrochemistry, membrane separation, oxidation, and adsorption. Among these methods, adsorption stands out

for its simplicity, cost-effectiveness, and environmental friendliness (Anićijević, 2023, Dolatabadi, 2023, Milanković, 2023). Various adsorbents were studied for organophosphate removal, including carbon-based materials derived from biowaste (Jocić, 2022, Lazarević-Pašti, 2018). These biowaste-derived carbon materials offer highly porous structures and large surface areas, making them an efficient and environmentally friendly solution for removing organophosphates from water (Pandiarajan, 2018, Tasić, 2023).

Viscose fibers, derived from cellulose, are frequently investigated as a potential source for producing activated carbon materials. These fibers possess versatility and find applications in various fields, particularly in pollutant removal. The primary objective of this study is to utilize carbon material derived from viscose fibers as an adsorbent for removing malathion. After that, carbon materials obtained from fibers were characterized using SEM micrography. Subsequently, the study examines the adsorption kinetics of malathion on the investigated carbon materials.

MATERIALS AND METHODS

Viscose fibers with specific dimensions (1.7 dtex, 38 mm) obtained from Lenzing AG (Lenzing, Austria) were chosen as the starting material. Before use, these fibers were thoroughly washed with distilled water and centrifuged using a spin dryer for 15 minutes. After this, they were dried for 24 hours at 90°C in a drying cabinet, and the remaining moisture was determined to ensure it was below 4.5%. The carbonization of the viscose fibers was carried out in a chamber furnace under a nitrogen flow atmosphere. The temperature was gradually raised to 850°C at a heating rate of 1.0°C per minute and held at that temperature for 30 minutes. Subsequently, the sample was cooled to room temperature under a nitrogen atmosphere. For the activation process, 10 grams of the carbonized sample were placed in a quartz glass reactor. The setup was purged with N_2 to remove any air, and then the temperature was increased from room temperature to the final activation temperature under an N_2 flow. The sample was kept isothermally under the N_2 flow for 30 minutes to ensure uniform temperature distribution. Then, the N_2 flow was stopped, and CO_2 was introduced at a specified flow rate for a specific duration, according to Table 1. The activation process was completed by terminating the CO_2 flow and resuming the N_2 flow until the kiln cooled to room temperature.

A PhenomProX scanning electron microscope (SEM) from Thermo Fisher Scientific, Waltham, MA, USA, was utilized for examining the samples' structure.

To measure the concentration of malathion, we employed the Waters ACQUITY Ultra Performance Liquid Chromatography (UPLC) system, coupled with a tunable UV photodiode array (PDA) detector controlled by the Empower software. Chromatographic separations were carried out on an ACQUITY UPLC™ BEH C18 column with dimensions 1.7 µm, 100 mm × 2.1 mm (Waters). Malathion solutions were analyzed under isocratic conditions with a mobile phase of 60% acetonitrile and 40% water (v/v). The eluent flow rate was 0.20 $cm^3\ min^{-1}$, and the injection volume was 5 mm^3. Optical detection for malathion was performed at 200 nm, and the retention time of OP was (3.15±0.05) min under the specified conditions. Malathion concentration in the samples was determined using linear calibration curves constructed with standard pesticide solutions covering a wide concentration range. This method has been optimized and cross-validated using in-house developed protocols and utilized in this and previous studies for malathion determination.

Table 1. The experimental conditions for activating the carbon materials

Sample	Activation temperature	Activation time	CO_2 flow rate
1	870 °C	30 min	80 L h^{-1}
2	670 °C	30 min	80 L h^{-1}
3	870 °C	180 min	10 L h^{-1}

RESULTS AND DISCUSSION

SEM analysis

To analyze the three-dimensional structure of the chosen adsorbent, we captured SEM micrographs, as depicted in Figure 1. The images show that the morphology of all the examined samples remains unchanged even after carbonization, reflecting the original morphology of the precursor viscose fibers. The precursor's morphology was successfully retained.

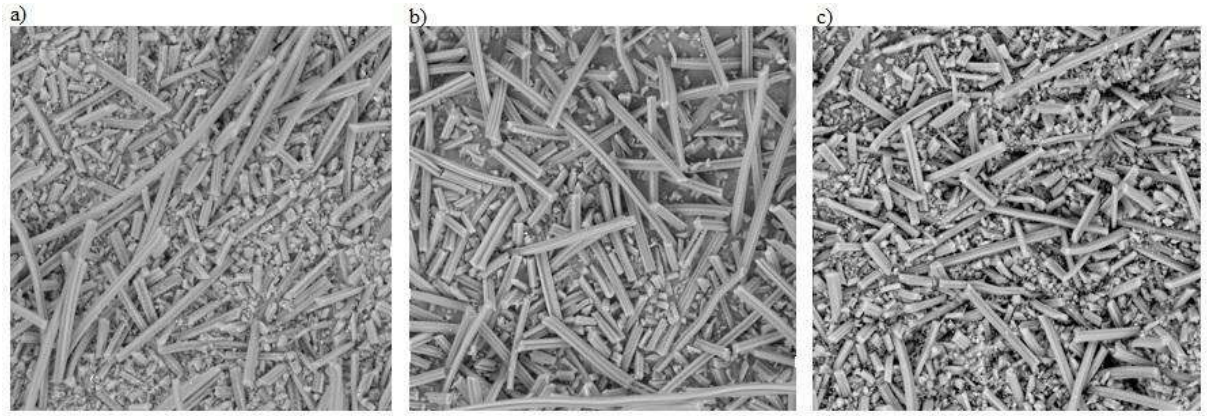

Figure 1. SEM images of samples a) 1, b) 2, and c) 3

Kinetics of adsorption removal of malathion from aqueous solutions

To determine the kinetic parameters of malathion adsorption on investigated carbon material, the tested adsorbent at a concentration of 1 mg mL^{-1} was incubated with malathion at a concentration of 5×10^{-4} mol dm^{-3} at 25 °C for 1, 5, 10, 30, 60 and 1440 min. The concentration of adsorbed malathion was calculated as the difference between its initial concentration (C_0) and the equilibrium concentration (C_e) of malathion measured by UPLC after removing the adsorbent. The kinetics of MLT adsorption onto investigated materials were analyzed using the linear pseudo-first (eq. 1), pseudo-second-order (eq. 2), Elovich kinetic model (eq. 3):

$$ln(q_e - q_t) = lnq_e - k_1 t \quad (1)$$

$$\frac{t}{q_t} = \frac{1}{k_2 q_e^2} + \frac{1}{q_e} t \quad (2)$$

$$q_t = \frac{1}{\beta} ln(\alpha\beta) + \frac{1}{\beta} lnt \quad (3)$$

Where the parameter q_t (mg g^{-1}) represents the quantity of adsorbed MLT at time t, parameter q_e denotes the quantity of OP adsorbed at equilibrium (mg g^{-1}). The parameter k_1 corresponds to the adsorption rate constant in the pseudo-first-order kinetic model (min^{-1}). On the other hand, k_2 represents the adsorption rate constant in the pseudo-second-order kinetic model (mg g^{-1} min^{-1}). In the Elovich model, α represents the initial adsorption rate (mg g^{-1} min^{-1}), while β represents the desorption constant (g mg^{-1}).

Figure 2 displays the experimental results and their linear representations. The equilibrium adsorption capacities and rate constants obtained from the data are summarized in Table 2.

The findings presented in Figure 2 show that the adsorption equilibrium for MLT is achieved after 60 minutes. Moreover, the linear pseudo-second-order kinetic model better fits the experimental data than the pseudo-first and Elovich models, as evidenced by higher R^2 values. Based on the k_2 values, it can be observed that the MLT adsorption rate on the investigated materials is relatively slow. However, when considering the Elovich kinetic model and examining the α and β values, it is apparent that sample 3 exhibits the highest initial adsorption rate, followed by samples 1 and 2. The calculated adsorption capacities of carbon materials are highest for sample 3, followed by samples 1 and 2, with values of 161.0, 42.5, and 22.0 mg g^{-1}, respectively.

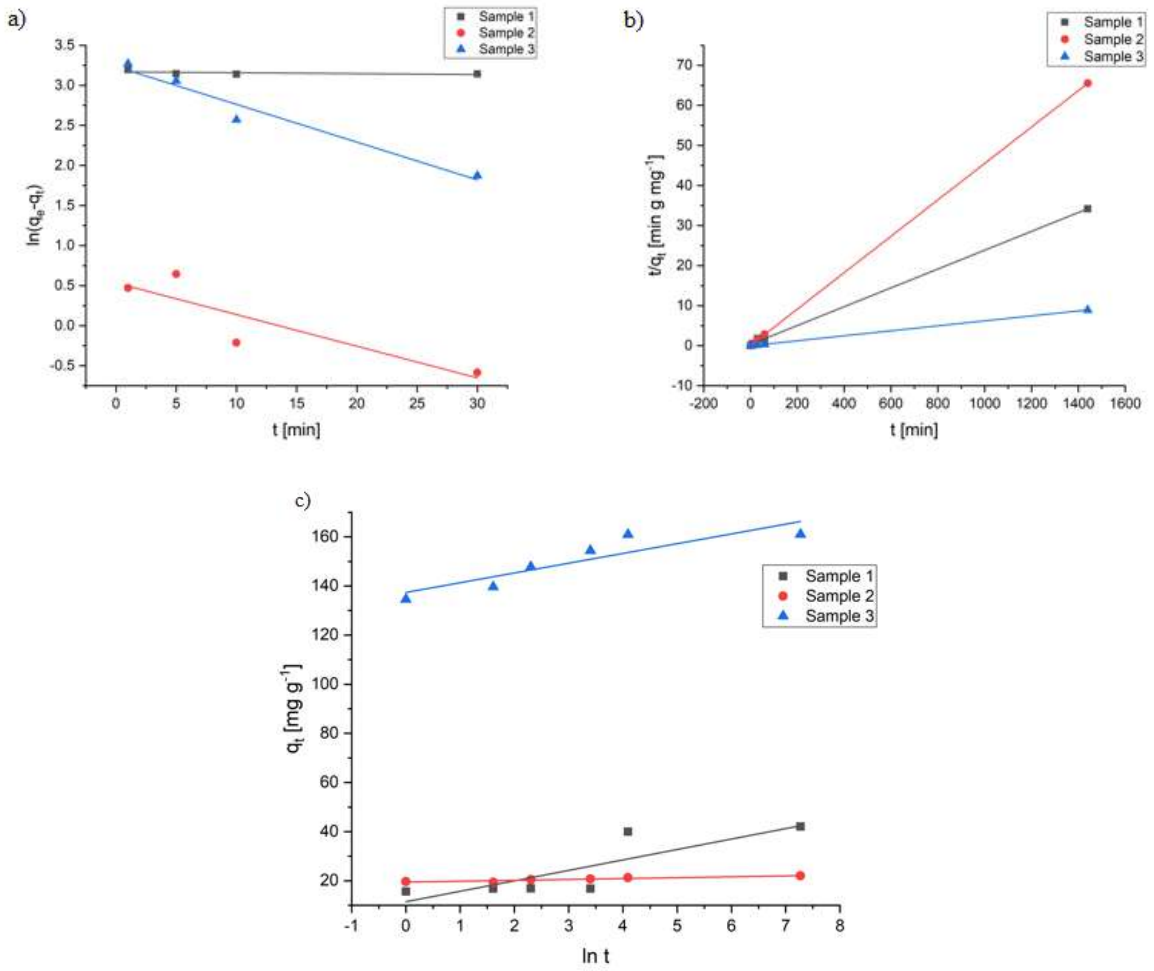

Figure 2. Kinetics of malathion: a) pseudo-first reaction order, b) pseudo-second reaction order, c) Elovich kinetic model.

Table 2. Kinetics parameters for malathion (5×10^{-4} mol dm^{-3}) adsorption on carbon materials (1 mg ml^{-1}).

Sample	Pseudo-first-order kinetics		
	q_e (mg g^{-1})	k_1 (min^{-1})	R^2
1	23.834	0.001	-0.051
2	1.707	0.040	0.666
3	25.447	0.047	0.935
	Pseudo-second-order kinetics		
	q_e (mg g^{-1})	k_2 (mg g^{-1} min^{-1})	R^2
1	42.535	0.002	0.999
2	21.997	0.043	0.999
3	161.031	0.010	0.999
	Elovich kinetics model		
	α (mg g^{-1} min^{-1})	β (g mg^{-1})	R^2
1	9.85×10^{4}	0.235	0.619
2	2.89×10^{8}	2.763	0.826
3	4.90×10^{59}	0.252	0.754

CONCLUSION

The carbon material derived from viscose fibers effectively removed malathion from water. The experimental data revealed that 1 gram of carbon material from samples 1, 2, and 3 could adsorb 42.5 mg, 22.0 mg, and 161.0 mg of malathion, respectively. Additionally, the results demonstrated that the adsorption of malathion on the respective adsorbents followed the pseudo-second-order kinetic model under the given conditions. This successful outcome confirms the viability of using the investigated adsorbent for malathion removal.

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RISING AWARENESS AS A TOOL FOR THE REDUCTION OF FOOD WASTE IN HOUSEHOLDS AND RESTAURANTS

Ubavin D. [1], *Tot B.* [1]

[1]University of Novi Sad, Faculty of Technical Sciences, Department of Environmental Engineering and Occupational Safety and Health, Trg Dositeja Obradovica 6, 21000 Novi Sad (e-mail: bojanatot@uns.ac.rs)

Abstract: The present paper intends to define general recommendations and implement key actions for the reduction and prevention of food waste from restaurants within the University of Novi Sad campus. For this, an awareness-raising campaign and promotion plan have been defined. The Restaurants Against Food Waste action aims at reducing food waste in restaurants and increasing customer awareness about their food choices. For this reason, part of the tool referred to the planning of their food consumption choices and awareness of the reduction of food waste and the consumption of leftovers. According to the authors, obtained results can be an essential first step and of great importance toward sustainable and feasible long-term management of food waste from restaurants in accordance with the idea and goals of a circular economy.

Keywords: *food waste; prevention; reduction; households; restaurants.*

INTRODUCTION

Food waste represents food and inedible parts of food removed from the food supply chain which are referred to treatment or disposal (Stenmarck, 2016). Food waste has become a major global issue in recent years, accounting for the highest percentage in Municipal Solid Waste (MSW). An estimated 1.3 billion tons, or one-third, of the edible food produced by humans is wasted each year. (FAO, 2011; Mu'azu, 2018) having a negative impact on the environment all the way from production to the post-consumer stage. A significant increase in food waste as a result of intensive food production and a larger population (consumers) led to highlighting food waste as a serious environmental impact in recent years.

According to the waste prevention hierarchy, priority should be given to the prevention of food waste, followed by recycling, recovery, and disposal (Pomponi, 2017). The primary focus of food waste prevention should be to act at source by limiting the generation of surplus food. The ideal option, which ensures the maximum value utilization of resources for edible food, is to redistribute surplus food for human consumption (GAWH, 2017). If the leftover food cannot be used for human consumption, it may be used as animal feed as long as it conforms with all applicable legal criteria. At the very bottom of the hierarchy is shoveling the food waste into a landfill or incinerating it. Currently, in developing countries, not enough attention is paid to the prevention of food waste. Usually, if food management actions are applied, they are mainly focused on treatment (composting, anaerobic digestion, and incineration). Significant environmental costs are incurred when food is wasted or used inefficiently (Notarnicola, 2017). Food waste occurs throughout the entire food chain. However, households, at the end of the chain - are one of the major contributors (Stenmarck, 2016, Zhang, 2018). Also, food waste generated in households represents the most avoidable food waste (Beretta, 2013) and at the same time has the greatest risk of increasing the amount of waste (Vesela, 2023). Therefore, it is necessary to find out which

factors have a significant impact on food waste in households, so that by knowing these factors, the end links of the food chain can be influenced, and the amount of food waste can be reduced (Vesela, 2023). The negative effects of food waste include the wasteful use of resources, the environmental costs entailed in food production and related supply chains, and the negative societal effects on food security (Scherhaufer, 2018). According to the waste hierarchy framework of the CE, the most preferable food waste management options are reduction, redistribution, feeding to animals, anaerobic digestion (AD), composting, incineration, and finally landfilling. In developed countries, the majority of losses occur in the post-consumer stage, but in developing countries, losses are most prevalent in the early post-harvest phases (Parfitt, 2010). Also, rural areas produce less food waste in comparison to urban areas (Sosna, 2019). It is estimated that almost 690 million people around the world (9% of the global population) experienced hunger, and 2 billion people (more than one-quarter of the population) were affected by moderate or severe food insecurity in 2019 (UN, 2021). Minimizing food waste not only paves the path to the Zero Hunger Goal of UN Sustainable Development Goals but also substantially reduces the pressure on natural resources, given that agriculture and food supply chain accounts for 70% of global freshwater abstractions and 30% of global energy consumption, respectively (FAO, 2014). It would also help to reduce the current 8–10% of global greenhouse gas (GHG) emissions associated with food loss and waste, which if it was a country, would have the third biggest carbon footprint in the world (UNEP, 2021). In addition, policymakers have placed the problem of food waste on their agendas. For example, the UN has established SDG 12.3, which calls for a decrease in food losses from production and retail-level waste of 50 percent by 2030. The European Commission has accepted this goal as part of the Farm to Fork strategy and will go on to propose legally enforceable goals for food waste at the Member State level (Casonato, 2023). According to the most recent estimates, 130 billion euros worth of food in Europe is wasted each year, or 59 million tonnes. (Eurostat, 2022). Food waste management, just like other waste streams, is based on a waste hierarchy framework, promoting avoidance and reduction of waste production prior to treatment and disposal options. However, this approach has been questioned in several studies. Eriksson et al. (2015) while comparing the GHG emissions of food waste in Sweden, conclude that the waste hierarchy framework is a 'useful, but approximate' tool for prioritizing the available options. Other research, comparing the impacts of treatment and disposal technologies on the food, water, energy, and health nexus, concluded that in-vessel composting is the worst option for environmental sustainability since in-vessel composting is a net consumer of grid electricity, and has the highest impact on the food, energy and health elements Slorach et al. (2020). The level of awareness of food waste on the environment is considered by many authors to be an important factor influencing household waste generation, e.g., (Richter, 2017; Roodhuyzen, 2017). If households become more aware of the social, environmental, and economic impacts of food waste, it could help to reduce the overall amount of food waste (Vesela et al, 2023). In general, there is a noticeable lack of knowledge about how food waste affects the environment. The activities that produce the largest levels of greenhouse gases (GHGs) during food production, such as cattle breeding, making dairy products, etc., are the ones about which the most information is now accessible. However, the level of information about how food waste affects the environment is far less available. This situation needs to be changed in order to raise awareness about food waste's impact on the environment and subsequently to reduce the level of food waste generated. The most common causes of food waste generation include (Stockli, 2018): shopping style (buying larger than needed quantities of food, impulse buying, poor planning); storage (inadequate storage of fresh products or prepared meals, preference for fresh

products); food preparation (overcooking, not using leftovers, poor cooking planning) and serving food (using large plates, uniform portion sizes). Numerous studies came to the conclusion that the way people shop for groceries and behave while doing so significantly influences how much food waste they ultimately produce (Setti, 2018; Stefan, 2013; Stancu, 2016). The most frequent causes of food waste related to shopping are large quantities of purchased food. (Stancu, 2016; Radzyminska, 2016). The frequency and planning of purchases are related to the amount of food bought for households which subsequently influences the volume of food waste in households. (Jorissen, 2015; Roodhuyzen, 2017). The underestimated amount of food required for the household could increase the frequency of food purchases excessively (Giordano, 2019). Also, discounts and lower prices per unit for the food in larger packages are one of the main reasons for buying more food than is needed in households (Jorissen, 2015; Van Geffen, 2020; Stancu, 2016). For that reason, following a pre-planned list and planning food consumption becomes an effective tool for avoiding piling up food on discounts or special offers and in general. (Stancu, 2016; Roodhuyzen, 2017). Food quality and appearance at the time of baying and during storage may influence how much fast food is wasted (Graham-Rowe, 2014; Gracia, 2020). All things considered, the process of food shopping can be an important factor influencing food waste in households.

When it comes to food preparation and consumption, there are many factors affecting the food waste generation, such as:

- habits, behavior – eating habits, appreciation of prepared food,
- cooking skills - how much food is wasted during preparation, taste, and desirability of food,
- economic factors - ability to buy prepared foods, affordability to throw away food,
- number of inhabitants in a household – for how many people is food prepared,
- lifestyle – the amount of time spent at home, age of inhabitants.

The level of appreciation of prepared food has been recognized as a factor with a significant impact on household food waste (Porpino, 2015; Stockli, 2018). Changes in lifestyle, number of household members, and the ability of the family to dine together have an impact on eating habits and food appreciation. Other factors related to eating habits and cooking skills, such as the taste of food or the ability to process the purchased food also play a role in household food waste production (Coskun, 2020). Activities like food peeling have a big impact on reducing food waste, in addition to cooking abilities and the capacity to prepare a variety of meals with the ingredients at hand, especially leftovers (Richter, 2017). With the growing influence of media marketing and advertising, there is an obvious rise in the consumption of food items with a perfect appearance. Consequently, less attractive food easily becomes waste. Food storage at home poses another significant food management issue (Stockli, 2018). Many households throw away food because it spoils before being eaten (Roodhuyzen, 2017; Van Geffen, 2020), they do not consume the food due to damaged packaging (Rohm, 2017) or they dispose of the food because since it has expired (Graham-Rowe, 2015; Roodhuyzen, 2017). All that leads to the fact that household food storage and general food management have an impact on the amount of food waste (Table 1).

Table 1. Mind map of food waste causes

Amount of food waste	
Food preparing	Food peeling, processing food prevent spoilage, incorrect estimate of prepared food, taste of food
Food waste knowledge	Food waste awareness, the importance of food waste
Food storage	Spoilage before consumption, damaged packaging, exceeded shelf-life
Food purchasing	Grocery price, package size, shopping list, quantity of purchased food, food quality and appearance, shopping frequency

MATERIALS AND METHODS

As a frame for our opportunity analysis, three areas were considered for optimization: 1) operating & business models 2) process improvements 3) capacity building, including awareness raising and education (EAUC, 2016). In this research, a focus is on the areas with the greatest potential for improvement, namely: 1) Capacity building: Awareness raising & education, and 2) Process optimization in food service.

Capacity building: awareness raising & education

Multimedia content - The short presentation aimed to raise customer's awareness of the problems associated with the generation of food waste, such as the amount of generated waste, food waste treatment, carbon footprint, global warming, water footprint, land occupation footprint, harmful farming, world hunger, food loss, and waste. The presentation further highlights 10 key tips for avoiding food waste at home and briefing the customers on how they and their families can reduce the amount of food they waste.

Posters and flyers - Posters and flyers showed ten tips with simple messages for customers. These tips remind them not to accept food they know they would not eat. During the campaign, the staff was informed about the amounts of plate waste generated and instructed to allow and even advise users to reject some specific food types and onward.

The questionnaire and quiz - The realization of research and data collection is based on questionnaires and quizzes. The questionnaires consisted of two parts. The first, more general part, is the questions referring to the identification and background information about students, such as gender, level, year of study, etc. The second part of the questionnaire contains questions about the level of customer awareness of food waste issues. The quiz differed from the questionnaire and contained questions that specifically related to food waste. Educational material, food donation ideas, tips, and recipes were shared on social media.

Process optimization in food service

The most important constraint to sustainable behaviors is a lack of knowledge among the members of the academic community. Major communication campaigns are needed to raise awareness of the issue and move stakeholders across the food supply chain towards taking specific actions. Raising awareness of food wastage creates the demand for a new product,

namely food wastage avoidance, which will result in a more rapid take-up of the proposed food waste solutions. Summary of the recommendations for the reduction and prevention of food waste given to the three representative restaurants within the University of Novi Sad campus can be defined as consumer education campaigns, overproduction and adapt portions, turning inedible by-products into new products, value-added processing, centralized composting, and anaerobic digestion, redistributing surplus edible food/social welfare.

The food saving campaign - Case study - Restaurant 1

A large-scale consumer advocacy campaign to raise awareness of food waste and educate consumers about ways to save money and reduce wasted food was conducted. During stage one of the research, a large amount of soup was being left in the bowls because the users accepted the soup and the standard portion of salad and bread. To change this behavior, informative posters were placed close to the area where food waste is collected. Multimedia content on monitors in the restaurant was displayed. Also, the flyers were prepared and distributed. The flyers were distributed by experts to customers during the purchase of food. Initial visual observations during meal consumption at the restaurant's canteen, performed during the 7 days, showed that most users left at least 1/3 of the food in their dish including wasted bread. This revealed a lack of knowledge and concern about food waste among the people community. For desserts, there were waste residues of apple, orange, or banana peel.

The food saving campaign - Case study - Restaurant 2

In the first phase of the implementation of food waste measurement activities, a very simple handmade poster was placed above the static tray slide, at eye level. The action with the purpose of reducing food waste started to raise curiosity among restaurant users. The questionnaire was printed out and distributed to customers at the entrance to the restaurant. Flyers were distributed and prepared. The flyers were also distributed by restaurant staff to customers during the purchase of food. The quiz program was conducted using tablets at the entrance of the restaurant. After completing the questionnaire, the customers were informed about the next part of the campaign (challenges on Facebook and quiz on campus) and wrote down their email addresses, so that experts could inform them about the date, place, and time of the quiz. The restaurant staff was informed about the tools and educate them about the importance of avoiding food waste. Initial visual observations during meal consumption at the restaurant, performed during the 7 days, showed that most users left at least 1/2 of the food in their dish including wasted vegetables and bread. For desserts, there was no waste. In addition, soup was served for lunch but 50% of this weight was water. Vegetables and bread were the food groups presenting the highest amount of food waste overall. However, the fact that the staff always served different amounts of meal components may have contributed to the high plate waste observed in the present research as all customers received different meal compositions.

The food saving campaign - Case study - Restaurant 3

The informative posters were displayed simple and affordable in strategic areas of the restaurant. Flyers were thrust right into the hands of customers in restaurants. The flyers were also distributed by restaurant staff to customers during the purchase of food. The flyers were of great importance because they serve as a reminder of how citizens of Novi Sad can act with their micro-actions on the prevention and reduction of food waste in everyday life. The usable life of foods through processing methods such as making soups, sauces, and other value-added products was extended.

RESULTS AND DISCUSSIONS

During the campaign, about 500 flyers and 20 posters were distributed to citizens across the Campus University area. The questionnaire contains basic questions about participants (gender, level, year of study, etc.), followed by 10 questions about the level of customer awareness on this topic. Through the questionnaire 189 participants were examined from the Campus University area, most of them are from the Faculty of Technical Sciences (52%) and the Faculty of Agriculture (25%), while other faculties contribute with ≥ 5% each. Most participants were female (58%), while males took 42%. According to the Food saving campaign and the conducted questionnaire, 49% of participants have learned new, practical, and easy-to-apply ways to reduce food waste that does not require much investment, in terms of money, time, or space (Figure 1). Results of the questionnaire showed that most participants (47%) have already been familiar with ways to reduce food waste. Also, 4% of participants reported that they are partially aware of the problem and have applied some of the ways to reduce food waste in their households.

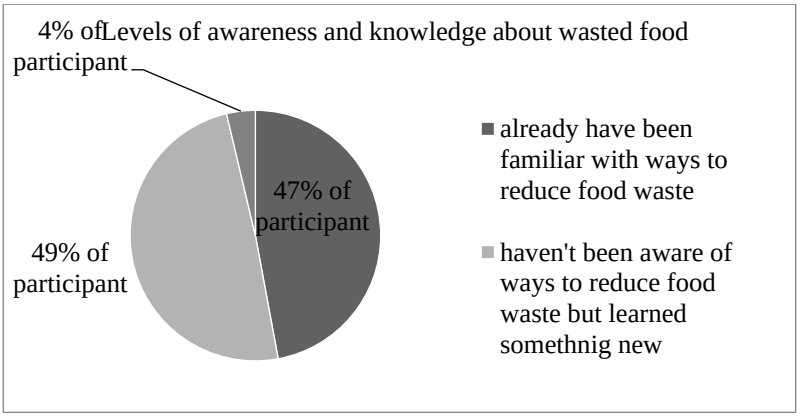

Figure 1. Level of awareness

Most participants find the information displayed on promotional material (flyers, posters) useful and 86% of the respondents said that it influenced them to change the way they handle food. Many were unaware of how much food is thrown away every day, how that waste can be reduced, and for what purpose. However, the positive result of this campaign is that in addition to ways to reduce food waste, questionnaires have become aware of how their habits in daily activities negatively affect the environment in general and how they can change it. After the questionnaire, a quiz program was conducted using tablets at the entrance of the restaurants and other places on the campus. Through the quiz, 66 participants responded to the questions and the answers showed that the majority of students have learned something new regarding food waste problems and that they began to think about food waste in a different way. In that sense, 96% of participants gave the correct answer to the first question in the quiz, which referred to how important it is to separate food waste from mixed waste to reduce the humidity of other fractions and facilitate their further management. 76% of participants had knowledge about how much food waste is generated in Serbia annually, 15% of them thought that the number is much lower and 9% thought that it is much higher.

CONCLUSION

This paper has presented the results from the food-saving campaign and results from the implemented key actions for the reduction and prevention of food waste from restaurants near the University campus in the city of Novi Sad (Republic of Serbia). This paper represents the first research in Serbia showing how customers and restaurants can apply step-by-step action to raise an awareness campaign and promotion plan for the implementation of a circular economy in practice. The proposed recommendations for the reduction and prevention of food waste can be also applied to drive change in other restaurants in the service sector that are looking to move towards a circular economy. According to the results, people waste less when they have a higher level of ability to plan their food purchases and consumption, regardless of how frequently they do so. Also throwing away food due to its expiration date is the most frequently cited reason for food waste in households.

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THE OPTIMIZATION OF EXTRACTION METHOD PARAMETERS FOR DETERMINATION OF SELECTED PRIORITY WFD POLLUTANTS IN SURFACE WATERS.

Urban K. [1], *Dunajský M.* [1], *Machyňáková A.* [1], *Špánik I.* [1] *Petrović M.* [2]

[1] Slovak University of Technology in Bratislava, Faculty of Chemical and Food Technology, Radlinského 2101/9, Bratislava, Slovakia

[2] University of Novi Sad, Faculty of Technical Sciences, Trg Dositeja Obradovića 6, Novi Sad, Serbia

Abstract: The presented work deals with the development, optimization, and comparison of SPE-GC-MS methods suitable for the determination of selected priority compounds from surface water samples. The aim of the work was to develop and optimize SPE-GC-MS methods suitable for the determination of pollutants from the groups of organochlorine pesticides (OCPs) and non-chlorinated pesticides, polyaromatic hydrocarbons (PAHs) and alkylphenols in water and to compare extraction techniques for water sample volumes in terms of extraction recovery. Various organic solvents were tested for the conditioning and elution of the sorbent. The best results were obtained using a mixture of acetone and hexane to elute the analytes from the SPE disc. Using this mixture of organic solvents, it was possible to achieve recovery values in the range of 40 to 113 percent for most of the monitored compounds, notably chlorinated pesticides.

Keywords: *priority pollutants; LLE; GC-MS; SPE-disc; WFD.*

INTRODUCTION

Nowadays, more than 15% of the Earth's land surface is covered with protected areas worldwide (Protected Planet Report 2020). Natural protected areas are considered as so-called clean and intact environments on our planet. The importance of these areas is reflected in their widely accepted role as an indicator for global targets and environmental assessments (Visconti, 2019). While it is assumed that these areas should not be affected by industry and agricultural practice, they have become convergence zones for selected polluting organic compounds. The most significant sources of pollution in these areas are incinerators, power and heating plants, agricultural activities, forest fires, etc. Organic pollutants in the environment are transported at low concentrations by the movement of fresh waters, and since they are semi-volatile, they are transported over long distances in the atmosphere. These compounds tend to accumulate in soils, sediments, and biota, or for several weeks in the air. As a result, organic pollutants are widely distributed across the globe, including regions where they have never been used, such as natural protected areas (Negrete-Bolagay, 2021).

Due to maximized effort to protect the environment, the Water Framework Directive (WFD) designated the list of priority pollutants and set a strategy for dealing with the pollution of water from chemicals (Article 16 of 2000/60/EC WFD). As a first step of this strategy, a list of priority substances was adopted (Decision 2455/2001/EC) identifying 33 substances or groups of substances of priority concern in surface waters throughout the European Union. The current list contains various pesticides, PAHs, benzene, halogenated solvents, flame retardants, a plasticizer, surfactants, and antifouling agents as well as some heavy metals. Control of chemical substances

is targeted at toxic effects on ecosystems. Directive 2008/105/EC set environmental quality standards (EQS) for these 33 substances, as well as for 8 other pollutants that pose a particular risk to plant and animal life. This directive was later replaced by directive 2013/39/EU, in which EQS for some substances were updated. Compliance monitoring for the WFD requires the achievement of a LOQ equal to or below a value of 30% of the relevant EQS. This is an analytical challenge since the values of most of the EQS are very low. Especially, Cypermethrin, Dichlorvos, Heptachlor and heptachlor epoxide, PFOS, Dicofol and Polyaromatic hydrocarbons (PAHs) have very low stated limits and are considered the most challenging substances. Since, it was proven that very low concentration levels have negative effects on the environment; it is of significant importance to develop analytical methods capable of reaching these low concentration ranges (Abdel-Shafy, 2016; Soursou, 2023). Gas and liquid chromatography methods in conjunction with mass spectrometry in SIM or SRM mode are the most frequently used methods to determine polluting organic compounds in these matrices to achieve the highest selectivity and sensitivity for targeted analysis.

However, reaching those low limits would not be possible without using suitable extraction techniques for the extraction of any organic compounds from water. For this purpose, two extraction techniques were compared, namely extraction in a liquid-liquid system (Liquid-Liquid Extraction, LLE) and extraction with a solid phase (Solid-Phase Extraction, SPE) on discs, which allows analytes to be concentrated even from whole water samples. In addition, SPE discs can also be used to filter large volumes of surface water samples, thereby achieving lower limits of detection (LOD).

MATERIALS AND METHODS

Chemicals

Organochlorine Pesticides Mixture 921 in acetone, PAH mix 61, aclonifen, bifenox, cypermethrin, dichlorvos, diuron, hexachlorobenzene, quinoxyfen, chlorfenvinphos, chlorpyrifos were obtained from Dr. Ehrenstorfer. The solvents hexane, methanol, and dichloromethane, acetone used for extraction were obtained from Supelco.

Sample treatment

Liquid-liquid extraction

The 1 liter of water sample was transferred into a separatory funnel and extracted using three 30ml portions of organic solvent (hexane, dichloromethane). After extraction, organic solvents were collected, mixed, dried with 3g of Na_2SO_4, and evaporated using rotovap to a final volume of 1 ml.

SPE-disc extraction

One liter of water sample was extracted by passing through Atlantic® HLB-H sorbent (47 mm diameter) disc with a balanced hydrophilic-lipophilic ratio suitable for environmental samples. Prior to extraction, the sorbent disc was conditioned according to the producer's instruction. After activation, a sample passed through a sorbent disc with a flow rate of 35 ml/min. In the next step, the sorbent was washed with 20 ml of CI water followed by drying using air. The catched organic compounds were extracted from SPE-disc by organic solvent (3 times by 4 ml). The collected extracts were evaporated using rotovap on a final volume of 1 ml.

Equipment

All analyses were performed using an Agilent Technologies (USA) gas chromatograph with programmed temperature vaporization (PTV) injector in connection to an Agilent 5975B Inert XL EI/CI MSD quadrupole mass spectrometer. Ionization was performed in EI mode with an ionization energy of 70 eV, while the quadrupole analyzer temperature was 150 ^{o}C and the ion source was at 230 ^{o}C. The transfer line between the gas chromatograph and the mass spectrometer was heated to 280 ^{o}C. Sample injection was performed with an Agilent 7693A Series autosampler using a 10 µl syringe (Agilent Technologies, USA). A non-polar HP-5 column (5% diphenyl, 95% dimethylpolysiloxane, Agilent) with a length of 30 m, an internal diameter of 0.25 mm, and a stationary phase thickness of 0.25 µm was used for chromatographic separation. The carrier gas was helium with a purity of 99.9990%.

RESULTS AND DISCUSSION

The LLE is the most frequently used extraction method recommended by various environmental standards. In our work, we focused on the selection of the most suitable extraction solvent to extract both non-polar and medium-polar pollutants. Thus, two types of extraction solvent (hexane as non-polar and dichloromethane as polar) were used. The GC-MS chromatograms in SIM mode obtained for standard solutions of three studied mixtures are shown in Figure 1.

The extraction recovery was calculated by dividing the peak areas obtained for the individual compounds in the extract and the peak areas obtained by analysis of the prepared standard solution, which contained the concentration of analytes that would be expected at 100% recovery. When comparing extraction recoveries, hexane provided higher values in the range of 83 – 120%. On the contrary, dichloromethane provided recoveries within a range of 21 – 47 percent. The recoveries obtained for all studied compounds are shown in Figure 2.

SPE extraction is a modern extraction method that minimizes solvent consumption and thus it is considered an environmentally friendly extraction method. SPE could be realized in two common set-ups, cartridge (column) or disc. SPE-disc extraction allows the use of higher sample volumes and the sample flow rate could be significantly higher. This saves time and extraction is performed much faster. During SPE-disc extraction we investigated the selection of suitable solvent mixtures for sorbent conditioning and elution of analytes. The recoveries obtained by different solvents and their combinations were monitored. However, the main problem we encountered during the sorbent drying step. This caused contamination of the obtained extract by water from the poorly dried sorbent which was difficult to remove. Its presence in the extract is not only problematic due to incompatibility with gas chromatography, but residual water also has a negative effect on the recovery and repeatability of the extraction. Figure 3 shows the obtained recoveries using SPE-disc extraction in the most suitable solvent mixtures.

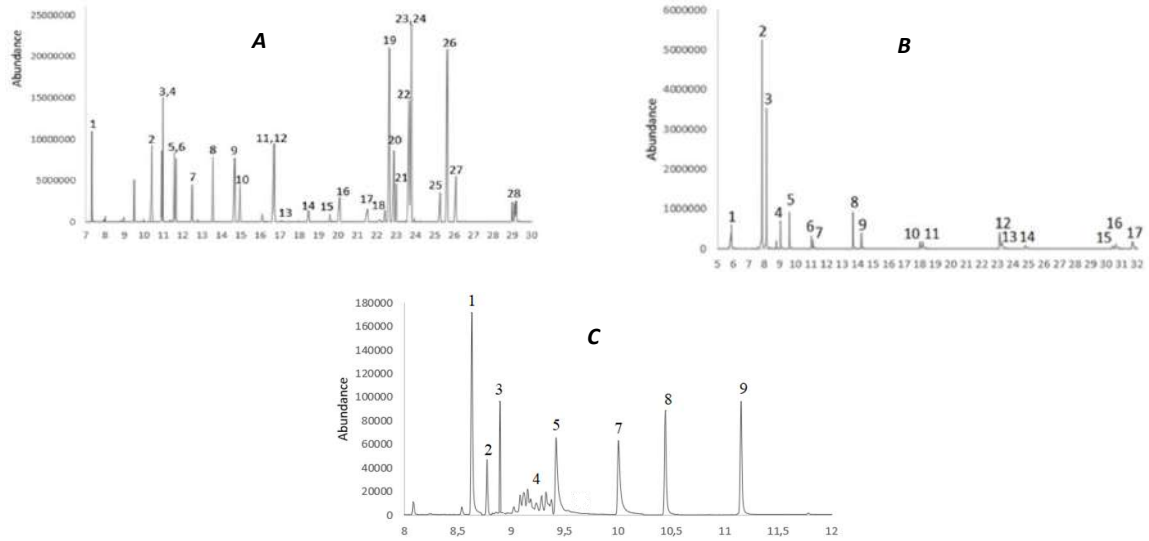

Figure 1. *A* – OCPs (1: α-HCH, 2: hexachlorobenzene, 3: β-HCH, 4: γ-HCH, 5: δ-HCH, 6: heptachlor, 7: chlorpyrifos D10, 8: chlorpyrifos, 9: aldrin, 10,11: chlorfenvinphos, heptachlor epoxid, 12: diuron, 13: α-endosulfan, 14: p,p'-DDE, 15: dieldrin, 16: endrin, 17: β-endosulfan, 18: p,p'-DDD, 19: aclonifen, 20: endrin aldehyde, 21,22,23: quinoxyfen, endosulfan sulphate, p,p'-DDT, 24: endrin ketone, 25: methoxychlor, 26: bifenox, 27: cypermethrin); ***B*** – PAHs (1: naphthalene, 2: acenaphthylene, 3: acenaphthene, 4: fluorene, 5: phenanthrene, 6: anthracene, 7: fluoranthene, 8: pyrene, 9: triphenyl phosphate D15, 10: benzo[a]anthracene, 11: chrysene, 12: benzo[b]fluoranthene, 13: benzo[k]fluoranthene, 14: benzo[a]pyrene, 15: benzo[g,h,i]perylene, 16: dibenz[a,h]anthracene, 17: indeno[1,2,3-cd]pyrene); ***C*** – alkylphenols and non-chlorinated pesticides (1: 4-tert-octylphenol, 2: trifluralin, 3: C17 internal standard, 4: nonylphenol (technical), 5: 4-n-octylphenol, 7: 4-n-nonylphenol, 8: terbutryn, 9: irgarol)

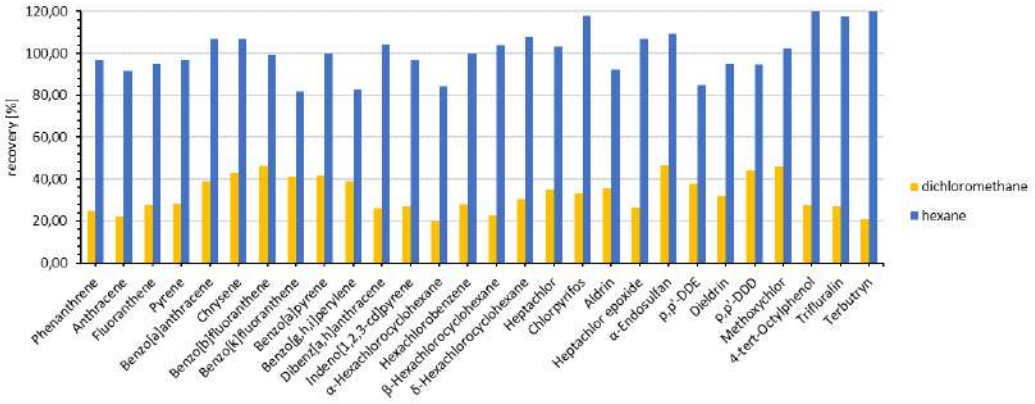

Figure 2. Recovery values obtained using LLE extraction

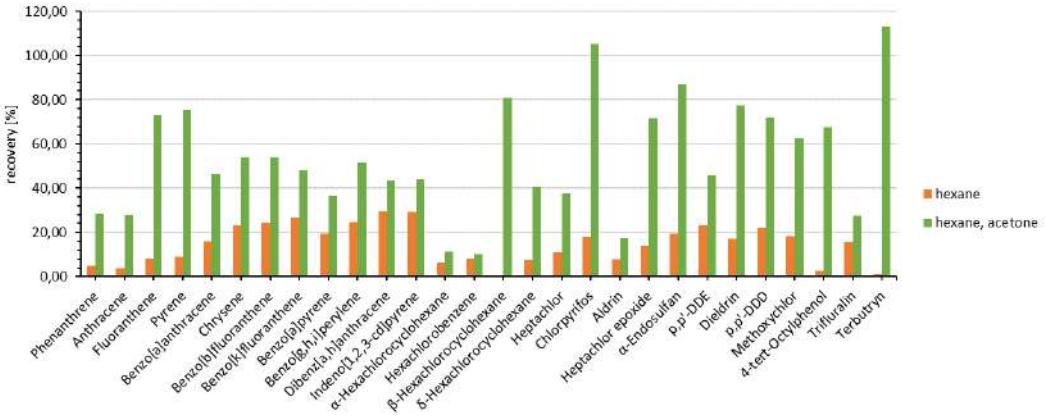

Figure 3. Recovery values obtained using SPE-disc extraction

CONCLUSION

The presented work was focused on the optimization of extraction method parameters for the determination of selected priority WFD pollutants in surface waters. LLE and SPE-disc extraction methods were compared. In terms of extraction recoveries, LLE provided the best results and still, it is an unbeatable extraction method. However, LLE already reached its limitations and there are not so many possibilities to improve it. SPE-disc method did not provide reasonable recoveries, especially for PAH compounds using investigated elution solvents. Nonetheless mainly for chlorinated pesticides recoveries were suitable (40 – 105 % for most compounds), and there is still space for significant improvement, for example:

1. it is much faster compared to LLE,

2. significantly lower solvent consumption,

3. the possibility to use even higher sample volumes (up to 50 l), which will significantly reduce LOD and LOQ, and thus the need to obtain high recoveries may not be necessary.

ACKNOWLEDGEMENT

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PROTECTION OF EMPLOYEES FROM PSYCHOSOCIAL RISKS IN INTERNATIONAL LABOR REGULATIONS

Veljković M.[1], *Stratijev M.*[2], *Živković S.*[1]

[1]Faculty of Occupational Safety – University of Niš, Čarnojevića 10a, Niš, Serbia (e-mail: milan.veljkovic@znrfak.ni.ac.rs)

[2]Faculty of Law – University of Niš, Serbia

Abstract: Over the last two decades, work environments have undergone substantial transformations driven by technological advancements, escalating workloads, and new employment trends. These transformations have introduced new psychosocial risks, including work-related stress, violence, and harassment, impacting the health and safety of employees. Addressing these factors and promoting a positive work environment is crucial for employee well-being and productivity. Psychosocial risks encompass various aspects of work organization and management that can negatively affect employees' health and safety. Regulations and guidelines from the International Labor Organization (ILO) and the European Union (EU) provide essential frameworks for protecting employees from psychosocial risks. The ILO offers recommendations and conventions to identify, prevent, and manage stress at work, while the EU sets minimum requirements for working time and work-life balance. By implementing these guidelines and promoting collaboration between employers, workers, and regulatory authorities, organizations can create safer and more supportive work environments prioritizing employee well-being.

Keywords: *psychosocial risks; work-related stress; regulations; guidelines; international labor organization.*

INTRODUCTION

During the past two decades, work environments have undergone significant changes due to various factors, including implementing new technology leading to automated work practices, increasing workloads and intensity, expanding the service sector, and emerging employment trends. This transformation in the world of work has introduced new risks that impact the health and safety of employees (ILO, 2014). In addition to physical, biological, and chemical risks, these changes have given rise to emerging psychosocial risks. Among them, work-related stress, violence, and harassment are now recognized as significant challenges to occupational health and safety (Leka, 2011a). Societal factors, such as economic recession, further burden and worsen psychosocial risks in the workplace. These risks have serious economic implications for all types of businesses, regardless of size and sector (Leka, 2008). Overall, addressing these work-related factors and promoting a positive work environment is crucial for the well-being and productivity of employees. Companies should strive to create supportive and inclusive workplaces prioritizing employees' mental health and work-life balance to foster a more engaged and content workforce.

TERM, CHARACTERISTICS, AND TYPES OF PSYCHOSOCIAL RISKS AT WORK

Psychosocial factors encompass various aspects of work organization, design, and management. These elements include work demands, the level of organizational support, the presence of

rewards, and the quality of interpersonal relationships within the workplace. It's important to note that these factors aren't inherently positive or negative. However, when referring to psychosocial hazards, it suggests that these work-related aspects can negatively impact individual health and safety, as well as other detrimental organizational outcomes, such as increased sickness absence, reduced productivity, or human error. Psychosocial risk, by its definition, refers to the possibility that these psychosocial hazards may lead to harm (Leka, 2011b). Psychosocial risk is the risk of detriment to a worker's psychological or physical well-being arising from the interaction between the design and management of work within the organizational and social context (Cox and Griffiths, 2005). Cox's (1993) research highlighted the significance of various work-related factors that contribute to psychosocial risks in the workplace. These factors encompass a wide range of challenges that employees may face, impacting their well-being and overall job satisfaction. One critical aspect is the issue of excessive workload and work pace, which can lead to high levels of stress and exhaustion for employees. Additionally, job uncertainty, characterized by unclear job roles and a lack of job security, can result in feelings of anxiety and insecurity among workers. Another factor that can negatively affect employees' work-life balance is inflexible work schedules, making it challenging for them to manage their personal and professional responsibilities effectively. Additionally, irregular, unpredictable, or unsocial work hours can disrupt employees' regular routines and significantly impact their physical and mental well-being. Poor interpersonal relationships in the workplace are also a significant concern. Negative interactions with colleagues or supervisors can contribute to a hostile work environment, affecting employee morale and productivity. Furthermore, when employees feel excluded from decision-making processes, it can lower their motivation and overall job satisfaction. Unclear role definitions within the organization can lead to confusion and stress as employees struggle with undefined job responsibilities and expectations. Poor communication channels also hinder effective collaboration and can result in misunderstandings among team members. Moreover, limited career development opportunities can lead to employee dissatisfaction and reduced engagement with their work. Finally, the conflicting demands of work and home life can create stress and work-family conflicts, further impacting employees' well-being and overall job performance. In addition, some risks may be unique to specific organizations and can be identified through regular risk assessments. Moreover, new risks might emerge as workplaces evolve and change, underscoring the importance of continuous monitoring and adaptation of strategies to manage psychosocial hazards effectively. Work-related stress is strongly linked to exposure to psychosocial hazards. The Health & Safety Executive (2001) defines work-related stress as the adverse reactions people experience due to excessive pressures or demands placed on them in the workplace. On the other hand, the European Agency for Safety & Health at Work (EU-OSHA) describes stress as arising when individuals perceive an imbalance between the demands placed on them and the resources they have to cope with those demands. OSHA defines work-related stress as tension experienced when the work environment demands exceed the workers' ability to cope with or control them (Chirico, 2019). It is widely recognized that work-related stress is one of the major contemporary challenges facing occupational health and safety. It is commonly understood that a need for stress prevention activities is prevalent in all European countries and across all types of organizations. Additionally, harassment at work takes place when one or more workers or managers are repeatedly and intentionally subjected to abuse, threats, and/or humiliation in work-related situations. This behavior can have significant negative impacts on the targeted individuals' well-being and the overall workplace environment.

It is essential to acknowledge that there is frequent confusion surrounding the terminology related to psychosocial factors in scientific publications, policy documents, and practical guides. This confusion can hinder the clear understanding and interpretation of legal texts by courts, institutions, and stakeholders. Consequently, the effective management of psychosocial risks in the workplace may be compromised.

REGULATIONS OF THE INTERNATIONAL LABOR ORGANIZATION

These regulations and guidelines are key instruments of the International Labor Organization for promoting a safe and healthy working environment, including protecting of employees from psychosocial risks. ILO Member States may adopt these guidelines into their national legislation to ensure better protection of workers in their territories. The International Labor Organization (ILO) has several basic regulations and guidelines related to protecting employees from psychosocial risks at work. Here are some of the most important:

The ILO Convention No. 155 (ILO, 1981.), also known as the Occupational Safety and Health Convention, sets out the basic principles and guidelines for creating and maintaining a safe and healthy working environment for all workers and focuses on promoting occupational safety and health across various workplaces to prevent accidents, injuries, and occupational diseases. One of its key objectives is to encourage member states to develop and implement national policies and programs concerning workplace safety and health. It entails defining the responsibilities of both employers and workers in ensuring a safe working environment, including complying with safety regulations and cooperating in implementing safety measures. Furthermore, the convention stresses the importance of worker participation and consultation in safety and health matters. It recognizes the value of involving workers and their representatives in developing and implementing safety policies, as they bring valuable insights and experiences to the table. The identification and prevention of workplace hazards are also critical aspects addressed by the convention. Member states are urged to identify potential hazards, assess associated risks, and implement appropriate preventive and protective measures to mitigate these risks effectively. To ensure that workers are well-informed and equipped to handle safety and health issues, the convention highlights the need for adequate training and information. By empowering workers with the necessary knowledge, they can actively contribute to maintaining a safe working environment. In line with ensuring compliance with safety regulations, the convention encourages establishing inspection services. These services are crucial in monitoring workplaces to enforce safety and health regulations effectively.

The main objectives of *ILO Convention No. 190 (ILO, 2019)* are focused on addressing violence and harassment in the workplace, including psychosocial violence and abuse. The convention has a comprehensive scope, addressing a wide range of behaviors and situations that can constitute violence and harassment, encompassing physical, psychological, and sexual forms of violence, as well as bullying and mobbing. Its primary focus is on protecting workers, ensuring that all workers, regardless of their employment status, are safeguarded in a safe and respectful working environment free from violence and harassment. Another significant objective is the promotion of prevention and remedies. The convention emphasizes the importance of taking proactive measures to prevent violence and harassment, including awareness-raising initiatives, training programs, and implementing workplace policies that foster a culture of respect and safety. Additionally, the convention emphasizes the need for effective victim remedies and appropriate

sanctions for perpetrators to ensure accountability and justice. Accompanying Recommendation No. 206 provides further guidance and practical measures for implementing the convention's provisions. It offers guidance on policy development, prevention measures, complaint mechanisms, support and protection for victims, and training for employers and workers. Both the convention and the recommendation are significant steps towards promoting a respectful and safe working environment and ensuring the protection of workers' mental and emotional well-being, including addressing psychosocial risks.

The *ILO guidelines on psychosocial risks and stress at work* offer a comprehensive framework to address the well-being of employees in the modern workplace (Forastieri, 2016.). Employers can proactively identify and manage potential stressors by emphasizing the importance of risk assessment, early recognition, and intervention to create a healthier work environment. Training programs for both employees and managers equip them with the necessary skills and knowledge to cope with stress and support their teams effectively. Implementing supportive policies and fostering a positive workplace culture encourages open communication and employee participation, reducing stress and improving overall well-being. Involving trade unions and workers in the process through collective bargaining ensures that employee mental health remains a priority. Additionally, robust legal and policy frameworks at the national level provide the necessary structure for organizations to address psychosocial risks and stress holistically and systematically. These guidelines promote a supportive work environment, enhancing employee well-being and productivity. They also aid in preventing and managing psychosocial risks and work-related stress.

The Stress Prevention at Work Checkpoints document (ILO, 2012) is designed to help organizations proactively manage stress and psychosocial risks. It includes a set of practical checkpoints that can be used as a self-assessment tool to evaluate an organization's stress prevention measures and identify areas for improvement. The Stress Prevention at Work Checkpoints document presents a comprehensive approach to promoting a healthier and more supportive work environment. Encouraging organizations to conduct risk assessments, helps them identify and understand the psychosocial risks and stress factors present in their workplace. Furthermore, the checkpoints emphasize the importance of designing jobs and work processes to minimize stress and support employee well-being. Factors like workload, job demands, and job control can significantly impact employees' stress levels and overall satisfaction. Effective communication and employee involvement are vital components of the checkpoints. The guidelines also recommend training programs and support systems to equip employees and managers with stress management skills, empowering a more resilient workforce.

Fostering a positive workplace culture that values employee well-being and promotes open communication is also emphasized in the checkpoints. A supportive and inclusive culture can significantly impact employees' stress levels and job satisfaction. Finally, the document addresses the prevention of workplace violence and harassment, recognizing their potential as significant stressors for employees. By preventing such incidents, organizations can create a safer and more respectful work environment that further supports employees' mental well-being.

EU REGULATIONS

EU regulations represent the basic framework for protecting employees from psychosocial risks at work in the European Union. Each member state can additionally develop and implement its

laws and measures to ensure adequate protection of employees. Basic regulations of the European Union related to psychosocial risks at work include:

Directive 2003/88/EC, a significant European Union (EU, 2003) directive, focuses on various aspects of working time organization to safeguard workers' health and safety. It establishes minimum requirements to ensure decent working conditions and promote work-life balance across EU member states. Key aspects include setting a maximum limit on the average weekly working time, including overtime, not exceeding 48 hours per week. It aims to prevent excessive working hours and potential adverse effects on workers' well-being.

The EU directive (2019) Work-Life Balance Directive (2019/1158) aimed to ensure the right to decent working conditions and promote work-life balance for workers. By offering measures supporting work-life balance, the directive aims to prevent stress and psychosocial issues resulting from excessive work demands and insufficient personal and family time. It ensures adequate parental and carers' leave and encourages flexible work arrangements to enhance employees' work-life balance. This balance can reduce stress, improve mental well-being, and prevent work-related psychosocial problems.

European social partners signed the Framework Agreement on Work-Related Stress in 2004 (Broughton, 2004). It encompasses key elements designed to address and manage work-related stress for employees. It emphasizes the importance of prevention and risk assessment, encouraging employers to proactively identify stressors and take measures to mitigate their impact on the workforce. Creating a positive work environment that supports employees' well-being and work-life balance is also prioritized to reduce stress levels. The agreement promotes consultation and cooperation between employers and trade unions, involving employees and their representatives in the decision-making process to develop effective stress prevention measures. Training and awareness programs are recommended to help employees and managers recognize and manage stress effectively. Additionally, the agreement recognizes the significance of providing support systems for workers experiencing stress, including access to counseling services or employee assistance programs. Finally, collective bargaining is acknowledged as a means to address stress at work and protect the overall well-being of employees. By adopting these key elements, organizations can create a more supportive and stress-resilient work environment for their workforce. The Framework Agreement on Stress at Work is a voluntary instrument for employers and trade unions to promote a joint approach to tackling work-related stress. By working together and creating a supportive and healthy work environment, the agreement aims to prevent and manage stress at work, ultimately benefiting both employees and employers. It complements existing national legislation and other EU occupational health and safety initiatives.

CONCLUSION

The ILO (International Labor Organization) demonstrates its commitment to promoting a positive work environment that prioritizes workers' well-being and mental health through its actions in addressing psychosocial risks. The organization provides guidelines, recommendations, and conventions to empower employers, unions, and governments to prevent and manage psychosocial risks in the workplace proactively. One key aspect of the ILO's efforts is addressing violence, harassment, and discrimination issues, which can contribute to psychosocial hazards. Additionally, the ILO focuses on work-life balance initiatives, recognizing the importance of allowing employees to balance work and personal life to reduce stress and improve overall well-

being. As we move forward, it becomes crucial for stakeholders at all levels to collaborate and implement the ILO's recommendations and guidelines. By doing so, they can create a work environment that fosters mental well-being, encourages open communication, and provides robust employee support systems. Prioritizing the prevention of psychosocial risks, the ILO continues to play a vital role in shaping a more inclusive, respectful, and healthy world of work for everyone.

Overall, this convention represents a comprehensive framework for fostering a workplace culture of safety and health. By promoting collaboration between employers, workers, and regulatory authorities, it aims to create safer working conditions and ultimately improve the well-being of the global workforce.

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ANALYSIS OF THE EFFICIENCY OF SOUND BARRIERS AS A METHOD FOR PASSIVE CONTROL OF TRAFFIC NOISE

Velkovski T.[1], *Anachkova M.*[1], *Domazetovska S.*[1], *Chaloska J.*[1]., *Petreski Z.*[1]

[1] University "Ss. Cyril and Methodius" of Skopje, Faculty of Mechanical Engineering - Skopje, North Macedonia (e-mail: trajce.velkovski@mf.edu.mk)

Abstract: In recent decades, the introduction of stricter environmental noise laws has resulted in a series of noise reduction measures of a different nature. These include urban planning measures such as the designation of noise-sensitive areas, regulations on vehicle speed limits or traffic restrictions, measures to improve the acoustic performance of vehicles, pavements, and buildings, and the construction of noise barriers. The most used method to reduce noise on thoroughfares and highways is the installation of sound barriers that are constructed and constructed along the highway. There are three types of acoustic barriers, namely reflective, absorptive, and reactive. Absorbing barriers are opaque and contain a porous element that absorbs sound, such as fiber concrete and granulated concrete. Reflective barriers can be opaque or transparent and do not contain sound-absorbing material (concrete, cement, metal, or wood) in their construction. Reactive barriers are opaque and are constructed to have cavities or resonators that are designed to absorb or reduce only certain frequencies that are part of the noise they are exposed to. Determining the effectiveness of noise barriers has attracted the attention of researchers over the past 40 years, and a wide variety of mathematical and experimental methodologies have been developed to assess it.

Keywords: *environmental noise; noise control; sound barriers.*

INTRODUCTION

Experimental studies are based on different approaches related to the assessment of the effectiveness of sound barriers on the reduction of population anxiety (Nilsson, 2004), the effects of sound barriers on the quality of the urban environment (Young Hong, 2012), the measurement of noise propagation based on experiments with scaled models (Li, Q, 2020) and the measurement of the acoustic properties of real-scale barriers. Measurements of the acoustic properties of barriers are the most commonly implemented method and refer to the analysis of the effectiveness of barriers based on their different acoustic characteristics.

Many research studies address the intrinsic characteristics of barriers, such as sound absorption and insulation. Two types of measurement methods are commonly used to assess these properties: laboratory methods using a diffuse sound field in acoustic laboratories and field measurement methods.

Most of the research studies to date are based on the evaluation of the effectiveness of the barriers for the calculation of the loss factor after installation which is defined as the difference in the noise level before and after the installation of the barrier (Kotzen, 2014). Installation loss is an external characteristic of noise barriers, which depends mostly on on-site geometry, meteorological conditions, ground impedance, and the relative positions of the noise source and receiver. These factors are generally not independent of each other, so the total loss factor cannot be calculated by adding the partial loss factors after placing the barrier.

The international standard ISO 10847:1997 (Zhang, X, 2019) establishes two methods for assessing barrier efficiency through field measurements, namely the direct and indirect methods. The direct method is used when the barrier is not yet installed or can be removed. The noise level is measured before and after the installation of the barrier to determine the post-installation loss factor. In this method, adequate conditions must be ensured so that measurements before and after the installation of the barrier are carried out under equivalent weather and traffic conditions. The indirect method is used when the barrier is already installed and cannot be removed. In this case, the estimated noise level before the installation of the barrier is obtained by measuring a location considered equivalent to the location of the measurement. In the Republic of North Macedonia, sound barriers have been installed in several locations throughout the country, covering the major highways. In the capital city of Skopje, sound barriers have been installed at 2 locations, namely a reflective barrier at the transport center in the City Center and reflective and reactive barriers on the Ring Road for entering and exiting the city (Figure 1).

IMPLEMENTATION OF AN INDIRECT METHOD FOR ASSESSING THE PERFORMANCE OF SOUND BARRIERS

According to ISO 10847:1997, the indirect method implies an approach to be applied when the noise barrier is already installed at the designated location and cannot be removed in order to carry out field measurements according to the direct method. The indirect method is the only practical approach in the case of most new roads, where sound barriers are installed during road construction and therefore it is not possible to carry out a measurement before installation of the sound barrier under normal traffic conditions. This method was applied to assess the efficiency of two sound barriers that have already been installed in the city of Skopje, with the aim of providing insight into the degree of protection of the barriers from traffic noise, which turned out to be the dominant source of noise in the city. One location is the sound barrier at the Transport Center which is set up to protect a settlement from a busy street and intersection in the city center, as well as a railway that passes in the immediate vicinity, and the other is on the Ringroad outside the city which is set up to protect a settlement from highway noise (Figure 1).

The ISO standard specifies general criteria for measuring the effectiveness of barrier placement, including the acoustic environments of the measurement points, microphone positions, and noise source conditions. The standard also proposes generic principles to ensure and maintain sufficiently equivalent conditions between "before" and "after" measurements to enable accurate determination of the loss factor after barrier installation.

When using the indirect measurement method, it is necessary to select at least 3 measurement points, that is, a measurement point behind the barrier, a measurement point at an equivalent measurement location where no barrier is placed, and a measurement point in front of the barrier. According to the standard, in order to correctly choose a suitable equivalent measurement location and determine the estimated noise level before the installation of the sound barrier, it is necessary to ensure the same environmental conditions (meteorological and traffic conditions) at the two measurement points, where there are already installed sound barrier and where there is no protective sound barrier.

Defining these equivalent locations requires a close match in emission characteristics, relative positions of source, barrier, and receiver, ground surface acoustic performance, terrain profile, infrastructure, reflecting surfaces, and meteorological conditions. It is also necessary to ensure ground surface equivalence, which refers to the acoustic impedance of the ground along the source-receiver propagation path (i.e., ground cover acoustic features such as paved soil, vegetation, gravel, etc.) The ISO standard further requires that the environment in the 30 [m] distance region behind and to the side of the receiver positions be similar. To ensure the consistency and relevance of the results, measurements at both locations are preferably performed simultaneously.

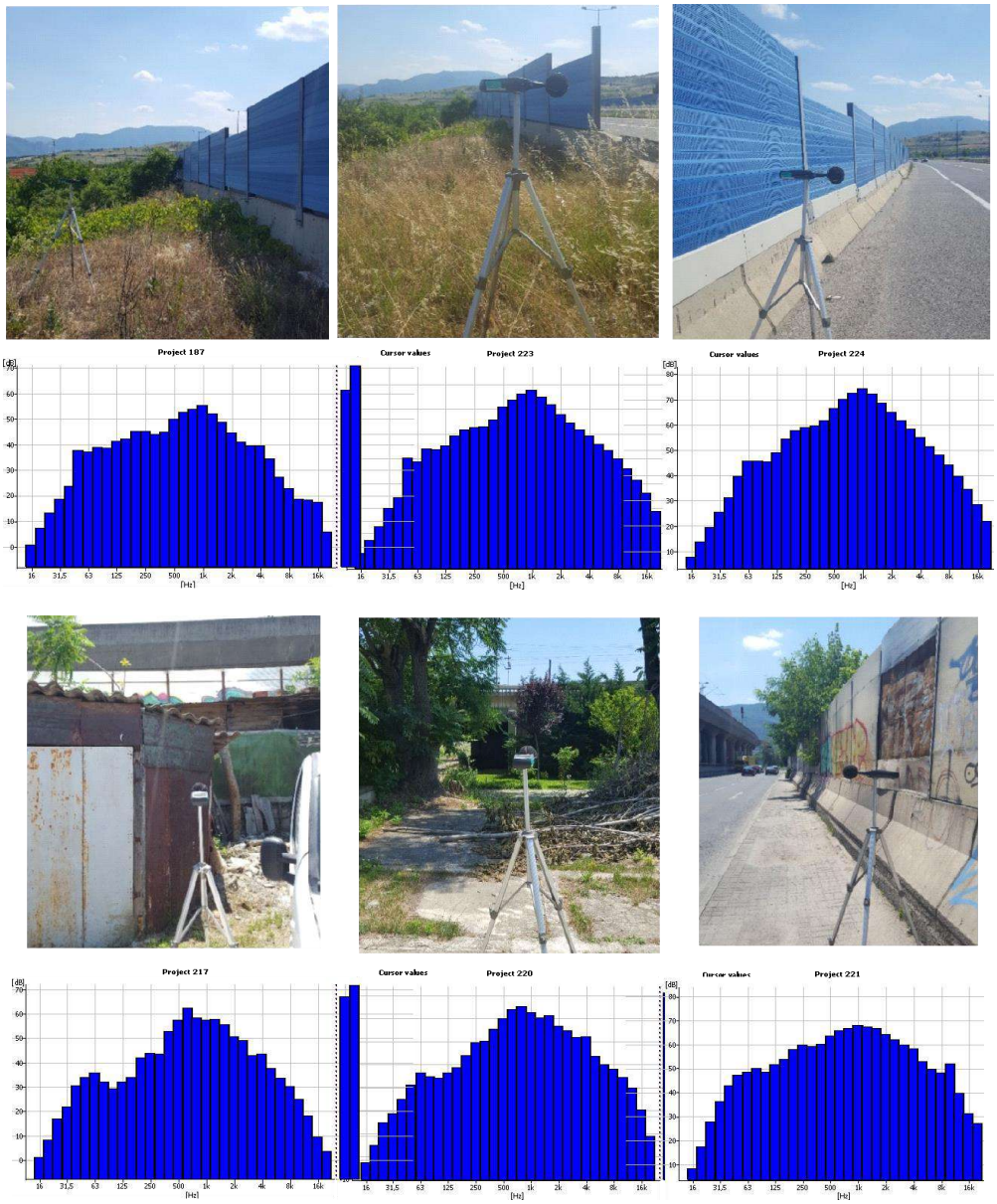

Figure 1. Measurement locations of sound barriers in the city of Skopje (top: Ringroad, bottom: in the City Center)

Most of the studies based on indirect methods use road traffic as a noise source. The ISO standard suggests that natural roadside noise be used as the sound source equivalence for the "before" and "after" measurements. The use of traffic noise has the obvious advantage of representing a

natural source, but also the lack of describing fluctuations in traffic volume, speed, and composition that can affect the accuracy of the results. The selected locations in the city of Skopje where sound barriers have been installed are exposed to an increased level of traffic noise, therefore the indirect method is an appropriate approach for determining their efficiency and assessing the degree of control and protection from traffic noise.

The ISO standard proposes general criteria that are a very general characterization of the open space behind the barrier, but there is no general standard for the locations of the receivers, that is, the measuring points. One of the key factors in using the indirect method is that the locations of the microphones relative to the noise source at the "before" and "after" positions should be identical, in terms of distance from the road and height above the road. Optional is the use of a reference microphone that takes into account the effect of possible fluctuations in the noise source, but it is assumed that possible fluctuations in the traffic during the measurements are not expected to significantly affect the results. The choice of these measurement points is largely determined by the possibility of finding equivalent locations to the "before" location. In most studies, microphones are placed at distances from the barrier that correspond to incremental doublings of the distance. The most common microphone height is 1.5 [m], although there are studies that consider additional heights that are similar to or higher than the barrier height (eg, 2, 4, 6 [m]).

RESULTS OF THE APPLIED METHOD FOR THE ANALYSIS OF THE EFFICIENCY OF SOUND BARRIERS

From the measurements carried out at the two selected locations in the city of Skopje, namely the ring road outside the city where sound barriers have been placed to protect the settlement from the noise from the highway and the location in the city center near the transport center where sound barriers have been placed to protect the settlement from noise from the street, intersection, and railway line, results were obtained for the level of total noise caused by these sources. Namely, Figure 2 presents the results for the noise level in front of the sound barrier and behind the sound barrier of the Ring Road in the city. From the results, the differences in the noise level before and behind the barrier in the entire frequency range are noticeable, which indicates that the sound barrier has a major role in reducing the noise at this location.

What is notable is the significant difference of 14 [dB] in the noise level in front of and behind the barrier which is greatest at a frequency of 1 [kHz] which is considered dominant when it comes to traffic noise.

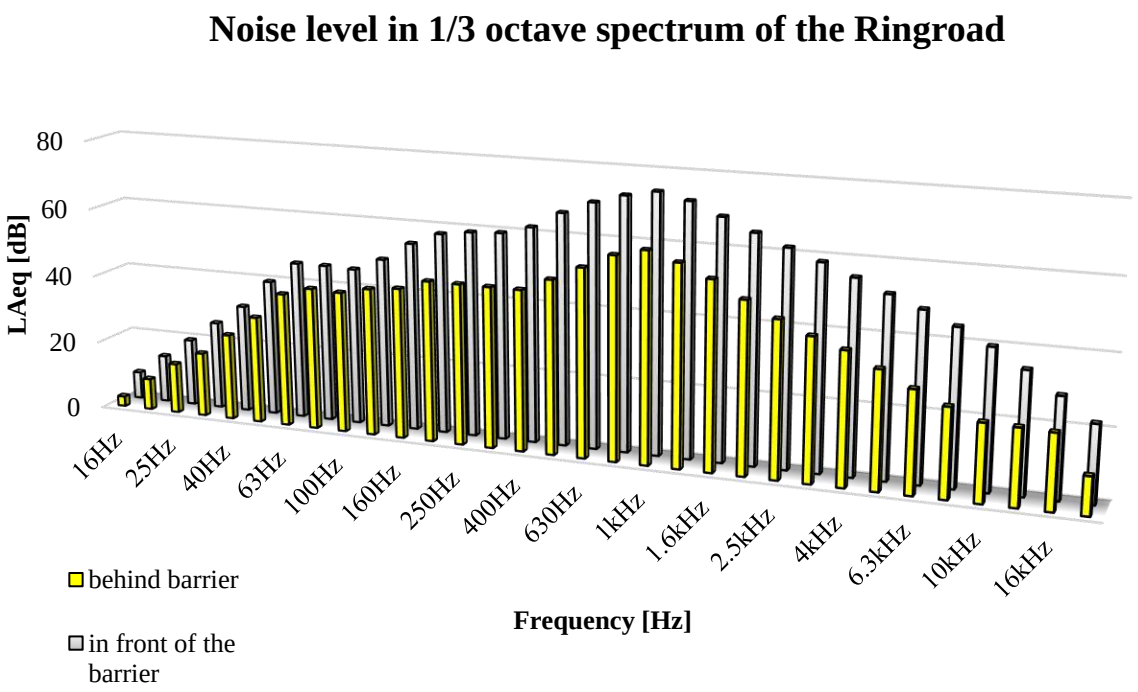

Figure 2. Results of the measured values for the noise before and behind the barrier placed on the ring road in the city of Skopje

Figure 3 presents the results of measured noise levels in front of and behind the sound barrier at the City Center location. The differences in noise levels in [dB] are obvious, but here you can also notice pronounced differences at other lower frequencies such as 31.5 [Hz] where the difference is approximately 18 [dB], and at higher frequencies such as 16 [kHz] where the difference reaches 28 [dB]. This difference in the discrepancies in the noise levels at different frequencies in one and the other location is probably due to the fact that other sources of noise are present in the location in the city center in addition to traffic (dominant source of noise from construction activities was observed, noise from barking of dogs, as well as noise from railway traffic), while at the measuring location of the ring road, the dominant source of noise is only traffic.

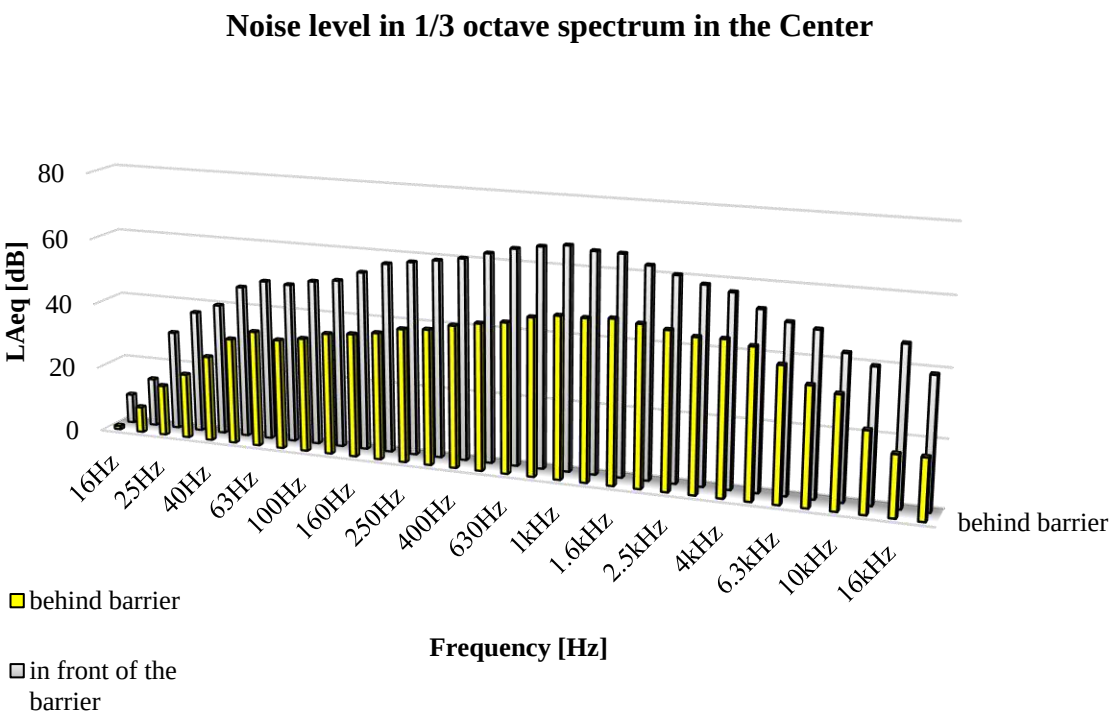

Figure 3. Results of the measured values for the noise in front of and behind the barrier placed in the Center of the city of Skopje

CONCLUSIONS

The conducted analyses that were presented in this chapter indicate that among the many factors that increase the level of noise in the city of Skopje, one of the most influential is road traffic noise. The noise map of the selected area in the city of Skopje "Debar Maalo" represents a really important first step for future work in the whole city to deal with the problem of noise pollution. Traffic noise mapping technology is convenient because it allows, through an easily accessible collection of traffic flow data, to provide a visual representation of the noise situation and the distribution of the noise level across the area, particularly focusing on the traffic noise problem. On the other hand, the validation of this methodology using a conventional methodology based on acoustic measurements provides a good solution for a better understanding of the causes of sound pollution and the impact of traffic noise on the total noise level. The discrepancies in the noise levels during the night and daytime hours that were ascertained are due to the difference in the noise sources in the night period of the day in relation to the day and evening periods. This may lead to the conclusion that traffic density at night is lower, but other sources such as human speech or music may be dominant. Therefore, additional analysis of the presence of different types of noise sources and their impact should be done in order to provide a more accurate insight into the noise situation in the area.

On the other hand, the most commonly applied solution to the problem of increased noise levels caused by road traffic is the installation of sound barriers where necessary in order to protect a certain neighborhood that is significantly exposed to noise, and in the city of Skopje, such sound

barriers have been installed only in a few locations. According to the research conducted in this chapter, the barriers installed in the city show a solid performance with a noise reduction rate of more than 10 [dB] in the entire frequency range. What was observed from the conducted analyses of the results at both locations is that the sound barriers show better characteristics at higher frequencies, while they show a lower rate of sound intensity reduction at lower frequencies. From here it can be concluded that sound barriers are an appropriate solution where protection is needed from traffic noise that is dominant at frequencies of 1 [kHz] and higher, but for locations where various sources of noise occur at lower frequencies, their application is not sufficient for complete noise protection and control. For this purpose, the research work is directed towards the development of systems for active sound control, the purpose of which is to deal with and control low-frequency sounds, which are often a source of unpleasant sound in the environment in addition to traffic noise.

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WORKPLACE INJURIES AT BIOGAS PLANTS

Viskovic M.[1], Djatkov Dj.[1], Zoraja B[1], Nesterovic A.[1]

[1]Faculty of Technical Sciences, Trg Dositeja Obradovica 6, Novi Sad (e-mail: miodragviskovic@uns.ac.rs)

Abstract: The nature of biogas production leads to a range of hazardous situations and potential workplace injuries. The aim of this study is to conduct a quantitative analysis of workplace injuries in biogas plants in Serbia, define the current state of occupational safety and health in the field, and provide guidelines. The analysis exclusively focuses on agricultural biogas plants. Data collection was carried out in two ways: through a targeted questionnaire and by phone. The installed capacity of the plants that responded represents approximately 60% of the total capacity in Serbia. The number of workers covered by the collected data is 85, with varying profiles. A total of 5 minor injuries were identified (fractures, cuts, impacts) because of equipment maintenance, and the injured workers were biogas plant operators. Almost all plants outsource their occupational safety and health obligations to specialized agencies. The research will continue to encompass other biogas plants, aiming to cover a larger number of workers in this field.

Keywords: *biogas; safety; injuries.*

INTRODUCTION

Biogas plants have become an important component of energy strategies globally, including in Serbia. Biogas is produced through the anaerobic fermentation of organic material such as manure, energy crops, and organic waste, primarily from industries, and represents a significant source of renewable energy. In Serbia, biogas plants play a relatively important role in the sector of generating so-called green electricity, but their significance increases when addressing waste management, promoting sustainable agriculture, and mitigating greenhouse gas emissions.

Although they essentially act as high-tech factories, biogas plants are not risk-free. The nature of biogas production, its properties, the configuration of the plants, and the equipment used, can potentially lead to a range of hazardous situations, opportunities for workplace injuries, and even incidents with fatal outcomes. There are dangers from electrical installations; dangerous substances are both used and produced; and there are risks of explosions, fires, and mechanical dangers (Bontempo, 2016).

A literature review in this field indicates the need for a comprehensive understanding of potential hazards and recommends appropriate protective measures. Huess Hedlund and Madsen (2018) describe a gas poisoning incident during the unloading of food waste at a biogas plant. This accident prompted many researchers to delve deeper into the potential dangers of biogas facilities since the inadequate response by workers and authorities, who failed to recognize the cause of poisoning and drew several incorrect conclusions, highlighted ignorance of the potential issue of hydrogen sulfide (H_2S) occurrence. Carboni et al. (2021) specifically address the safety of the working atmosphere concerning H_2S concentration, pointing out that this gas can be toxic even tens of meters from the emission source. For instance, Stolecka and Rusin (2021) study the potential hazards that can occur in biogas facilities and emphasize that gas storage of average capacity could cause an explosion if there are malfunctions in safety valves, with a potential explosive zone reaching up to 50 meters. Severi et al. (2022) identified critical operational risks

in biogas processing plants using a multicriteria decision-making approach, emphasizing that if there's an additional purification step to obtain purified gas forms, these extra purification units are the riskiest parts of the plant. The degree of automation has been recognized as a vital factor in improving efficiency and safety in biogas plants (Sahu, 2017). Procedure errors and component malfunctions are crucial for risk assessment document creation in biogas plants (Barozzi, 2021). Explosion protection is of fundamental importance for biogas plants, according to Schroeder et al. (2014), emphasizing the potential danger these plants can pose if not managed appropriately. Works by Casson Moreno et al. (2016, 2018) are dedicated to identifying key safety barriers in biogas plants.

Travnicek et al. (2018) conducted a quantitative analysis of accidents in biogas plants across Europe. From 2006 to 2016, they identified approximately 200 accidents of various causes, with 10 fatalities caused by asphyxiation due to toxic gas inhalation.

The first agricultural biogas facility in Serbia began operations in 2012, and to date, there has not been a single accident that can be categorized as a fire, explosion, or leakage according to the classification of accidents provided by Travnicek et al. (2018). This claim is based on the authors' knowledge of the situation in biogas plants in Serbia. However, it is entirely unknown if there have been workplace injuries at biogas plants, and if so, their nature. Officially available work injury reports do not distinctly recognize this category of plants, making it impossible to conclusively draw conclusions about the number and types of injuries (MINRZS, 2019, 2020, 2021, 2022, 2023). Furthermore, it is unclear if these reports categorize such facilities under electricity supply activities or agriculture. In Serbia, no scientific work has been identified that deals with the quantitative analysis of accidents and/or workplace injuries at biogas plants. The aim of this study is to conduct a quantitative analysis of workplace injuries at biogas plants in Serbia, define the state of occupational safety and health, and provide guidelines.

MATERIAL AND METHOD

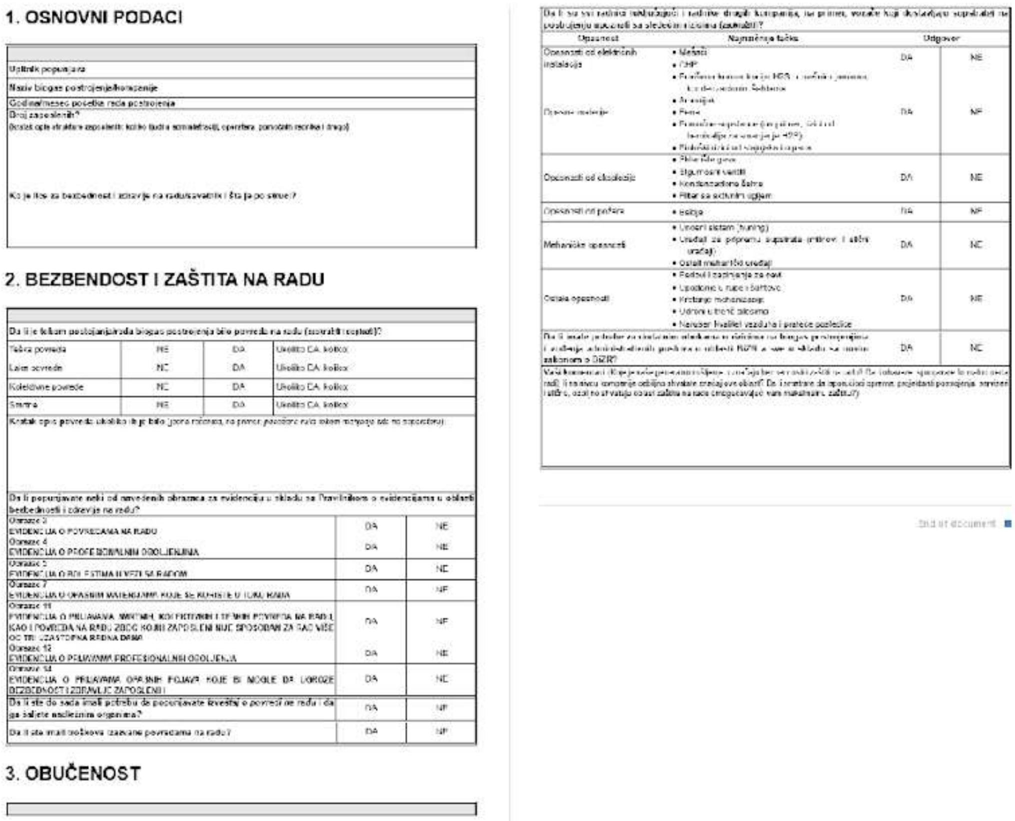
Material

In Serbia, there are industrial biogas plants (part of industrial production with the aim of treating generated waste), biogas plants within wastewater treatment plants, and agricultural biogas plants. The process is similar in all, but there are significant differences in the technological equipment used. The most notable difference lies in the substrates (raw materials) used for biogas production and the fact that agricultural biogas plants operate as independent legal/business entities. This study exclusively focuses on agricultural biogas plants. By the end of 2022, there were 28 locations with operational biogas plants. Two plants ceased operation but are covered in this study. The total installed electrical power of operational biogas plants is approximately 33 MW. Individual plant power ranges from 0.5 MW to 3.7 MW. All plants have fermenters, one or more gas storage units, cogeneration units for biogas combustion and electricity generation, gas pipelines, pumps, compressors, and flares for burning excess biogas. Variations exist in terms of substrate input equipment (for solid and liquid substrates), pretreatment (usually physical), mass mixing within fermenters, gas desulfurization (physical or biological principle), and the use of additional fuel – natural gas. All facilities are based on so-called wet fermentation, and absolutely all biogas plants burn biogas to generate electricity. The number of workers varies; the minimum is three, and the total number does not exceed 15. It depends on the level of automation, substrates used (e.g., using waste materials or milled harvest

residues requires more auxiliary workers), and the level of integration with the agricultural company from whose activities the plant originated (a farm or agricultural company).

Method

Data collection was conducted in two ways. Initially, a targeted questionnaire was sent to the managers of all biogas plants, shown in Figure 1. The questionnaire was designed to collect a series of general data, focusing on the number of employees and the person responsible for occupational health and safety/advisor. The questionnaire asked about the number of injuries, the level of injury (severe, minor, collective, fatal), and its description. A question was also posed about the fulfillment of obligations – completing records in accordance with the Regulation on Records in the Field of Occupational Safety and Health. The final part of the questionnaire relates to the level of information and training, with questions on awareness of hazards from electrical installations, hazardous substances, explosions, fires, mechanical, and other dangers. In addition to the questionnaire, data was also collected over the phone, as the initial response was very low. The analysis of the collected data was conducted using basic elements of descriptive statistics.



1. OSNOVNI PODACI

Naziv biogas postrojenja/kompanije

Broj zaposlenih?

2. BEZBENDOST I ZAŠTITA NA RADU

Teška povreda	NE	DA	Ukoliko DA, koliko:
Laka povreda	NE	DA	Ukoliko DA, koliko:
Kolektivne povrede	NE	DA	Ukoliko DA, koliko:
Smrtna	NE	DA	Ukoliko DA, koliko:

Obrazac 3 EVIDENCIJA O POVREDAMA NA RADU	DA	NE
Obrazac 4 EVIDENCIJA O PROFESIONALNIM OBOLJENJIMA	DA	NE
Obrazac 5	DA	NE
Obrazac 7	DA	NE
Obrazac 11	DA	NE
Obrazac 12	DA	NE
Obrazac 14	DA	NE

3. OBUČENOST

Opasnost	Najmanje tačke	Odgovor	
Opasnosti od električnih instalacija		DA	NE
Opasne materije		DA	NE
Opasnosti od eksplozije	• Sigurnosni ventili • Filter sa aktivnim ugljem	DA	NE
Opasnosti od požara		DA	NE
Mehaničke opasnosti	• Ostali mehanički uređaji	DA	NE
Ostale opasnosti		DA	NE
		DA	NE

Figure 1. The questionnaire used work data collection.

RESULTS AND DISCUSSION

Of the 28 questionnaires sent out, responses were received from 7 plant managers. Oral responses via telephone were given by 9 managers. Information of interest was received from 16 locations in total, while 12 facilities provided no response whatsoever. The installed power of the plants that responded amounts to approximately 19 MW, representing roughly 60% of the total capacity in Serbia. The total number of workers covered by the collected information is 85, varying

in hierarchy levels within the biogas plants. The average number of employees in agricultural biogas plants in Serbia is around 5. Though it wasn't possible to provide an exact structure of the workers based on the provided information, it's clear that most employees occupy the position of biogas plant operators (at least two are mandatory). These individuals work with machinery, maintain equipment, and often oversee a whole plant process. Three plants identified a category of auxiliary workers (though the authors suspect that more biogas plants employ auxiliary workers). These workers handle tasks like opening food waste packaging or milling harvest residues, and some are strictly drivers. Biogas plants also employ staff in departments like accounting, and often, the plant owners themselves hold managerial positions. Administrative workers are the least common. One problem in quantifying the number of employees and their positions is that many biogas plants, even if they formally represent a separate legal entity, practically fall under a larger company where certain administrative tasks are performed by individuals who aren't formally employed solely at the biogas plants.

In terms of gender representation, men predominantly occupy positions at the plants, with women being the exception, mainly in administrative and managerial roles. Of the 16 plants, only one facility has an employee dedicated to occupational health and safety. All the others have outsourced this responsibility to a third-party agency.

In total, 4 biogas plants reported 5 minor injuries that occurred during their operation period. Of these, 2 injuries were fractures, and the rest were various physical injuries such as cuts and blows. Among the plants that reported injuries, those that have been in operation longer weren't necessarily dominant as one might expect. It's noticeable that among the plants that reported injuries, the number of employees was higher than the average, suggesting a potential correlation. No facility reported cases of severe, collective, or fatal injuries.

Based on the questionnaire responses and oral data collection, the determined injury count isn't realistic. The authors are aware that at least one plant didn't provide injury information due to ongoing legal proceedings. It's possible that there were workplace injury cases in other biogas plants that chose not to provide this research with information.

Descriptions of injuries and their causes indicate that injuries were solely due to workers' carelessness. Fractures, cuts, and blows weren't caused by inappropriate equipment. All 5 injuries occurred during equipment maintenance and can be categorized as injuries resulting from mechanical dangers. 86% of all injuries at biogas plants result from mechanical hazards (Bontempo, 2016), a finding consistent with the results of this study.

Regarding obligations in the form of completing forms according to the Regulation on Records in the Field of Occupational Safety and Health, all plants responded positively. However, it's evident that they're unfamiliar with the documentation. They're certain they've filled out certain forms at some point, but they're unsure about others. It's confusing that some forms are filled out by them, while others are filled out by the hired agency. Specifically, only one facility reported sending the Injury at Work Report to the competent institution.

Regarding worker education, every plant stated that they take the field of occupational safety and health very seriously, primarily due to the fear of potential serious injury or death, and potential employee lawsuits. In terms of specific costs to the facility caused by workplace injuries, only one facility reported an injury that resulted in compensation to the worker. In terms of training and understanding hazards, every facility reported awareness of hazards from electrical installations, dangerous substances, explosions, fires, mechanical and other dangers. However, informal

conversations the authors have had with operators suggest that working with potentially dangerous chemicals like $FeCl_3$ and $FeCl_2$, various chemical additives to enhance the process, the presence of H_2S and its negative effect, as well as anoxic zones that occur in condensation manholes are not well known to operators, or they don't pay enough attention to these hazards.

One biogas plant mentioned an instance of working with a company that was hired for fermenter maintenance, but they noticed that the workers were not informed about potential risks associated with fermenter maintenance, highlighting it as a negative experience. Specifically, they criticized the lack of appropriate safety equipment for working in potentially toxic environments.

Plants report having periodically organized training sessions where workers are informed about potential dangers. The authors are aware that the Biogas Association of Serbia has also organized public training sessions on occupational safety and health. However, these were mostly attended only by facility management and administrative employees, not by those directly exposed to potential risks at the biogas plant.

CONCLUSION

Agricultural biogas plants in Serbia have been present since 2012 and employ between 100 and 150 workers as of 2023. Of the 85 workers covered in this study, a total of 5 minor injuries (fractures, cuts, blows) have been identified. Although potential hazards are varied, all identified injuries were the result of equipment maintenance, and the injured workers hold positions as biogas plant operators.

The trend in fulfilling administrative obligations in the field of occupational health and safety shows that practically all plants transfer this obligation to specialized agencies. Regarding worker education, information accessibility, and awareness of the necessity of health and safety, it is concluded that the situation is satisfactory but there is room for further improvement. This particularly refers to enhancing the transparency of information and specifying training focused on preventing physical injuries that occur during equipment maintenance. It is recommended to emphasize to workers the necessity of using protective equipment and strictly adhering to safety instructions and equipment manufacturer's maintenance guidelines.

Further research should include the remaining agricultural biogas plants. A potential reason for not providing data for this study could be an unfounded fear of complications which mentioning workplace injuries might cause. Additionally, it would be desirable to include biogas plants that are part of industrial facilities and wastewater treatment plants in the study but primarily focus on workers performing tasks at the biogas plant itself. By including such plants, as well as upcoming agricultural plants expected to become operational in the coming period, combined with those discussed in this paper, a significant number of workers in this field in Serbia would be covered. The obtained data will also provide a basis for clearly positioning such enterprises in official reports on workplace injuries, enabling a systematic approach and the necessary measures to improve the state of occupational health and safety.

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SYSTEM OF OCCUPATIONAL SAFETY IN THE REPUBLIC OF SERBIA AND THE REPUBLIC OF SRPSKA (B&H)

Vranješ B.[1], Zoraja B.[2]

[1]University of Banja Luka, Faculty of Mechanical Engineering, S.Stepanovića 71, Banja Luka, Republic of Srpska (B&H) (e-mail: biljana.vranjes@mf.unibl.org)

[2]University of Novi Sad, Faculty of Technical Sciences, Trg Dositeja Obradovića 6, Novi Sad, Republic of Serbia

Abstract: Healthy and safe working conditions are a prerequisite for a healthy and productive workforce. The aim of the paper is a comparative analysis of the situation in the two states, the Republic of Serbia and the Republic of Srpska, in order to establish the basis for future joint research. This paper will show mechanisms for managing occupational safety and health in the two countries. In addition, one of the indicators for identifying the OSH situation in a country will be analyzed. As an explicit indicator of the situation, injuries at work were chosen. The trend of injury growth is specific for both countries, as opposed to the situation in the EU. In addition to the visible increase in the number of injuries, there are differences in the management of databases and the collection of data on injuries, which will be the subject of future research.

Keywords: *safety; health; analysis; work; injuries.*

INTRODUCTION

Occupational safety and health (OSH) must be an inseparable part of the work process. Protection and safety at work refers to the working conditions and the work position itself. The life and health of each employee is a very important issue within the work process since the employees spend so many hours per day at work. Depending on the work position, the employees are exposed to different dangers and harmfulness to their lives and health. Thus, the principle human right of righteous and suitable work conditions must be obeyed, and it should represent the responsibility and obligation of the entire society. Apart from health and well-being, there are strong economic reasons for a high level of worker protection. At the same time, it ensures the protection for employers from unforeseen and uncontrollable economic and material losses caused by accidents because of the non-application of safety and health measures at work. The costs of work-related accidents and diseases for the EU economy amount to more than 3.3% of GDP per year, for example around EUR 460 billion in 2019. Although the welfare implications behind these figures are immeasurable, good occupational safety and health practice helps businesses become more productive, competitive, and sustainable. Estimates show that for every euro invested in OSH, the return for the employer is approximately twice as high. The International Labor Organization established OSH as the primary international labor standard, and the Labor Law considers OSH as one of the basic legal principles within labor relations (European Commission, 2021).

The goal of the work is a comparative analysis of the situation in two countries Republic of Serbia (Serbia) and the Republic of Srpska (B&H), in order to establish a base for the next planned joint research. This paper graphically shows and describes the mechanisms for managing safety and

health at work in two countries. Additionally, will also analyze one of the indicators for OSH state identification in some countries. For the explicit presentation of the situation, injuries at work were chosen.

MATERIAL AND METHODS

The functioning of the OSH system, primarily through the application of certain measures (legal, technical, organizational, health, personal protective equipment, and others that also can be considered as indicators of OSH) should ensure the protection of the physical, psychological and health integrity of workers at the workplace. Another aspect of the effective functioning of OSH is reflected in its wider economic and social importance (additional indicators), which can be seen from the number of interested parties that participate in this system (employers, employees, state authorities, customers, insurance companies, trade unions, etc.). The immediate consequences of unfavorable working conditions and the non-functioning of the OSH system are also manifested in the form of indicators such as injuries at work, occupational diseases, work-related illnesses, and other diseases of occupationally exposed persons.

In the Republic of Srpska, as well as in Serbia, OSH is understood as an activity of general interest, which in the working environment should achieve safety, protection of health, and workability and eliminate, prevent, and reduce the effects of hazards and harm that can be the cause of injuries at work, professional, and work-related diseases (Šobat, 2021). The basic management of the OSH system is carried out at two levels:

1. Micro level, management at the level of each business system;

2. Macro level, at the state level, with organizational professional support for management at the public level.

As an indicator of the state of these systems, injuries at work will be used, followed in the next section. For this basic analysis, injuries are shown in accordance with available data, while more comprehensive research will follow in the next papers.

Republic of Serbia

The OSH management system in Serbia is shown in Figure 1. Simplified, OSH is the responsibility of the Ministry of Labour, Employment, Veterans and Social Affairs. The Ministry includes two administrative bodies active in the subject area, the Directorate for Safety and Health at Work, which, among other things (professional exams, and licences), prepares laws and regulations, and the Labor Inspectorate responsible for supervising its implementation. The Ministry directly cooperates with other authorities, primarily the ministry responsible for health, institutions responsible for health, pension, and disability insurance, as well as with social partners, etc. The management of the OSH system at the employer level begins with the drafting of the Rulebook on Rights, Obligations, and Responsibilities and the Act on Risk Assessment at Workplaces in the working environment, which procedurally identifies and analyses all hazards and harms at workplaces in a specific production and business system. Also, including the decision on appointing a person for OSH. The next important step is the training of employees for safe and healthy work, in accordance with the identified hazards and harms, established risks, and given measures, for which a training program is adopted. Employees have the right to elect one or more representatives in the OHS Committee and join to a Union established for more effective

protection of their rights (Directorate for Occupational Safety and Health, 2018, 2019, 2020; Labor Inspectorate 2018, 2019, 2020).

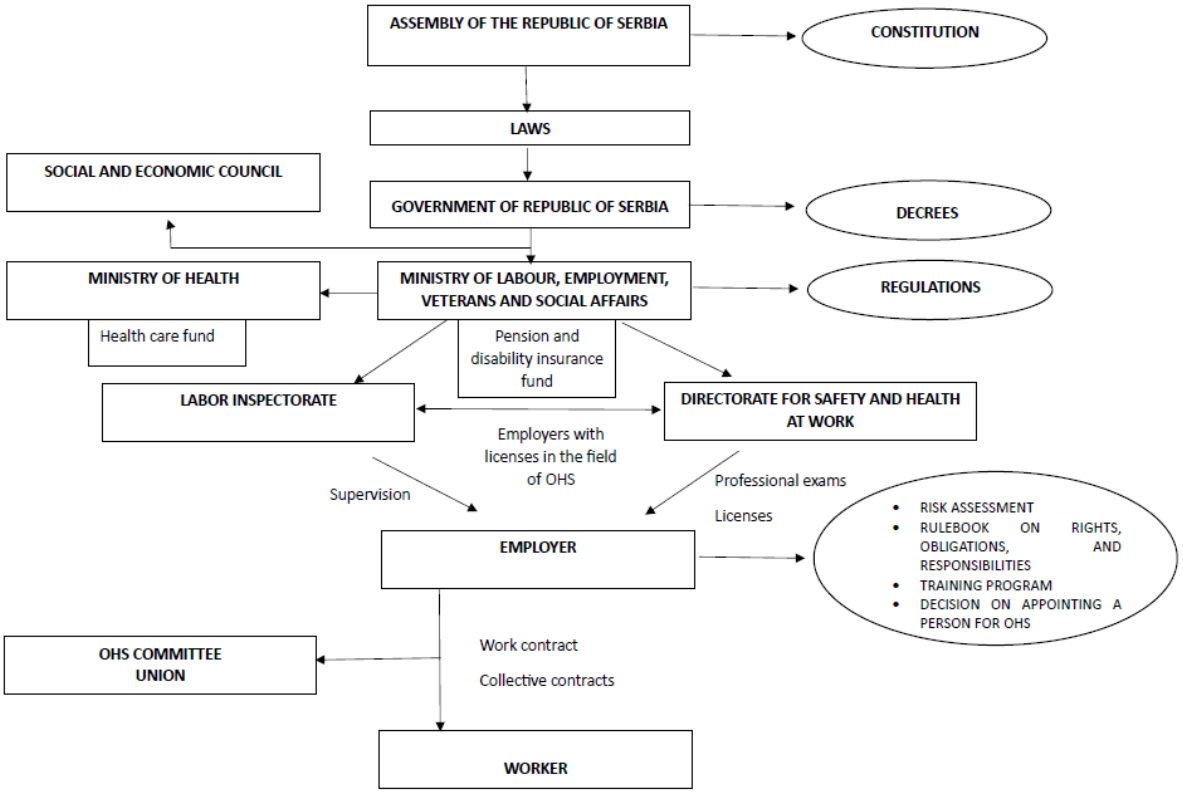

Figure 1. Presentation of the OSH management system in Serbia

Republic of Srpska

Figure 2 shows levels of management in the Republic of Srpska OSH system. The complexity of the state-political organization of Bosnia and Herzegovina (the existence of two entities: the Republic of Srpska and the Federation of Bosnia and Herzegovina and the Brčko District) caused the management of the OSH system, which implies the state level, to be transferred to the entity level. The management of OSH at the state level is within the scope of the competence of the institutions of the Ministry of Labor, War Veterans and Disabled Persons' Protection, and the Republic Administration for Inspection Affairs related to OSH. The Economic and Social Council at the level of the Republic, through the work of the Committee for Occupational Safety and Health, systematically monitors the state of safety and health at work. Occupational health and safety management at the business level is the most important part in the sense that all workers in all categories of business entities are provided with the exercise of OSH rights. By analyzing the legal regulations in the Republic of Srpska, the following requirements for planning and organizing OSH can be determined:

- planning: determination of rights, obligations, and responsibilities in the area of OSH (collective agreement, general act); that the work process, work environment, means of work, and means and equipment for personal protection at work are regulated and produced in accordance with the principles of OSH; implementation of the risk

assessment procedure with all necessary documentation, resources, information and coordination of persons involved in the risk assessment process;

- organization: adoption of an Act on risk assessment for all workplaces in the working environment with preventive measures; occupational health and safety jobs (employee or authorized organization with a license); informing workers or their representatives about all OSH issues, especially about the measures taken; cooperation of workers and/or their representatives with the employer in activities related to solving the issue of OSH (Vranješ, 2020.).

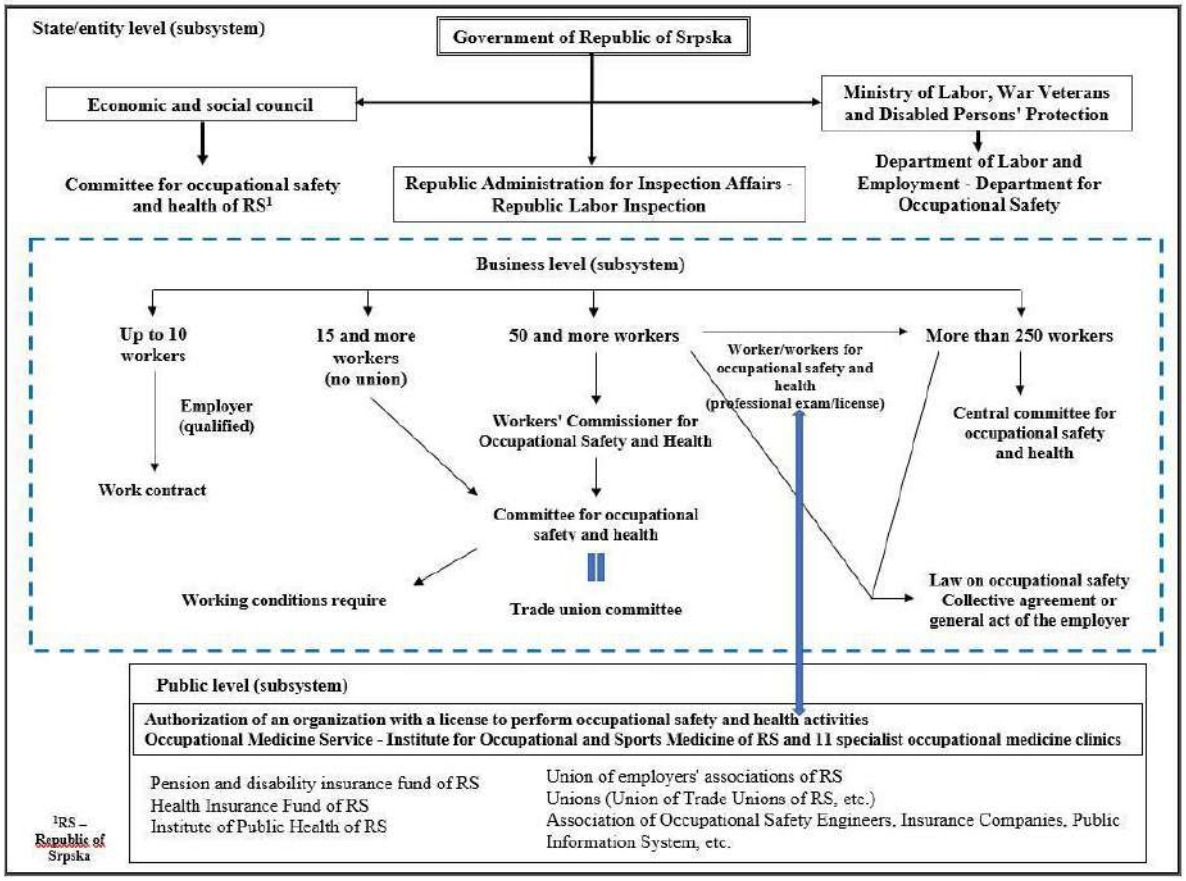

Figure 2. Organizational structure of the OSH system management in the Republic of Srpska (Vranješ, 2017)

For both countries the field of OSH is regulated through Law (adopted in 2023 in Serbia, 2008 in Srpska) in such a way as to define the rights, obligations, and responsibilities of all participants in the OSH system, primarily: employers and workers. Specific areas are managed by regulations (rulebooks). Until new regulations are adopted, a certain number of regulations from the previous period are applied. Strategy for the period 2021-2024. the improvement of the legislation on OSH of the Republic of Srpska is foreseen.

DISCUSSION AND RESULTS

Unfavorable working conditions in the working environment (presence of dangers and harmfulness) are manifested in the form of direct consequences - the frequency of accidents at work and indirect consequences in the form of economic consequences that accidents at work cause in the company's operations. To monitor these consequences, absolute (number of injuries at work, dynamics of injuries at work, number of lost working days due to injuries at work, etc.) and relative indicators (frequency of injuries at work, injury severity index, etc.) are used. The state of the OSH system described above results in the absolute indicator of injuries for the Republic of Serbia shown in Figure 3, and the relative indicator of injuries for the Republic of Srpska shown in Figure 4.

Republic of Serbia

Figure 3 shows the trend of fatal and serious injuries, given in the Labor Inspectorate Reports (Labor Inspectorate, 2018, 2019, 2020). For the observed period, the number of fatal injuries has increased, while serious oscillate. During 2020, there was an evident decrease in the number of injuries, which is directly related to the pandemic and the working conditions that have changed. Data on injuries provides different institutions: the Labor Inspectorate, the Directorate for Occupational Safety and Health, and the Health Insurance Fund, which are not harmonized, and only one kind is presented in this paper. Since 2019, the Occupational Safety and Health Administration has started applying the ESAW methodology for the processing and analysis of work injuries, which enables a more precise analysis of work injuries and the possibility of developing strategies to reduce work injuries in accordance with the given results. The analysis of these data will be the subject of future research and papers.

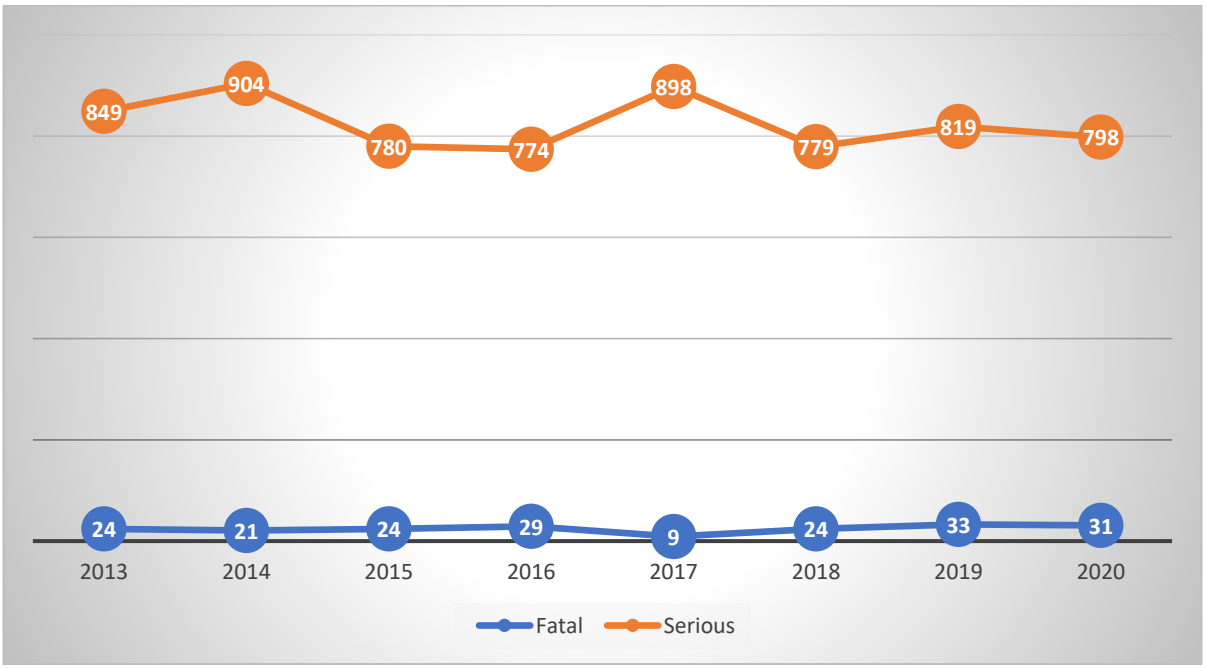

Figure 3. The trend of fatal and serious injuries in Serbia over the years

Republic of Srpska

Figure 4 shows the trend in the Republic of Srpska of an increasing number of injuries in relation to the number of employed workers, except in the case of fatal injuries, which have a slight

downward trend. Available official data for the Republic of Srpska are given only for minor injuries and analysis period 2018-2020 in the Strategy (Ministry of Labor, War Veterans and Disabled Persons' Protection, 2021). Shown in the image below are the author's data, collected verbally at official meetings and conferences. Data on the number of employed people in the Republic of Srpska were taken from the Statistical Yearbooks of the Republic Institute of Statistics (Republica Srpska Institute of Statistics, 2022).

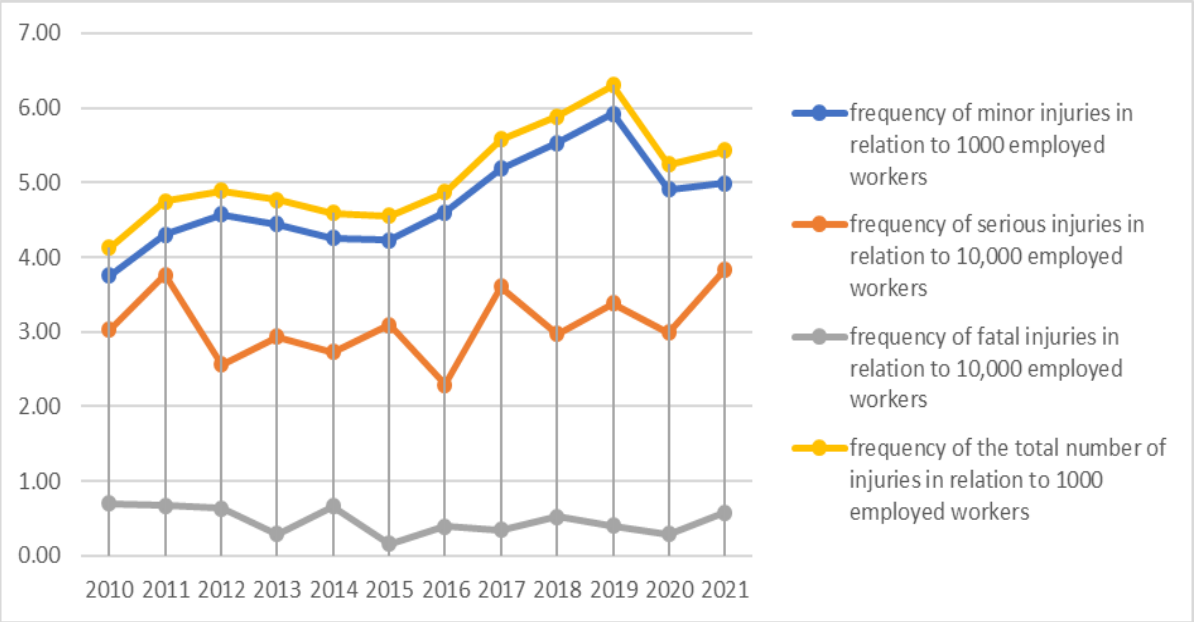

Figure 4. The trend of injuries in the Republic of Srpska in relation to the number of employed workers

According to EU Strategy for 2021-2027 in the last three decades, considerable progress has been made in the field of occupational safety and health: the number of fatal accidents at work in the EU decreased by around 70% between 1994 and 2018 (European Commission, 2021). The data presented for both countries indicate that this trend differs. In these countries, there is a growth trend with occasional oscillations, but not enough to say that there has been a general improvement.

Therefore, maintaining and improving worker protection standards is a permanent challenge and need. Several major conclusions can be made:

- A unified injury database with the sole approach to collecting data on work injuries is necessary for the improvement of work safety.
- In the Republic of Srpska, injuries should be processed in accordance with the recommended ESAW European methodology.
- Management should motivate workers at all levels to be actively involved in all aspects of the organization's health and safety management system (Živković, 2008).

The system for reporting injuries at work (minor, serious, or fatal, occupational, and work-related diseases) is slow, outdated, and disconnected from the institutions responsible for collecting, monitoring, and analyzing injuries. The result of such a situation is an incomplete analysis and an inadequate assessment of how much the work process suffers due to injuries at work, nor how

much the budget of the Republic of Serbia and Republic of Srpska costs to rehabilitate injuries or treat occupational diseases. These circumstances prevent a realistic assessment of the OSH situation in both countries and therefore the adoption of protection measures that should improve that situation. As mentioned, more data will be analyzed (reports on work injuries according to ESAW methodology in Serbia, or reports of authorities in the Republic of Srpska) for better understanding and further improvement directions. The right to safety and health at work is a fundamental work right. To achieve this right, it is necessary generally to apply the following measures and activities:

- Suitable application of the Law on OSH;
- Efficient performance of the Safety and Health Councils and Committees;
- Concluding collective contracts among the employers in order to regulate the issues referring to the safety and health at work;
- Employees who work in hazardous positions should be insured in specialized companies;
- Chosen employee representatives for safety and health at work should be educated permanently in order to early identify the symptoms of any potential professional disease before it develops into a chronic illness;
- The sector for OSH within the Ministry as part of the State Labour Inspectorate should be enhanced with personnel in order of efficient performance, especially for supervision of the employers regarding the conditions for hygienic and technical conditions, preparations and submission of requests for misdemeanor and criminal procedures, recording the claimed injuries at work;
- Establishing dynamic and practically conducted social dialogue between the syndicate, employers' organizations, and the country regarding mutual and synchronized resolution of the issues related to OSH;
- OSH should be integrated into our educational system through adequate vocational subjects and curriculum, thus providing the pupils with basic knowledge about this area from an early age;
- Syndicates, professional organizations, and other similar associations should influence, through the media, the strengthening of public awareness about the importance of the OSH.

CONCLUSION

A healthy and productive workforce is the carrier of the economic development of any country, therefore it is necessary to safe and healthy working conditions should be provided. No one should be affected by work-related illnesses or accidents. It is also an important aspect of the sustainability and competitiveness of the EU economy. A strong OSH support structure that meets the specific needs of small and medium enterprises, which form the backbone of these two countries' (and EU) economies, will make a key contribution to a sustainable economy and the success of OSH as a whole. A good system of safety and health at work reduces healthcare costs and other social burdens, while, in contrast, the costs of a poor occupational health and safety system are high for individuals, companies, and society.

Safety at work is a "living thing", subject to constant changes that occur within the occupational system itself and in the environment, so it should be subject to constant development and improvement. Arrangement of the occupational safety management system and the organization of the implementation of occupational safety measures is a continuous process that requires constant additions and corrections in order to constantly improve.

The paper shows a growing trend of injuries in both countries, in contrast to the EU. Also, injury databases come from multiple institutions, process different types of injuries, and are not uniform. Therefore, it is not possible to obtain relevant data on the condition based on the number of injuries. The results of this work will be used to further improve the situation in these countries, primarily through joint research projects in the field of OHS.

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CONSTRUCTION SITE RELATED CHEMICAL HAZARDS

Vukadinović A.[1], Radosavljević J.[1]

[1]Faculty of Occupational Safety in Niš, Čarnojevića 10a, Serbia (e-mail: ana.vukadinovic@znrfak.ni.ac.rs)

Abstract: The major health hazards with reference to various construction activities can be chemical (paint solvents, exhaust fumes), biological (bacteria, pathogens), physical (noise, vibrations) and psychological (occupational stress). Chemical hazards are extremely dangerous for human health because of their long-term effect and frequency of occurrence. Hazardous substances at a construction site include those used directly in the work processes (glues and paints), those produced by work activities (welding fumes) or those which occur naturally (dust). This paper addresses the issue of chemical hazard management at a construction site. Safety and health professionals should make an effort through information, training, support for safe work procedures, and utilization of personal protective equipment (PPE) to ensure that construction workers are not exposed to chemicals which result in exposures that might cause health effects.

Keywords: *chemical hazards; construction site; occupational safety.*

INTRODUCTION

Occupational health and safety affects all aspects of work and it is relevant to all branches of industry. The architecture, engineering, and construction industry is vital to the local and global economy, providing an average of 6% of global gross domestic product (GDP) (Ikudayisi et al., 2023). The construction industry in Serbia, in 2022., accounted for 5.54% of its gross domestic product and had an annual turnover of over 392994.3 million RSD (SORS, 2023).

The construction industry is one of the most hazardous industries. The rate of non-fatal injuries in the construction industry was 71% higher than in all industries (Zeng and Li, 2021). The construction industry remains one of the most dangerous in the UK. In 2004/05, the fatal injury rate (per 100,000 workers) was 3.4 while the industrial average was 0.8. In 2006/07, there was a 28% increase in fatalities in the industry, which accounted for 32% of all notifiable fatal injuries. (Hughes and Ferrett, 2016)

In addition to other hazards, hazardous substances are also encountered on the construction site, which can be the cause of work injuries or illnesses. Such substances can be directly used by the workers on the construction site (e.g. glues, paints) or they may be a product of some activity on the construction site (e.g. dust particles). (Radosavljevic and Vukadinović, 2019.) Occupational exposures to hazardous substances such as fumes, dusts and chemicals in various forms account for around 4,000 deaths a year and some 38,000 individuals suffer breathing or lung problems possibly caused by their work. (Hughes and Ferrett, 2016). By knowing the nature of hazardous substances on the construction site, the risks to human health and safety can be managed and reduced to the smallest extent.

FORMS OF CHEMICAL AGENT IN CONSTRUCTION INDUSTRY

In the construction industry, chemicals can be transported by a variety of agents and in a variety of forms such as (Hughes and Ferrett, 2016) dusts, fibres, gases, vapours, liquids, mists and fumes.

Dusts are solid particles slightly heavier than air but often suspended in it for a period of time. The size of the particles ranges from about 0.4 μm (fine) to 10 μm (coarse). The fine dust (cement, granulated plastic and silica dust produced from stone or concrete etc.) known as respirable dust is hazardous because it penetrates deep into the lungs where it can cause damage to organs by entering the bloodstream. Repeated exposure may lead to permanent lung disease.

Fibres are threads or filaments that can occur naturally (e.g. asbestos) or be man-made such as glass fibre, nylon and polyester. Fibres are commonly used in insulation boards, electrical insulation and in the reinforcement of plastic and cement. Fibres have a very high length-to-width ratio of at least 100. Many fibres are in the respirable range causing concern about the negative effects like fibrosis of the lung. Exposure to large concentrations of some fibres may irritate the upper respiratory tract. Fibres include asbestos and glass fibre, synthetic and semisynthetic fibres (e.g. cellulosic fibres), and a range of other non-organic fibres, carbon fibres or nanofibers.

Gases are substances at a temperature above their boiling point. Steam is the gaseous form of water. Common gases include carbon monoxide, carbon dioxide, nitrogen and oxygen. Gases are absorbed into the bloodstream where they may be beneficial (oxygen) or harmful (carbon monoxide).

Vapours are substances which are close to their boiling temperatures. They are gaseous in form. Many solvents, such as cleaning fluids, fall into this category. The vapours, if inhaled, enter the bloodstream and can cause short-term effects (dizziness) or long-term effects (brain damage).

Liquids are substances that are sometimes referred to as fluids which normally exist at a temperature between freezing and boiling.

Mists are similar to vapours. There are suspended, very small liquid droplets present in the vapour. A mist is produced during a spraying process (such as paint spraying). Many industrially produced mists can be very damaging if inhaled.

Fumes are a collection of very small metallic particles condensed from the gaseous state. They can be generated by the welding process. The particles tend to be within the respirable range (approximately 0.4–1.0 μm) and can lead to long-term permanent lung damage. The nature of harmful effects depends on the metals used in the welding process and the duration of the exposure. (Hughes and Ferrett, 2016)

HAZARDOUS SUBSTANCES AT CONSTRUCTION SITE

A hazardous substance is one which can cause ill health to people at work. Such substances may include those used directly in the work processes (glues and paints), those produced by work activities (welding fumes) or those which occur naturally (dust). Hazardous substances are classified according to the severity and type of hazard. According to the United Nations Globally Harmonised System (GHS), hazardous substances can be classified as health hazards, serious health hazards, and corrosive and acute toxicity substances. Other types of hazardous substances

include carcinogenic, mutagenic and reproductive toxins. The European Regulation on Classification, Labelling and Packaging of Substances and Mixtures became law across the EU in 2009 and is known as the CLP Regulation. (Hughes and Ferrett, 2016).

Routes of entry of hazardous substances into the body

There are three principal routes of entry of hazardous substances into the human body (Hughes and Ferrett, 2016):

inhalation – breathing in the substance with normal air intake. This is the main route of contaminants into the body. These contaminants may become airborne by a variety of modes, such as sweeping, spraying, grinding and bagging. They enter the lungs where they have access to the bloodstream and many other organs;

absorption through the skin – the substance comes into contact with the skin and enters through either the pores or a wound. In this way, toluene, benzene and various phenols can enter the human body.

ingestion – through the mouth and swallowed into the stomach and the digestive system. This is not a significant route of entry to the body. The most common occurrences are due to airborne dust or poor personal hygiene (Hughes and Ferrett, 2016)

Typical hazardous chemicals in the construction industry

There are many different types of hazardous chemicals used in construction that you may be exposed to. Common materials found on construction sites that can be related to chemical hazards are Solvents, Cleaners, Acids, Bases, and Alkalines, Adhesives and Sealants, Fuels, Concrete and Wood related chemicals.

Solvents - Solvents are liquids that dissolve another substance without changing the basic characteristic. In construction sites solvents that are often used are thinners, cleaners, degreasers, fuels, and glues. There are three main classes of solvents: aqueous solutions such as acids, alkalines, and detergents; organic solvents like acetone, toluene, and gasoline; and chlorinated solvents like methylenechloride and trichloroethylene. Solvents can enter into body by inhalation or absorption thereby causing dizziness or headache, and within longer exposure nose, throat, eye and lung irritation and even damage to the liver, blood, kidneys, and digestive system. (Reese and Eidson, 2006)

Cleaners - Cleaners in the construction industry can contain acids, alkalis, aromatics, surfactants, petroleum products, ammonia, and hypochlorite. Because of these ingredients, cleaners are considered to be irritants. Some cleaners can cause eye, nose, throat, skin, and lung irritation, can be burnt easily and are flammable. (Reese and Eidson, 2006)

Acids and Bases - Acids and bases can be in the form of liquids, solid granules, powders, vapours, and gases. A few commonly used acids include sulfuric acid, hydrochloric acid, muriatic acid, and nitric acid. Some common bases (caustics) are lye (sodium hydroxide) and potash (potassium hydroxide). Both acids and bases can be corrosive, causing damage to whatever they contact. Various acids react differently and can cause skin burns. Hydrofluoric acid may be absorbed into the muscle tissue and can cause deep burns. In reaction with water, acetic and nitric acids form vapours that can be inhaled and that way quickly penetrate the lungs causing serious damage. Concentrated bases easily dissolve tissue and, therefore, can cause severe skin damage on contact. Cement and mortar are alkali compounds in their wet or dry form. As dust and powder,

they can cause damage to the skin and eyes when they react with moisture in the body. (Reese and Eidson, 2006)

Adhesives and Sealants - Many adhesives and sealants are toxic because of their chemically reactive ingredients, can be flammable and also eye and skin irritants. Epoxies contain epoxy amine resins and polyamide hardeners, which cause skin sensitization and respiratory tract irritation. Epoxy is an important component of paints and varnishes, adhesives or putty. They are resistant to high temperatures, high loads, and strong chemical substances, and are widely used in industry (Kowalik et al., 2019.). Overexposure to epoxies can result in dizziness, drowsiness, nausea, and vomiting. In cases of prolonged exposure kidney and liver damage may occur. Floor adhesives may contain acrylics that can be irritating to the skin, and may cause nausea, vomiting, headache, weakness, asphyxia, and death.

Fuels are either flammable or combustible. Excessive inhalation of fuels may cause central nervous system depression. Leukaemia is a potential side effect of chronic exposure to some fuels and may lead to death. Ingestion of fuels may cause poisoning and possible lung damage if aspirated into the lungs when ingested.

Wood treatment chemicals - Wood, which has been preserved by pressure treatment with a pesticide, to protect it from insect attack or decay, can be dangerous. Inorganic arsenic, copper, zinc, and a pesticide are used in the pressure treatment process. These chemicals are forced deeply into the wood where they remain for long periods of time. As a result, treated wood can pose health hazards if not properly handled. Inhalation of sawdust from treated wood must be avoided. (Reese and Eidson, 2006)

Health risks and controls associated with specific chemical agents at the construction site

Asbestos. Exposure to asbestos can cause four main diseases: mesothelioma (a cancer of the lining of the lungs; it is always fatal and is almost exclusively caused by exposure to asbestos), asbestos-related lung cancer, asbestosis (a scarring of the lungs) and diffuse pleural thickening (a thickening of the membrane surrounding the lungs). Asbestos produces fine fibrous dust which can become lodged in the lungs. The fibres can be very sharp and hard causing damage to the lining of the lungs over a period of many years. (Hughes and Ferrett, 2016)

Ammonia is a colourless gas with a distinctive odour. It is a corrosive substance which can burn the skin, burn and seriously damage the eye, causing soreness and ulceration of the throat and severe bronchitis and oedema of the lungs. Eye and respiratory protective equipment is essential when maintaining equipment containing ammonia. (Hughes and Ferrett, 2016)

Chlorine is a toxic gas, highly irritant to the respiratory system, producing severe bronchitis and oedema of the lungs and may also cause abdominal pain, nausea and vomiting. (Hughes and Ferrett, 2016)

Organic solvents are used widely in industry as cleansing and degreasing agents. All organic solvents are heavier than air and most are sensitisers and irritants. Some are narcotics, while others can cause dermatitis and after long exposure periods liver and kidney failure. (Hughes and Ferrett, 2016)

Solvents are used extensively in a wide variety of industries as varnishes, paints, adhesives, glue strippers, printing inks and thinners. One of the most hazardous is *dichloromethane*, also known as methylene chloride. It is used as a paint stripper, normally as a gel. It can produce narcotic

effects and has been classified as a Category 3 carcinogen in the European Union. (Hughes and Ferrett, 2016)

Lead is a heavy metal most commonly associated with plumbing and roofing work. The toxicity of lead affects nerve and red blood cell production. Symptoms include abdominal pains, muscular weakness and tiredness. Inhalation is the most common means for the entry of lead into the body. The main targets for lead are the spinal cord and the brain, the blood and blood production. Headaches and nausea are the early symptoms followed by anaemia and muscle weakening. Lead can be transferred to an unborn child through the placenta. Lead is used in construction by roofers as a roofing and guttering material and by plumbers. (Hughes and Ferrett, 2016)

Silica is a crystalline substance made of silicon and oxygen. It occurs in quartz, sand and flint which are present in a wide variety of construction materials. If silica dust is inhaled it can lead to silicosis (acute and chronic), fibrosis and pneumoconiosis. The dust which causes the most harm is respirable dust which becomes trapped in the alveoli. This type of dust is sharp and very hard and causes scarring of lung tissue. Silicosis can result in the development of tuberculosis as a further complication. Hard rock miners, quarrymen, and stone and pottery workers are most at risk. Silica is commonly produced during construction activities of cutting building blocks and other stone masonry work, cutting and drilling paving slabs and concrete paths, demolition work, sandblasting of buildings and tunnelling. (Hughes and Ferrett, 2016)

Cement dust and wet cement is important in construction and is also a hazardous substance. Contact with wet cement can cause serious burns or ulcers which will take several months to heal and may need a skin graft. Dermatitis, both irritant and allergic, can be caused by skin contact with either wet cement or cement powder. Plasterers, concreters and bricklayers or masons are particularly at risk. Personal protective equipment in the form of gloves, overalls with long sleeves and full-length trousers, and waterproof boots must be worn on all occasions.

Wood dust can be hazardous, particularly when it is hardwood dust, which can lead to nasal cancer. Composite boards, such as medium-density fibreboard (MDF), are hazardous due to the resin bonding material used, which can also be carcinogenic. The resins used to bond the fibreboard together contain formaldehyde. It is recognised that formaldehyde is carcinogenic to humans. At low exposure levels, it can irritate the eyes, nose and throat and can lead to dermatitis, asthma and rhinitis. The main hazards associated with all wood dusts are skin disorders, nasal problems, such as rhinitis, and asthma. There is also a hazard from fire and explosion. (Hughes and Ferrett, 2016)

CONTROL MEASURES FOR CHEMICAL HAZARDS AT THE CONSTRUCTION SITE

Control measures for chemical hazards at a construction site consist of (Hughes and Ferrett, 2016): elimination; substitution; provision of engineering controls; provision of supervisory controls and provision of personal protective equipment.

Measures for preventing or controlling exposure to hazardous substances include one or a combination of the following (Hughes and Ferrett, 2016):

- elimination of the substance;
- substitution of the substance (or the reduction in the quantity used);
- the total or partial enclosure of the process;

- local exhaust ventilation (hood and intake, ventilation ducting, filter or other air cleaning device, fan, exhaust duct);
- dilution or general ventilation;
- reduction of the number of employees exposed to a strict minimum;
- reduced time exposure by task rotation and the provision of adequate breaks;
- training and information on the risks involved;
- effective supervision to ensure that the control measures are being followed;
- personal protective equipment (such as clothing, gloves and masks);
- welfare (including first-aid);
- medical records;
- health surveillance.

Personal protective equipment

Personal protective equipment (PPE) is to be used as a control measure only as a last resort and it does not eliminate the hazard. There are several types of personal protective equipment, which are used for protection from hazardous chemicals. Table 1 shows common types of personal protective equipment (PPE) in accordance with the chemical hazard.

Table 1. The hazards and types of PPE for various parts of the body (Hughes and Ferrett, 2016)

	Hazards	PPE
Eyes	chemical or metal splash, dust, projectiles, gas and vapour, radiation.	safety spectacles, goggles, face shields, visors.
Head	impact from falling or flying objects, risk of head bumping, and hair.	a range of helmets and bump caps.
Respiratory system	dust, vapour, gas, oxygen-deficient atmospheres.	disposable filtering facepiece or respirator, half- or full-face respirators, air-fed helmets, and breathing apparatus.
Hand and arms	abrasion, temperature extremes, cuts and punctures, impact, chemicals, electric shock, skin infection, disease or contamination.	gloves, gauntlets, mitts, wrist-cuffs, armlets.
Feet and legs	wet, electrostatic build-up, slipping, cuts and punctures, falling objects, metal, and chemical splash, and abrasion.	safety boots and shoes with protective toe caps and penetration-resistant midsole, gaiters, leggings, and spats.
Whole body	temperature extremes, adverse weather, chemical or metal splash, spray from pressure leaks or spray guns, impact or penetration, contaminated dust, excessive wear or entanglement of own clothing.	conventional or disposable overalls, boiler suits, specialist protective clothing, and high visibility clothing.

CONCLUSION

Health hazards may be present in the construction site through various chemical agents. Chemicals can be transported as dust, fibres, gases, vapours, liquids, mists, and fumes. Construction workers are every day exposed to hazardous substances that can enter the human body in three principal routes: inhalation, absorption, and ingestion. Common materials found on construction sites that can be related to chemical hazards are solvents, cleaners, acids, bases, alkalines, adhesives and sealants, fuels, concrete, and wood-related chemicals. Exposure to those chemicals can lead to various acute or chronic health effects. The paper provides an overview of chemical hazards at the construction site with an overview of the possible health effects caused by exposure to those hazards. This research may help in developing a safety management strategy for construction site safety from chemical hazards.

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ASSESSMENT OF WATER QUALITY PARAMETERS CORRELATION IN WWTP FOR PREDICTION OF NUTRIENT REMOVAL

Vukmirović A.[1], Jovišić N[2], Ilić S.[3], Vukmirović S.[2], Mihajlović I.[1]

[1]University of Novi Sad, Faculty of Technical Sciences, Department of Environmental Engineering and Occupational Safety and Health, Trg Dositeja Obradovića 6, 21000 Novi Sad, Serbia

[2]University of Novi Sad, Faculty of Technical Sciences, Department of Computing and Control Engineering, Trg Dositeja Obradovića 6, 21000 Novi Sad, Serbia (e-mail: nikolajovisic4@gmail.com)

[3]Institute for Artificial Intelligence R&D, Fruskogorska 1, Novi Sad, 21000, Serbia

Abstract: Models and conclusions derived from machine learning could be used for the monitoring, simulation, evaluation, and optimization of water treatment processes. The aim of the paper is to use machine learning to assess correlations between operation and water quality parameters such as Hydraulic Retention Time (HRT), temperature (T) and pH, total nitrogen (N), and total phosphorus (P) in raw influent with N and P in treated effluent in order to predict nutrient removal effectiveness within wastewater treatment plant (WWTP). The results showed that changes in operation parameters have a limited impact on the variations of P and N. However, a correlation between N and its previous concentrations in treated effluent was observed which suggests time-dependent trends in concentrations of total nitrogen.

Keywords: *nitrogen; phosphorus; wastewater treatment plant; machine learning.*

INTRODUCTION

Population growth, industrialization, and economic development caused increased generation of wastewater and pollution load. Wastewater poses significant problems when released into the environment untreated or without proper treatment. Untreated wastewater contains different pollutants, including nutrients (such as nitrogen and phosphorus), heavy metals, and organic matter (Chen et al., 2020) When released into surface water, these contaminants can degrade water quality and pose harmful effects to aquatic organisms and indirectly to human health (Tang et al, 2022).

Improperly treated or untreated wastewater can leach into groundwater, contaminating drinking water sources and causing public health concerns. Proper treatment and responsible management of wastewater are crucial for the preservation of water resources and the protection of ecosystems.

Since the composition of communal wastewater is complex, evaluation of water quality before treatment is important for wastewater treatment plant (WWTP) technology optimization. Machine learning has proven to be a useful tool in various aspects of wastewater treatment (Zhu et al, 2022). It is widely used for water quality monitoring and prediction, technology optimization, and WWTP operation and management. Machine learning can be an important tool in optimizing wastewater treatment systems, reducing costs, and improving water quality.

To enhance the accuracy and reliability of machine learning models, it is of great importance to collect comprehensive and high-quality data from laboratory analyses of water quality. This is often difficult due to the cost or technology limitations. According to the large amounts of high-

quality data on physical and chemical water quality parameters, analysis by machine learning methods could be performed to optimize wastewater treatment systems (Wang et al, 2021). Artificial neural networks (ANNs) were effectively used to predict pollutant removal in WWTP (Taoufik et al, 2022). Bayat Varkeshi and Cooperates (2018) used ANN to predict COD and BOD concentrations in wastewater effluent. Zaghloul and Achar applied machine learning techniques to model a full-scale WWTP with biological nutrient removal and predict 15 process parameters. In this research, it was shown that the effluent quality of WWTPs can be affected by many factors. Therefore, machine learning can be performed to provide WWTP managers with opportunities to reduce costs and improve their operations.

The aim of research is to use machine learning in the prediction of total nitrogen and total phosphorus in the outflow of WWTP. The paper is based on an assessment of correlations between operation and water quality parameters such as Hydraulic Retention Time (HRT), pH, temperature (T), total nitrogen (N), and total phosphorus (P) in influent wastewater with N and P in effluent of WWTP.

MATERIAL AND METHODS

The raw data set used in this study was collected daily for a period of six years. The experimental data used in this study were obtained from the municipal WWTP in Serbia. The treatment process in WWTP is based on biological treatment with activated sludge. Therefore, it is important to examine nutrient (N and P) removal.

In a wastewater treatment plant, HRT presents the average time spent keeping wastewater in a tank, i.e. time for absorption and biodegradation in the bioreactor. HRT regulates the conversion of volatile solids to gaseous products in an anaerobic digester. Therefore, it is an important operational parameter that influences the treatment process and methane generation determining the conversion of volatile solids to gaseous products among other operational conditions, such as temperature and pH value of the water sample.

After considering the available options for modeling the treatment plant performance, it was decided to relate the quality of the raw influent wastewater (pH, HRT, T, N, and P) to the quality of the final treated effluent (N and P) to predict nutrient removal. The raw data underwent refinement procedures to eliminate outliers, which were conceivably the by-products of measurement inaccuracies. Filling in the gaps in the dataset was achieved through linear interpolation, utilizing a rolling mean method. A process of standardization was implemented to the input data, thereby enhancing its statistical significance and interpretability.

Machine learning models – Linear Regression (LR), Multi-Layer Perceptron (MLP), 1D Convolution, and Long Short-Term Memory (LSTM) were then used to evaluate the importance of input parameters and time-dependent trends in concentrations.

RESULTS AND DISCUSSION

The raw data had issues such as outliers, missing measurements, and large differences in scale between variables that needed to be resolved before model development. The outliers and missing values in the dataset could be the consequence of the quality of influent samples and uncertainty in laboratory measurements. Therefore, it was necessary to preprocess the data to

handle missing values, outliers, and normalization, making it suitable for training the machine learning model. The statistical properties of influent wastewater and treated effluent (min, max, mean and standard deviation) for the selected dataset are shown in Table 1.

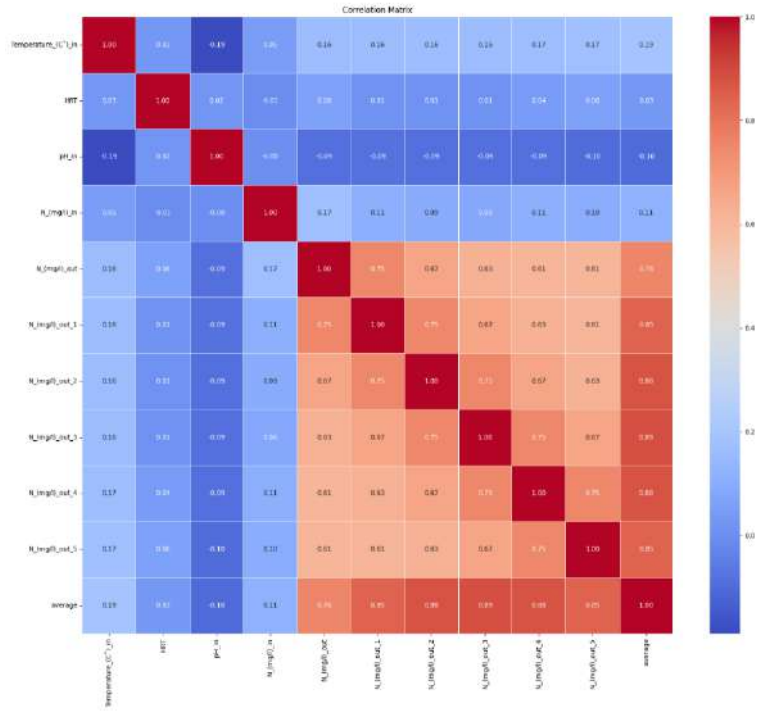
Table 1. Descriptive statistics for pre-processed data of influent wastewater and treated effluent

Influent wastewater						Treated effluent	
	pH	HRT	T (°C)	N (mg/l)	P (mg/l)	N (mg/l)	P (mg/l)
MIN	5.2	0.4	11.4	17.9	3.7	0.1	0.1
MAX	9.4	855.0	24.9	790.0	36.8	71.3	13.9
MEAN	7.5	32.4	18.0	81.7	12.7	19.0	2.7
SD	0.7	2.6	3.3	35.0	4.2	12.0	1.9

Removal efficiencies are 78.7 % and 76.7 % for P and N, respectively. Although the removal efficiencies are high, the concentrations of total phosphorus and total nitrogen are elevated in relation to the limit values for wastewater prescribed by the legislation in Serbia (Official Gazette of RS, 67/2011, 48/2012, 1/2016).

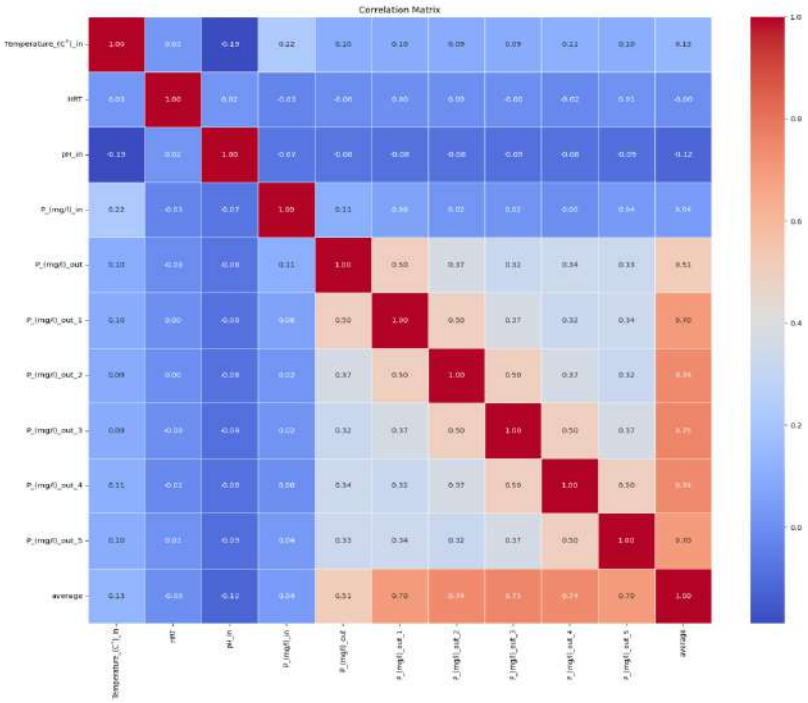
The correlation matrix of selected predictors for N such as pH, T, HRT, and N in raw influent is presented in Figure 1, while the correlation matrix for total phosphorus is presented in Figure 2. The highest degree of correlation was found between the output parameters and their values in the previous days, and, additionally, the average value of measurements through those previous days. This trend can be explained as a perpetuation of momentum in the temporal concentrations of these parameters. This momentum has a greater influence over output parameters than current measurements of relevant physical and chemical parameters.

The mean value outperformed any individual daily data in terms of correlation strength. This suggests that the cumulative effect, or the 'integral influence', provides a more reliable and robust parameter to predict future outcomes, demonstrating greater resilience against the noise. This underscores the value of temporal analysis over isolated measurements in effective wastewater management.



*The number in labels of N indicates the number of days in past measurement

Figure 1. Correlation matrix of selected predictors for total nitrogen



*The number in labels of P indicates the number of days in past measurement

Figure 2. Correlation matrix of selected predictors for total phosphorus

The correlations of operation parameters with variables P and N were weak. This implies that changes in temperature, HRT, or pH have a limited impact on the variations of P and N. Selected operation parameters didn't show strong associations with P and N. However, a correlation between N and its previous concentrations in treated effluent was observed. This suggests that the concentrations of N are influenced by its previous concentrations and there might be time-dependent trends in concentrations of total nitrogen. This has also been observed through the process of training the machine learning models where models were more successfully trained on time-dependent inputs.

CONCLUSIONS

Machine learning was used to assess water quality parameters correlations for the prediction of nutrient (N and P) removal in WWTP. According to correlation matrices and model performance, it could be concluded that operation parameters, such as HRT and temperature have a limited impact on nutrient removal. However, time-dependent trends in concentrations of total nitrogen were observed. Therefore, further research of machine learning models such as the Long Short-Term Memory (LSTM) or Multi-Layer Perceptron (MLP) model could be useful in exploring the WWTP treatment efficiency for nutrient removal. Also, investigation of other potential water quality and operation factors that might influence P and N concentrations could provide more insights into their removal in WWTP.

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