21st International Conference Man and Working Environment
SEMSIE
Safety Engineering & Management - Science, Industry, Education

REVIEW PAPER

DOI: 10.46793/SEMSIE25.251K

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# NOISE AND SILICA DUST AS KEY RISK FACTORS DURING EARTHWORKS AT CONSTRUCTION SITES

**Abstract:** *Construction sites involve different activities and operations, each contributing to various forms of pollution that elevate mortality rates and give rise to different occupational diseases. Earthworks include operations such as excavation, digging, and demolition, which generate high noise and silica dust. This research focuses on two key risk factors of every construction site – noise and silica. The aim of this research has a twofold effect: (1) to show measured levels of noise during earthworks with both a sound level meter (SLM) and a personal dosimeter, to establish how noise impacts the possibility of communication through communication devices, and to determine the negative impact of noise on human health with a recommendation of preventive measures; (2) to show that silica dust is a causative agent of serious respiratory diseases – such as silicosis, autoimmune disorders, infections, and other lung diseases – during the earthwork construction phase, using measured quantities from various studies, and to propose preventive measures that should be implemented. To lower the risk of noise and silica dust, it is necessary to represent their risk on a global level, with the intention to reduce worker exposure and prevent diseases like occupational hearing loss and silicosis through different research and innovation models.*

**Keywords:** noise, dust, construction site, occupational hearing loss, silicosis

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## INTRODUCTION

Every unpleasant and unwanted sound is defined as a noise – a significant pollutant (Samardžić, 2021; Anees et al., 2017) that can lead to hearing loss, high blood pressure, and other related symptoms (irritability, stress, anxiety, insomnia, reduced cognitive abilities, etc.) (Jain et al., 2016). Construction sites are a source of noise, where different construction machinery, tools, and operations can lead to high levels of noise (Mučenski, 2018) exceeding the permissible noise level – above 85 dB (Ministarstvo za rad, zapošljavanje, boračka i socijalna pitanja, 2019). Workers who manipulate construction machinery for earthworks, such as excavators, bulldozers, and loaders are exposed to high noise levels (usually between 97-107 dB, according to OSHA (2012)) and there is a possibility of hearing loss (Kantová, 2017; Movahed and Ravanshadnia, 2022). The noise level mostly depends on the type and complexity of the task (Movahed and Ravanshadnia, 2022). To ensure better management of noise on construction sites, measurement of noise levels generated by different machinery is a fundamental step in identifying potential sources of excessive noise, alongside a comprehensive analysis of noise sources, machinery, processes, and human activity and the application of adequate preventive measures.

In addition to noise exposure, exposure to chemical hazards such as dust at construction sites poses an everyday problem that has a negative impact on workers' health. The air present on construction sites and in the production of building materials contains high levels of these harmful chemical substances (OSHA, 2012). Construction sites represent one of the primary sources of air pollution, where dust is mostly of natural origin, e.g. silicate dust, wood dust, and low-toxicity dust generated from materials such as gypsum, limestone, marble, and dolomite (Mučenski, 2018). The problem occurs when free crystalline silica appears in the air of a construction site, because once inhaled, it causes various diseases, of which silicosis is the most common (Keramydas et al., 2020). Excavation, drilling, rock processing, tunnelling, demolition of buildings, and cutting of brick, concrete, and granite tiles are activities with the highest exposure to dust, where silica dust is present (HSE UK, 2020). Exposure to silica dust is a growing worldwide problem responsible for the largest cases of silicosis across Asia, Africa, and South America (Hoy et al., 2022). In addition, more than 5.5 million workers are exposed to silica dust in the European Union, 1.7 million in the USA, and 350,000 in Canada (Wiebert et al., 2023; Sauvé et al., 2013), which significantly increases the risk of mortality (Requena-Mullor et al., 2021). Through the implementation of suitable preventive measures, such as measuring the exposure to silica dust, using water sprays and ventilation of containment structures, and using personal protective equipment (PPE), it is possible to minimize the negative effect of silica dust on the human body (OSHA, 2012).

To lower the risk of noise and silica dust, it is necessary to represent their risk on a global level, to reduce worker exposure, and prevent diseases like occupational hearing loss and silicosis, through different research and innovation models.

The aim of this research has a twofold effect: (1) to show the noise levels recorded during earthworks using a sound level meter (SLM) and a personal dosimeter, and additionally to establish the detrimental effects of noise on human health, to determine how noise interferes with communication through communication devices, and to suggest preventive measures; (2) to demonstrate that exposure to silica dust during the earthwork construction phase contributes to serious respiratory conditions – including silicosis, autoimmune disorders, infections, and other lung diseases – based on data from multiple studies, and to recommend appropriate preventive measures.

## OCCUPATIONAL NOISE IN EARTHWORKS

### Noise measurement results and preventive measures in earthworks

Through revising documentation on occupational environmental assessments, noise measurements are mostly conducted in industrial settings, and such insight indicates the existence of a gap in noise measurement assessments within the construction sector. Therefore, since construction sites are recognized as the source of noise (Mučenski, 2018), there is a need to implement the measurement of noise on construction sites with both an SLM and a personal dosimeter.

With the intention to assess noise exposure of excavator operators who performed earthworks, with both newer and old excavators, previous research (Kužet et al., 2024a, Kužet et al., 2024b) was designed to capture real working conditions and actual noise exposure. By applying combined measurements, both with an SLM and a personal noise dosimeter, a holistic assessment was obtained. Measurements conducted by the SLM were taken for 15 minutes, depending on the process and fieldwork conditions, but long enough to capture all the changes in the observed operational process. Personal dosimeter measurements were taken over the entire duration of the shift (8-hour shift) to measure the operators' exposure at their exact location and for their particular behaviour.

Results of measured equivalent continuous noise level – $L_{eq}$ (Kužet et al., 2024a) showed that:

- noise level during the operation of loading soil material into the truck was between $L_{Aeq}$ = 69.9-75.3 dB;
- noise level during the excavation operation was between $L_{Aeq}$ = 65.8-85.4 dB; and
- noise level in idle operation was between $L_{Aeq}$ = 70.9-81.3 dB.

Based on the results, the measured noise levels ranged between 65.8 to 85.4 dB. Although the peak value was marginally higher than 85 dB, this does not necessarily mean that the allowable daily noise exposure limit of 85 dB was exceeded (Ministarstvo za rad, 2019). Also, 65.8 dB during the same operation was measured on the newer model of excavator and explained as a good example of regular maintenance, service, and design of the machine. Regardless of the fact that the measured values were mostly below the exposure noise level, further analysis of noise measurements showed that there was difficulty to communicate through communication devices. In 81.25% of the cases, communication was difficult, and in the remaining 18.75%, the possibility of communication using communication devices was unsatisfactory because it exceeded $L_{Aeq}$ = 75 dB. This finding is consistent with data from the European Community, where it was determined that one in five workers in Europe has to raise their voice for more than half of the working time to be heard by other workers, while 7% of workers suffer from health problems caused by noise.

Personal dosimeter measurements (Kužet et al., 2024b) showed that throughout the 8-hour work shift, there were values exceeding 85 dB and 90 dB and that measured values of noise varied between $L_{Aeq}$ = 85 and 95 dB, with the highest value for $L_{Aeq}$ of 94.7 dB, which is 9.7 dB higher than the exposure noise level of 85 dB. Also, a very high value of C-weighted Peak Sound Level ($L_{Cpeak}$) was recorded during the measurement, indicating the existence of high-value periodic or impulsive noise that requires hearing protection at work. In the end, the dose value suggests that during 20% of the workday, the operator of the excavator is exposed to disturbing noise. Figure 1 shows recorded levels of noise when the operator was simultaneously excavating and loading soil material, where the average $LA_{eq}$ value was 89.2 dB, and $L_{Cpeak}$ was 143.1 dB.

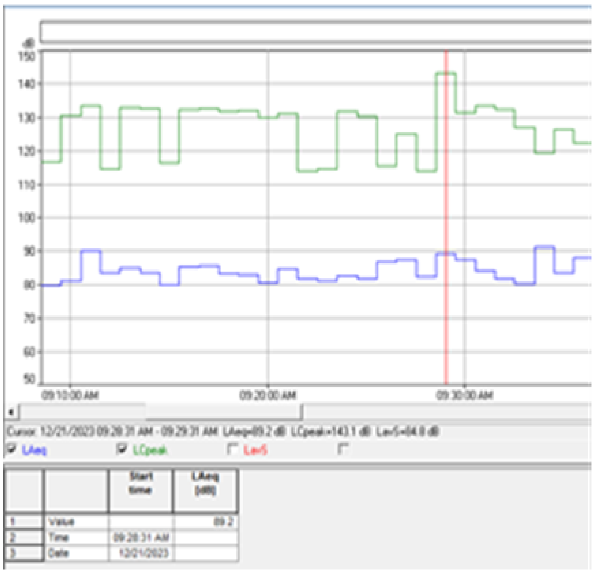


**Figure 1.** *Partial personal dosimeter readings for an eight-hour working shift (source: Kužet 2024b)*

The results of the overall measurements show that if the excavator operator was exposed to noise greater than 80 dB at certain moments during the measurement, it means that exposure to high noise levels during working hours is guaranteed and that appropriate protection measures must be taken. According to the Rulebook on preventive measures for safe and healthy work during noise exposure (Ministarstvo za rad, 2019), when daily noise exposure level for an 8-hour working shift exceeds the upper exposure action value of 83 dB, the worker must wear personal protective equipment or employers must pause work and organize working hours differently. To improve the current protection system, which includes: work breaks, organization of working hours, employee training, use of personal protective equipment, and regular maintenance of heavy construction machines (OSHA, 2012; European Agency for Safety and Health at Work, 2004), it is necessary to introduce mandatory noise measurements at construction sites.

When measuring, preference should be given to the use of a personal dosimeter, due to the collection of precise data on the actual exposure of workers to noise. In this way, it would ensure not only the monitoring of workers' exposure to high noise levels during working hours and a better definition of preventive measures and work organization, but it would also make it possible to prevent related diseases and illnesses from exposure to high noise levels in time, during which the prevention of hearing loss would be of key importance.

## Negative effects of noise on human health

Exposure to loud noise causes different morphological and physiological alterations in the human body. In the auditory system, it lowers the levels of necessary enzymes in the cochlear fluid and causes structural damage to the stereocilia, which are fine hair-like structures responsible for the transmission of sound. Besides that, noise exposure also causes hypertension and mental health disturbances. Moreover, Xue (2018) states that genetic factors account for more than half of hearing impairments present since birth or early childhood.

The impact of noise on the human body is manifested in two ways – acute and chronic traumas. Acute trauma happens when the operator is exposed to a very high noise level for a very short time, and can cause mechanical damage to the eardrum and auditory ossicles. Chronic trauma happens when the operator is exposed to a high noise level, but exposure is prolonged and can cause damage to sensory cell sensors. Both acute and chronic trauma can lead to deafness, hearing loss, progressive hearing loss, and total hearing loss. Damage and loss of hearing are most often caused by damage to cells, nerves, and the entire structure inside the ear (OSHA, 2012).

A perfect example of the negative impact of noise on human health is the paralysis of fine hairs inside the inner ear due to excessive noise, which can cause immediate hearing loss, and prolonged exposure to this level of noise can destroy them. Figure 2 shows what happens during prolonged exposure to high noise levels – in the inner ear of the spiral curve of the cochlea, there is a complete loss of hairs and their accompanying nerve fibres, which results in irreversible damage of hair cells (Sripaiboonkij et al., 2013).

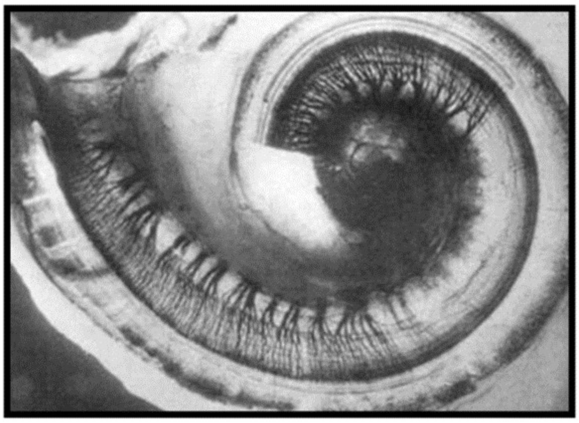

**Figure 2.** *Cochlear damage (source: https://nap.nationalacademies.org/read/18593/chapter/26#295)*

The most common damage that occurs due to noise exposure is tinnitus – a ringing in the ears. Tinnitus is not characterized as a disease but as a symptom of something wrong. People who are exposed to high noise levels (e.g. construction workers) may develop tinnitus over time due to damage to the sensory cells in the inner ear (OSHA, 2012).

It has been established that noise is one of the causes of cardiovascular problems; it promotes the risk factors of coronary diseases and disturbs the work of the heart, and the changes are easily observed on the electrocardiogram. Fritschi et al. (2011) concluded that a noise level of 55 dB is enough to cause stress in a person. Upward of that, a noise level of 65 dB causes cardiovascular disorders, a noise level of 70 dB leads to hypertension, a noise level of 70 dB causes heart disorders, and a noise level of 80 dB leads to hearing loss. Diseases of the endocrine, gastrointestinal, peripheral, and central nervous system caused by increased noise can be easily determined by biochemical analysis.

Pahlavan and Arouss (2016) confirmed that the impact of noise on humans is reflected in aggressive behaviour, and exposure can lead to an increase in excitement, which is a trigger for various negative health effects, primarily stress. Stress itself causes immediately visible effects, such as emotional reactions or physiological changes, which significantly affect social and psychological behaviour (Gross, 1998). It has been concluded that the direct link between noise-induced suffering, depression, migraines, and aggression is based on biochemical processes related to hormones and neurotransmitters, due to the release of large amounts of hormones such as adrenaline, cortisol, and noradrenaline, which are associated with depression and aggression (Ramirez, 2006).

Noise has a negative effect on a person's biorhythm – sleep issues, insomnia, waking up during the night, and influence on the Rapid Eye Movement (REM) phase during sleep. Anees et al. (2017) determined through research that 30 dB is enough to disrupt sleep.

## OCCUPATIONAL EXPOSURE TO SILICA DUST

According to OSHA (2012), silica dust is a chemical substance that acts as a pollutant in the construction site air and affects people's health in different ways, whether as a simple irritation or a serious illness. The origin of silica is natural, but it still poses a danger to the respiratory system and human health, which can lead to a serious disease called silicosis (Mučenski, 2018). The highest concentrations of silica dust are mostly found during excavation, drilling, rock processing, tunnelling, demolition of buildings, cutting and processing of concrete, brick, ceramic and granite tiles, etc. (HSE UK, 2020).

Two high-quality sources (Luo et al., 2021; Bello et al., 2019) provide essential data about the measurement approaches and exposure levels that occur when staff perform earthwork duties because directly relevant research on silica dust exposure at construction sites is lacking. Through different monitoring technologies and construction site working conditions, these studies provide important information about workplace hazards in Table 1.

**Table 1.** *Measurement approaches and exposure levels of silica dust during earthworks*

| Study | Measurement Method | Context/Job tasks | Silica Dust Concentration |
|---|---|---|---|
| Luo et al. (2021) | Optical laser – scattering detectors (PC-3B, PH-YC01); 15-min intervals | Earthwork phase – excavator drivers, truck drivers, site command ers | Up to **9.635 mg/m³** (excavator driver); others: 0.2–6.7 mg/m³ |
| Bello et al. (2018) | Gravimetri c sampling + FT-IR (NIOSH Method 7602) | Crushing machine tenders processing excavated material | GM: **93.3 µg/m³**; max: **239 µg/m³**; 50% of samples exceeded OSHA PEL of 50 µg/m³ |

The measured values of silica dust during earthworks depend on operation – the excavator and truck operator experienced the highest average dust concentrations (almost 9.6 mg/m³ at some point of measurement) that exceed the permissible exposure limit (PEL) of silica dust. It was noticed that the level of dust near the excavation site, where the intensity of work was at its highest point, can reach about 130 mg/m³, while workers who were located further from the source tended to encounter lower dust concentrations (Luo et al., 2021). Bello et al. (2018) revealed that 50% of samples collected from the crushing machine during measurements of silica dust exceeded the OSHA PEL of 50 µg/m³, with a geometric mean of respirable crystalline silica (RCS) 93.3 µg/m³, and the highest concentration of 239 µg/m³. (Bello et al., 2019).

While RCS is the fine, inhalable fraction that can penetrate deeply into the lungs and have major health effects, silica dust is the general term for airborne particles from materials containing silica. RCS is contained in silica dust, has no colour and smell, is non-irritating, and does not cause immediate health effects. When small particles of silica dust (less than 5 µm in diameter) are inhaled, they travel to the lower part of the lungs and usually form scars (Requena-Mullor et al., 2021; Xiao and Li, 2023). Since silica dust is a chemical substance that can have a toxic effect on human health, this effect is divided into two categories: acute and chronic. Acute signs happen quickly and after high exposure, whereas chronic signs develop more slowly, over a longer period. Both types of effects can cause different diseases, where the main disease is silicosis. In addition, it is important to highlight that silica dust can also have systemic health effects, where a substance like silica penetrates target organs (such as lungs), accumulates, and exerts its negative effects (OSHA, 2012). Long-term exposure (15 to 20 years) to medium and low concentrations can lead to diseases of the respiratory system, namely bronchitis, silicosis, and cancer. Due to the large amounts of silica dust deposited in the workers' lungs, their immunity weakens and thus they become more susceptible to diseases such as tuberculosis. As a result, workers may exhibit one or more of the following symptoms: shortness of breath during physical exertion, severe coughing, fatigue, loss of appetite, chest pain, and fever. Also, Hoy and Chambers (2020) determined that acute silicosis exhibits significant differences compared to chronic silicosis. Acute silicosis is caused by a very high level of exposure to silica dust over several weeks to 5 years. It is typical for workers who carry out sandblasting, those who work in tunnels, and those who process silica flour. It presents as a progressive condition with nonspecific symptoms, including dyspnoea, cough, fatigue, weight loss, fever, and pleuritic pain. Disease progression can be rapid, and there is a high mortality rate.

Overall, exposed workers might not suffer directly from silicosis, but rather from groups of associated diseases (Kreuzer et al., 2013), such as

- cardiovascular diseases;
- sarcoidosis;
- pulmonary tuberculosis;
- lung infections;
- chronic obstructive disease;
- certain types of tumours;
- lung cancer;
- autoimmune diseases;
- kidney disorders,

whereby it is important to highlight that an increased risk of mortality is observed in workers who smoke cigarettes (Wang et al., 2020). It is important to emphasize that one of the main causes of mortality and increased mortality of workers exposed to silica dust is the development of Mycobacterium tuberculosis (TB) infection (Barboza et al., 2008). TB rates are extremely high in workers exposed to silica dust in regions with high base rates of TB and HIV. TB infection is associated with an increased risk of progression of silicosis and severity of the disease. The effects of TB are also exacerbated by HIV infection and smoking, which often coexist, especially in developing countries, like South Africa (Rees and Murray, 2007; Leung et al., 2012). Also, Rees and Murray (2007) concluded that exposure to silica dust increases the risk of tuberculosis, even without silicosis, and continues after exposure has stopped.

The cure for silicosis does not exist (Requena-Mullor et al., 2021; OSHA, 2012), and the way to determine if a worker has silicosis is to conduct a complete medical examination, which contains a complete work history, an X-ray of the chest, and a lung function test. The X-ray test is significant for diagnosing chronic silicosis since it can be unnoticed in the early stages and seen on an X-ray after 15-20 years of exposure. The importance of chest X-rays was confirmed by Keramydas et al. (2020).

Keramydas et al. (2020) presented a study where 86 construction workers were exposed to silica dust in underground construction works – underground excavation and tunnelling. They recorded low exposure to silica dust (0.0125 $mg/m^3$) among workers, but also discovered interesting information that during the lung X-ray examination, 5 employees (7.2%) were diagnosed with a specific finding, and 12 employees (17.4%) had non-specific findings. As a suspicious enlargement of the right hilum was observed in one X-ray finding of the lung, a CT scan of the lung confirmed the presence of a right hilar tumour.

According to laws and regulations, the risk from silica dust must be estimated through risk assessment, risk control, and review of the list of preventive measures. Preventive measures against silica dust can be divided into:

- Engineering – of which water curtains and tool extraction systems are best-known, and
- Administrative – breaks during work, training of employees, limiting the number of people who work with silica dust, ventilation, proper choice of PPE, etc.

If used correctly, with delivering sufficient amounts of water to appropriate places during the entire time the work is being performed, water curtains are a good choice to be used as a preventive measure against silica dust on construction sites (Figure 3). Also, the tool extraction system removes the dust while it is being produced, and it is placed directly on the tool (Figure 4). Considering that water curtains or tool extraction systems are not always applicable, adequate use of respiratory PPE represents a last-resort preventive measure, intended to lower exposure to silica dust (Figure 5).

**Figure 3.** *Use of water curtains during excavation (source: https://www.instagram.com/p/DF-sMSfS34x/)*

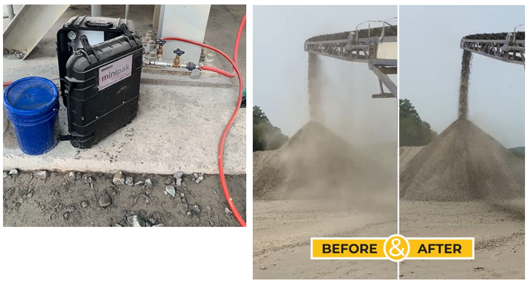


**Figure 4.** *Using a dust suppression system (left) and results of implementation (right) (source: https://benetechglobal.com/products/minipak-dust-suppression-system/ )*

Respiratory PPE must be adequate and comfortable for work, with the assigned protection factor (APF) for the construction industry – 20, which means that the user inhales only 1/20 of the total amount of dust in the air. Respiratory PPE must adhere to the face, be compatible with other PPE, and be worn in the proper way (OSHA, 2012).

**Figure 5.** *An example of respiratory PPE for construction workers (source: https://i0.wp.com/www.safetysuppliesunlimited.net/wp-content/uploads/2020/02/respirator-safety.png?fit=895%2C545&ssl=1 )*

In addition to that, since PPE is one of the easiest ways to protect from silica dust, the situation on construction sites shows a weak system of using PPE. Pérez-Alonso et al. (2014) noticed that in most cases PPE is not provided, or if PPE is provided, workers do not know how to use it properly.

Workplace protocols that decrease silica dust exposure involve task organization and personnel training as administrative safeguards. The organization reduces the number of workers in the area and implements personnel rotation while using barriers to separate workstations, providing general mechanical ventilation, and selecting appropriate dust-free clothing. Training of employees is the most important administrative measure, which should be focused on understanding silica dust hazards and the proper use of PPE. The effectiveness of these measures must be followed through control of work procedures, measurement of exposure to the silica dust, regular maintenance of equipment, and health surveillance.

Health surveillance of exposed workers is widely recommended and usually includes a periodic health questionnaire, physical examination, lung function measurements, and a chest X-ray. After diagnosis of silica dust-related disease, cessation of further exposure is recommended (Rees and Silica, 2017).

Therefore, the measurements for silica dust on construction sites should be taken into account as a normal part of an examination of working conditions. This fact is supported by Hoy and Chambers (2020). When available, regular measurements of ambient silica levels are essential to ensure compliance with regulatory limits and to make control effective and productive. Respirators should not be the primary means of protection for employees but should be used only after more effective control measures, such as elimination, replacement, and venting.

## CONCLUSION

Dual occupational hazards of noise and silica dust exposure during earthworks on construction sites are highlighted in this research, showing that noise levels and silica dust significantly varied. Measured with both an SLM and a personal dosimeter, noise levels were almost always above the exposure noise level of 85 dB. The excavation phase was the loudest, whereby a personal dosimeter measured an equivalent noise level of $L_{Aeq}$ = 94.7 dB, and a very high value of $L_{Cpeak}$ – 143.1 dB, indicating the risk of deafness, difficulty in communication, and stress among the construction workers during earthworks phase. Simultaneously, measured concentrations of RCS during earthworks where maximum levels were above 239 μg/m³ exceeded the permissible limits set by OSHA (50 μg/m³).

The occurrence of these hazards significantly increases the overall risk exposure for construction workers. Noise exposure leads to hearing loss and affects communication between workers, while on the other hand, silica dust precedes irreversible health conditions, such as silicosis, both of which affect workers' safety and health. Therefore, this research showed that regular personal measurements should be taken and be legally binding, not only to precisely determine actual exposure and efficient planning of preventive measures but also to prevent professional diseases, raise awareness among workers, and provide them with proper education and training in order to enhance the safety at work. To lower the risk of noise and silica dust, it is necessary to represent their risk on a global level, to reduce worker exposure, and to prevent diseases like occupational hearing loss and silicosis through different research and innovation models.

## ACKNOWLEDGEMENTS

This research has been supported by the Ministry of Science, Technological Development and Innovation (Contract No. 451-03-137/2025-03/ 200156) and the Faculty of Technical Sciences, University of Novi Sad through project "Scientific and Artistic Research Work of Researchers in Teaching and Associate Positions at the Faculty of Technical Sciences, University of Novi Sad 2025" (No. 01-50/295).

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