OCCUPATIONAL NOISE EXPOSURE ON CONSTRUCTION SITES: CONSEQUENCES FOR SAFETY MANAGEMENT

DOI: 10.5937/JEMC2600007K

UDC: 613.644:624
Original Scientific Paper

Željana KUŽET[1], Vladimir MUČENSKI[2], Selena SAMARDŽIĆ CVIJANOVIĆ[3], Jovana TOPALIĆ[4], Andrea IVANIŠEVIĆ[5], Goran BOŠKOVIĆ[6], Ranko MAKIVIĆ[7], Tamara GAJIĆ[8]

[1]University of Novi Sad, Faculty of Technical Sciences, 21000 Novi Sad, Trg Dositeja Obradovića 6, Republic of Serbia
ORCID ID (https://orcid.org/0009-0004-0958-517X)
[2]University of Novi Sad, Faculty of Technical Sciences, 21000 Novi Sad, Trg Dositeja Obradovića 6, Republic of Serbia
ORCID ID (https://orcid.org/0000-0001-9830-4747)
[3]University of Novi Sad, Faculty of Technical Sciences, 21000 Novi Sad, Trg Dositeja Obradovića 6, Republic of Serbia
ORCID ID (https://orcid.org/0000-0003-2578-7412)
[4]University of Novi Sad, Faculty of Technical Sciences, 21000 Novi Sad, Trg Dositeja Obradovića 6, Republic of Serbia
Corresponding author. E-mail: jovanatopalic90@uns.ac.rs
ORCID ID (https://orcid.org/0000-0001-7854-3257)
[5]University of Novi Sad, Faculty of Technical Sciences, 21000 Novi Sad, Trg Dositeja Obradovića 6, Republic of Serbia
ORCID ID (https://orcid.org/0000-0003-3342-7257)
[6]University of Kragujevac, Faculty of Mechanical and Civil Engineering in Kraljevo, 36000 Kraljevo, Dositejeva 19, Republic of Serbia
ORCID ID (https://orcid.org/0000-0002-4597-922X)
[7]University of Novi Sad, Faculty of Technical Sciences, 21000 Novi Sad, Trg Dositeja Obradovića 6, Republic of Serbia
ORCID ID (https://orcid.org/0009-0006-8132-7858)
[8]Geographical Institute "Jovan Cvijic" SANU, 11000 Belgrade, Djure Jaksica 9, Republic of Serbia
ORCID ID (https://orcid.org/0000-0003-3016-8368)

Paper received: 08.04.2026.; Paper accepted: 24.05.2026.

This study analyzes noise exposure among construction workers using hydraulic excavators at construction sites in Novi Sad and Subotica, based on 16 Sound Level Meter (SLM) measurements and one full-shift personal dosimetry measurement. The use of this methodology enabled the identification of the most common excavator activities and their manufacturers that produce noise in actual working conditions. The findings indicate significant differences in noise levels produced by excavators, depending on the manufacturer and the activities they perform. The results demonstrate the significance of combining the Sound Level Meter (SLM) with personal dosimetry, as personal dosimetry provides more reliable information about 8-hour work-shift exposure than a stationary SLM. In addition, results also showed an urgent need to reshape occupational safety management in construction. The principal scientific contribution is a novel Noise Risk Management Framework that translates measured acoustic parameters directly into operational management decisions for construction site managers.

Keywords: Noise; Construction; Excavators; Personal dosimeter; Sound Level Meter.

INTRODUCTION

Noise is one of the most ubiquitous yet underdocumented risk factors in the construction sector (Anees et al., 2017). Unlike other forms of pollution, noise is invisible and intangible; however, its long-term impact on hearing, concentration, and psychophysical health is well known (Papadimitriou et al., 2020). Many studies confirm that, in construction machines, particularly hydraulic excavators, sound emissions frequently exceed the normative maximum acceptable exposure limits set by European and national legislation (Tánczos et al., 2007). However, the implementation of preventive actions in practice is inconsistent, particularly on lower-priority construction sites, where acoustic measurements are infrequent and control of workers' exposure to noise is limited (González, 2014).

ISSN 2217-8147 (Online)

A careful examination of the relevant literature reveals several deficiencies that limit understanding of workers' actual noise exposure. Most of the research undertaken so far relies solely on standard tools, such as sound meters, to measure ambient noise rather than personal exposure. Therefore, the cumulative impact of several hours of exposure is not properly quantified (Jain et al., 2016). At the same time, in practice, there is a gap between the available technological solutions and their application. Modern digital noise-monitoring systems, IoT sensors, and portable devices are rarely used in dynamic working conditions, where measurements are exposed to vibrations, weather, and spatial variability (Lee et al., 2012). Moreover, the relationship between technical features of the machines (manufacturer, age, operating mode) and the actual level of exposure of the operator to noise during the shift has not been studied in depth enough; that is why the technical and organisational protection measures cannot be defined precisely (Praščević et al., 2018/19; Sripaiboonkij et al., 2013).

The purpose of this research is to scientifically establish the level of exposure of workers to noise in operation with hydraulic excavators handling construction works at construction sites in Novi Sad and Subotica, as well as to identify the most significant excavator activities of excessive noise in real working conditions on construction sites. It is also intended to investigate noise level differences across excavator models and various work activities, and to relate these to results obtained with an SLM and a personal dosimeter. When these instruments are combined, a multidimensional system of acoustic risk assessment is obtained, enabling evaluation of external and personal exposure factors. Despite the clearly defined limits, construction site managers lack an operational decision-making framework based on measured noise exposure parameters. This research seeks to fill this void by relating measured noise parameters to a framework for risk classification and decision-making in construction safety systems. Beginning from the above-mentioned objective, the research attempts to answer the two questions:

R.Q.1. Are there statistically significant differences in excavation activities (excavation, loading, idling) of a specific machine, as well as between machine models?
R.Q.2. Do the years of manufacture and technology have an impact on the sound pressure level generated by the operation of hydraulic excavators?

In addition, research aims to provide a scientific basis for improving regulation, more efficient machine maintenance planning, and educating workers about the dangers of noise exposure. At the same time, the research helps implement the concept of smart safety systems, integrating monitoring, ergonomics, and human factors into a unique model of occupational safety management. The use of an SLM and a personal dosimeter simultaneously in real working conditions enables a more accurate estimate of workers' exposure to excavator noise. An approach like that improves the scientific and practical foundation for creating an efficient working environment, thereby achieving greater safety, efficiency, and protection of workers' health.

LITERATURE REVIEW

Exposure of workers to noise in the construction sector is one of the most common, yet most underestimated occupational risks, which, in the long term, causes gradual and irreversible hearing damage known as occupational noise-induced hearing loss (ONIHL) (Nelson et al., 2005). Chen et al. (2020) indicates that damage results from cumulative exposure to high sound intensities, but that even moderate levels can cause microscopic damage to the inner ear. Although there is a clear definition of the standards and preventive measures, their application in practice is not always consistent, creating an overlap between the prescribed norms and the actual protection of workers. Thus, the problem of noise on construction sites is not merely a matter of control, but rather one of understanding real working conditions, where noise sources are variable, and exposure is cumulative and uneven (Latorre-Arteaga et al., 2017). While the health literature emphasizes the cumulative effects of noise exposure and the need for continuous monitoring of worker conditions, technical studies increasingly highlight the limitations of existing instruments and the need to integrate digital technologies into risk assessment (Sørensen et al., 2024). The emergence of modern technologies, such as digital sensors, IoT systems, and smart wearable devices, has opened the door to more detailed insight into exposure. Still, their application in the construction industry faces challenges related to costs, complexity, and standardization (Chis et al., 2025).

Choi et al. (2021) have developed an automated model for integrating noise data into safety systems. Still, it remains limited in terms of reliability in actual construction site conditions, where noise sources are constantly varying. Lu et al. (2021) analyze the potential of integrating acoustic data into BIM frameworks for preventive planning, but note that the quality of the results depends on the quality of the input data and designers' expertise, which often limits practical application. Patel et al. (2022) highlight the benefits of wearable technologies for monitoring workers' physiological responses, which have been limited by high costs and a lack of uniform protocols. Existing models for assessing industrial and construction noise are based on different theoretical and technological approaches, but all have methodological limitations (Prayogo et al., 2025; Yang et al., 2025). Classical empirical models, e.g., those elaborated by Babazadeh et al. (2025), permit the assessment of noise sources under controlled conditions but do not account for performance alterations, wear, or variations in machine operating mode. Predictive models based on acoustic spectra and machine learning (Hou et al., 2025; Movahed and Ravanshadnia, 2022) show high potential for risk detection and prediction but require continuous data updates and sophisticated sensor infrastructure, which are not widely available at construction sites. BIM-integrated models are an important theoretical change as they link the planning and acoustic protection, but their implementation demands a high level of technical training and institutional support, which is often lacking (Chen et al., 2025; Hakimian et al., 2025; Liu et al., 2025; Ouis et al., 2025). Also, Barkokebas et al. (2012) integrate conventional and digital techniques through hybrid models that bridge phonometric measures and wearable monitoring, and Masterson and Themann (2025) verify that machine learning and sensor devices facilitate acoustic peak detection and risk management. However, most of these models have been tested under controlled conditions and have not been empirically validated in a real working environment with variable microclimatic and technical conditions; therefore, they have limited reliability and applicability.

Despite advances in digital solutions, research largely remains within the scope of classical measurements using SLMs, which do not reflect the complexity of real working conditions or full-shift exposure. There is no empirical study that compares measurement results from an SLM and a personal dosimeter in real conditions of construction machine operation, with simultaneous analysis of the impact of age and technical features on noise emissions (Ding et al., 2024; Samara et al., 2024). On that basis, this research proposed an example of measurement using an SLM and a personal dosimeter, which can concurrently measure ambient and individual noise exposure. Such an approach indicates the possibility of establishing a management mechanism to improve work organization and safety management.

MATERIALS AND METHODS

Research design and sampling

The fieldwork was conducted under real working conditions on three construction sites in Novi Sad and one in Subotica during December 2023. The first part of the research, conducted with an SLM, measured noise in the working environment produced by hydraulic excavators at three different construction sites in Novi Sad. Three basic work activities were observed: digging, loading, and idle operation, with each process measured continuously for approximately 30 minutes during the period of highest noise exposure. The research included excavator operators operating hydraulic excavators from different manufacturers (Dosan, Takeuchi, Liebherr, and JCB) to ensure sample variability in terms of age, technical condition, and machine acoustic characteristics. The machinery used for the research included both newer and older hydraulic excavators. The measurements were taken during December 2023, roughly between 9:00 a.m. and 2:00 p.m., when the construction work intensity was at its highest. During the measurement, the sound meter was 1.5-2 m from the hydraulic excavator, depending on the operation being performed, with the safety distance taken into account.

On a construction site in Subotica, the second part of the research was conducted on 21st December 2023. This part of the research was a pilot study intended to demonstrate the benefits of personal dosimetry and to show that these measurements provide more rational information about daily exposure during the 8-hour work shift than stationary sound-level meters. The machinery included a modern Liebherr hydraulic excavator. It should be noted that the personal dosimetry component of this study constitutes a pilot measurement (n=1 worker, n= 1 shift), and its findings should be interpreted accordingly. While the results are indicative and methodologically significant, they are not statistically generalizable and are presented as a proof-of-concept for the dual-instrument approach. Measurements were collected in two ways:

- one measurement with an SLM during the most intense operation for 30 minutes continuously,
- during the whole eight-hour shift– the work shift started at 7:23 am and ended at 3:30 pm.

The units of analysis were work activities and machine types, while the main dependent variable was the equivalent noise level (L_{eq} in dB(A)). The statistical analysis aimed to determine whether there is a significant difference in noise level between activities and between excavator models.

Instruments, calibration, and measurement procedure

Measurements were performed with two high-accuracy certified devices. The first instrument was a Sound Level Meter (SLM), also referred to as a phonometer in practice, type TES 1358A, IEC 651 standard, first class, used to measure the equivalent sound pressure level (L_{eq}) and the maximum level (Lmax) in the immediate environment of the excavator. The measurements have been performed at a distance of 1.5 to 2 meters from the noise source (with due safety distance). The SLM was used with an applied A-filter for weighting, a "Slow" time response in the frequency range from 25 Hz to 10 kHz, which allowed for the correct recording of the entire operating cycle of the noise change. Before each measurement, a standardized acoustic calibrator was used to ensure accurate results. The measurements were performed in compliance with the international standards ISO 1996-2:2017 and ISO/IEC 61672-1, as well as the domestic regulations on occupational safety (International Organization for Standardization, 2017; Institute for Standardization of Serbia, 2021; Ministry of Labour and Social Policy, 1992). It is important to note that when measuring with an SLM, whenever the sound pressure level exceeded the specified threshold (85 dB(A)), frequency analyses were performed at 1/1- and 1/3-octave bands. Given that the experimental Leq values were measured in 1/3-octave bands, which provide an in-depth view of noise levels across the frequency composition, the N-80 curve at the 1/1-octave band is interpolated. The level of a 1/1 octave band can be converted to three 1/3 octave bands by subtracting $10 \log_{10}(3) = 4.771$ dB from the 1/1 octave band level (Blevins, 2015).

The second instrument was the Bruel & Kjaer type 444-8B personal dosimeter, which was used to determine the workers' actual noise exposure during an eight-hour work shift. The dosimeter was mounted on the excavator's shoulder, 10 cm from the ear and 4 cm above the shoulder, and continuously recorded L_{eq}, L_{Cpeak}, dose, and accumulated exposure energy (Pa2h). The measurement was performed at the construction site in Subotica, where a newer model of a Liebherr excavator was used, which emits lower noise. With this approach, it was possible to obtain a detailed understanding of the daily dose of exposure (Dose %) and the time-weighted average (TWA), in accordance with the European Directive 2003/10/EC and domestic legislation.

Statistical data processing

The results were analyzed using IBM SPSS Statistics 28 and Microsoft Excel 365. In addition to the descriptive indicators (average, standard deviation, minimum, and maximum), inferential analyses were conducted to assess the significance of differences between observed groups of activities and excavator types.

A one-way analysis of variance (ANOVA) was used to test the statistical significance of differences in the average noise levels (L_{eq}) across the three work activity categories (excavation, loading, and rest). In this context, the dependent variable was the equivalent noise level (L_{eq}), and the independent variable was the type of excavator activity. In addition, to compare various machine manufacturers, a separate ANOVA was performed with excavator type as the independent variable (Dosan, Takeuchi, Liebherr, JCB). The Shapiro-Wilk test ($p > 0.05$) was used to test the normality of the distribution, and the Levene test (Rahardja & Aini, 2025) was used to test the homogeneity of the variances. Statistical significance was assessed at $p < 0.05$. An independent samples t-test was used to detect for differences between older and newer excavator models, Cohen's d effect size coefficient was determined (small = 0.2; medium = 0.5; large = 0.8) (Ismail & Sahid, 2024), confidence intervals (95%) were determined for all main acoustic parameters (L_{eq}, L_{max} and L_{Cpeak}) and correlation analysis (Pearson r) tested for relationship between machine age and average noise level (Dinamarca et al., 2025). In addition to descriptive quantification, this methodology enabled scientific confirmation of a significant difference in noise emissions between activities and models, thereby guaranteeing the validity and trustworthiness of the interpretation of the results.

The research was conducted in accordance with the Rulebook on preventive measures for safe and healthy work when exposed to noise (Ministry of Labour and Social Policy, 2019). On the construction site in Subotica, where a pilot measurement with a personal dosimeter was conducted, the worker was previously informed of the research's purpose and voluntarily consented to wear the dosimeter. Measurements conducted with an SLM on both construction sites were carried out without endangering their health or interrupting work processes. Special attention was paid to instrument calibration, measurement repeatability, and the elimination of systematic errors, ensuring a high degree of reliability and controlled research conditions. By combining standardized instruments, validated measurement procedures, measurement uncertainty control, and advanced statistical methods, the research achieves a high degree of scientific rigor. This approach enables reproducibility and verifiability of results, international comparability, and clearly defined conclusions about the impact of noise on workers' health and the need to improve the occupational safety system in the construction industry. Since the research does not involve the collection of personal or health data, but only technical measurements in accordance with the law, no additional ethical approval was required.

RESULTS AND DISCUSSION

Quantitative display of measurements

In the first phase of the analysis, the quantification of equivalent (L_{eq}) and maximum (L_{max}) noise levels according to work activities was carried out. The results show that measured noise levels differ between excavation, loading, and idle activities, with the highest values recorded during excavation. Table 1 shows the measured equivalent (L_{eq}) and maximum (L_{max}) noise exposure levels at construction sites. These values were measured for the three most common excavator work activities: excavation, loading, and idling. Results show that measured equivalent noise values range from 59.9 to 85.4 dB(A), with the highest Leq of 85.4 dB(A). This value stands out significantly and differs from other measured values, likely due to the excavator's handling of a specific material type. The same operation, which involved excavating and manipulating its bucket, also reached the highest maximum of 98.9 dB (A).

On the other hand, the Liebherr excavator recorded the lowest L_{eq} value of 65.8 dB. This finding supports the assertion that this particular excavator model is a recent production and generally operates at lower noise levels, as shown statistically in this research. The workers present at the construction site further validated this observation.

Table 1: Results of L_{eq} and L_{max} measurements using an *SLM at the construction site*

Activity of the excavator	Manufacturer of an excavator	Measurement level of noise [dB (A)]	
		L_{eq}	L_{max}
Loading material	Dosan	74.0	81.5
Loading material	Dosan	74.8	88.5
Excavation	Takeuchi	74.2	83.4
Excavation	Takeuchi	76.5	83
Excavation	Takeuchi	74.3	82.7
Excavation	Liebherr	65.8	83.5
Idle operation	JCB	71.3	75.3
Excavation	JCB	85.4	98.9
Idle operation	JCB	71.1	79.0
Idle operation	JCB	70.9	75.5
Loading material	JCB	75.3	96.2
Loading material	JCB	59.9	78.0
Loading material	JCB	72.4	84.2
Excavation	JCB	73.7	87.7
Excavation	JCB	71.5	88.5
Excavation	JCB	70.9	84.4

The equivalent (L_{eq}) and maximum (L_{max}) noise levels for three types of hydraulic excavator activities are presented in Table 2. The results show that the highest average noise level was measured during excavation (Leq = 74.0 dB(A)), which also coincided with the phase with the highest engine load and vibration emissions. Material loading activities have a somewhat lower average level (L_{eq} = 71.3 dB (A)), while rest is characterized by the lowest noise values (L_{eq} = 71.1 dB (A)) and by the minimum variability (SD = 0.2). These results confirm that most intensive activities, namely excavation, are the dominant sources of excessive noise, while rest is the control phase with stable, moderate sound levels.

Table 2: Mean values and SD of L_{eq} and L_{max} measurements for the specific activity of the excavator

Activity of the excavator	L_{eq} [dB (A)]		L_{max}[dB (A)]	
	Mean	Std. Dev.	Mean	Std. Dev.
Loading material	71.30	6.46	85.70	7.02
Excavation	74.00	5.60	86.50	5.46
Idle operation	71.10	0.20	76.60	2.08

To determine which operation and excavator type produce the highest sound pressure equivalent values, the mean and standard deviation of the results were calculated (Tables 2 and 3). Nonetheless, it is noteworthy that all three excavator categories display elevated L_{eq} values during excavation. All mean values are approximately the same, except for L_{max} for idle operation and L_{aeq} for the Liebherr excavator.

Table 3: Mean values and SD of L_{eq} and L_{max} measurements for specific manufacturers of excavators

The manufacturer of an excavator	L_{eq} [dB (A)]		L_{max} [dB (A)]	
	Mean	Std. Dev.	Mean	Std. Dev.
Dosan	74.40	0.57	85.00	4.95
Takeuchi	75.00	1.30	83.00	0.35
Liebherr	65.80	/	83.50	/
JCB	72.20	6.18	84.80	8.22

Supplementary measurements and analyses were conducted to thoroughly assess noise pollution at the construction site and its potential implications for workers. Upon surpassing the allowable 85 dB threshold for industrial noise and eight-hour work shifts, an investigation was conducted on the JCB excavator. The excavator's frequency response was compared to the N-80 curve. According to Fig. 1, the noise levels exceeded the permissible values at frequencies between 1600 and 4000 Hz. The measured exceedances in the 1600–4000 Hz range are particularly significant because this band overlaps with the frequencies most critical for human speech perception and for the onset of hearing damage (Salvendy, 2012), with management implications addressed in the decision framework (Table 9).

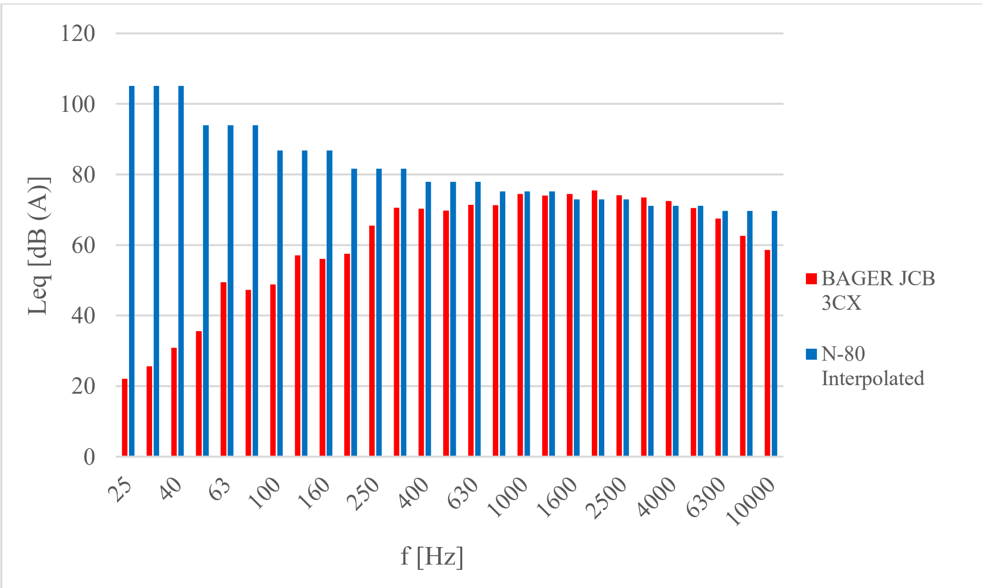

Figure 1: Comparison of 1/3 octave band for L_{eq} and interpolated N-80 curve.

Statistical analysis of differences and associations of noise levels

The results of the one-factor ANOVA analysis indicate a statistically significant difference between the average noise level values for the three types of excavator activity ($F(2,13) = 5.76$, $p = 0.016$). Post hoc analysis (Tukey HSD) showed that the difference between the digging and resting phases was significant ($p = 0.012$), whereas that between digging and loading was not ($p = 0.08$). This confirms that excavation is the activity with the highest acoustic load on construction sites (Table 4).

Table 4: ANOVA test - differences in noise level according to excavator activity

Source of Variation	SS	df	MS	F	p
Between Groups (Activities)	132.40	2	66.20	5.76	0.016
Within Groups	149.50	13	11.50	—	—
Total	281.90	15	—	—	—

The results show that there are statistically significant differences in average noise values between different manufacturers of excavators ($F(3,12) = 6.32$, $p = 0.008$) (Table 5). The highest average noise level was recorded at JCB (M = 72.2 dB(A)) and Dosan (M = 74.4 dB(A)), while the lowest values were present at Liebherr (M = 65.8 dB(A)). The results confirm that newer excavator models, especially Liebherr models, have significantly lower noise emissions, thanks to better sound insulation and more modern drive systems.

Table 5: ANOVA test - differences in noise level according to excavator manufacturer

Source of Variation	SS	df	MS	F	p
Between manufacturers	228.70	3	76.20	6.32	0.008
Within Groups	144.60	12	12.10		
Total	373.30	15			

The results of the t-test indicate a statistically significant difference between older and newer excavator models ($t(14) = 3.11$, $p = 0.008$), with the newer models producing an average noise level 7.5 dB(A) lower (Table 6). The effect size (Cohen's $d = 0.86$) indicates a large difference, confirming the impact of technological improvements on reducing workers' exposure to noise.

Table 6: Results of t-test - comparison of older and newer excavator models

Machine Group	N	Mean Leq [dB(A)]	SD
Older Models (Dosan, JCB)	12	73.8	5.8
Newer Models (Takeuchi, Liebherr)	4	67.3	4.5

The results indicate a positive, statistically significant correlation between the machine's age and the average noise level ($r = 0.68$, $p = 0.005$). This means that as the excavator ages, the level of emitted noise increases, which can be attributed to wear of mechanical parts, inadequate maintenance, and lower engine efficiency in older models (Table 7).

Table 7: Correlation between machine age and average noise level (Leq)

Variables	Pearson r	p	Interpretation
Machine Age ↔ Leq	0.68	0.005	Moderately strong positive correlation

Analytical interpretation and assessment of noise exposure conducted with a personal dosimeter

On the other hand, a pilot measurement was conducted to compare the equivalent sound pressure values. In this regard, a measurement was performed simultaneously with an SLM and a personal dosimeter, which was attached to the worker on this excavator for eight working hours. Measurement with SLM was performed on the Liebherr excavator during the most intense operation – continuous excavation and loading soil into the truck for 30 minutes- and it showed a measured L_{eq} of 75 dB (A). On the other side, the personal dosimeter readings for an 8-h work shift show the following values: L_{eq} = 82.9 dB A, sound exposure = 0.62 Pa2h, dose = 19.3%, and L_{Cpeak} = 143.1 dB. The noise-equivalent level measured by the personal dosimeter is close to the allowable limit of 85 dB(A) for an eight-hour workday. However, the L_{Cpeak} is very high, indicating the presence of another high-value periodic or impulsive noise. According to the new regulations, hearing protection must be worn at and above L_{Cpeak}=137 dB(C), while no one will be exposed to levels at or above L_{Cpeak}=140 dB(C). Despite this, the dose-value indicates that the worker was exposed to excessive noise for approximately 20% of the workday. One of those time intervals was when the worker excavated soil and loaded it into a truck for 30 minutes, during which the equivalent noise level (L_{eq}) value was 89.2 dB(A), and L_{Cpeak} was 143.1 dB(C) (Fig. 2)

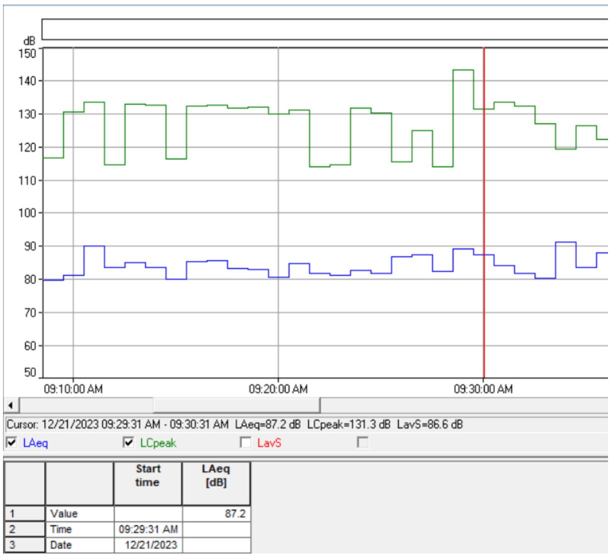

Figure 2: Personal dosimeter readings for an eight-hour working shift on the Liebherr excavator

A personal noise dosimeter can provide more accurate, valuable data from these measurements. This information can aid in determining more effective protection measures for workers, as the results can be used to calculate the time-weighted average noise level (TWA in dB) for machinery operators. This information can help determine the proper hearing protection device (HPD) and predict the likelihood of occupational hearing loss.

The results of measurements using a personal dosimeter show that the average noise level during an eight-hour shift is 82.9 dB(A), which is close to the legal threshold of 85 dB(A). However, the peak level (L_{Cpeak} = 143.1 dB(C)) exceeds the permissible limit, which indicates the presence of impulse noise in the working environment. Total exposure (Dose = 19.3%) indicates that the worker was exposed to increased noise levels during approximately one-fifth of the shift, particularly during excavation and loading activities, which require the application of mandatory hearing protection and engineering control measures (Table 8).

Table 8: Results of the personal dosimeter during the eight-hour shift

Parameter	Measured Value	Reference Limit (RS Standard)	Interpretation
L_{eq} [dB(A)]	82.9	≤ 85	Within the permissible exposure limit, but close to the threshold
L_{Cpeak} [dB(C)]	143.1	≤ 140	Exceeded (impulse noise)
Dose [%]	19.3	≤ 100	Approximately 20% of the daily exposure limit
Sound Exposure [Pa^2h]	0.62	–	Moderate acoustic load
TWA [dB(A)]	83.2	≤ 85	Within the permissible average level

DISCUSSION

The research results confirmed that the noise emitted by hydraulic excavators is a function of several mutually related factors: machine type, age, technical condition, and the type of activity. The values obtained for the equivalent noise level (L_{eq}) ranged from 59.9 to 85.4 dB(A), and for the maximum level (Lmax) from 98.9 dB(A), both of which exceed the limit values set by national regulations and Directive 2003/10/EC. Although the equivalent noise level calculated from the personal dosimeter (L_{eq} = 82.9 dB(A)) approached the permissible limit, the impulse peaks of 143.1 dB(C) indicate the presence of short-term, extremely dangerous acoustic shocks, which can lead to hearing damage and psychophysiological fatigue among workers. It is concluded that even when measured noise equivalent levels are below regulatory levels, the actual risk could be quite high due to the heterogeneous sound load distribution over the working cycle.

The first research question (R.Q.1) concerned the degree of noise level variation among excavators, excavations, loaders, and across different machine models. The results indicated that the excavation and loading periods are the most critical, with equivalent noise levels ranging from 59.9 dB(A) to 85.4 dB(A). These findings are consistent with those of Movahed and Ravanshadnia (2022), who also found that excavation work was the main source of noise. Still, our results showed a larger range of variation and a much higher impulse level, indicating more realistic working conditions. Compared with the 80 dB(A) reported by Chis et al. (2025) for similar classes of machines, our results indicate that the values may be up to 10 dB(A) higher in real dynamic conditions. This difference might be explained by the fact that cumulative exposure, vibration, and change in machine operation regimes have been included and were not fully considered by previous authors.

The second research question (R.Q.2) concerned the effects of the age and technological generation of hydraulic excavators on the intensity and nature of noise exposure under real operating conditions. Marked differences were found between the older models (Dosan DX225 and JCB 3CX) and the newer ones (Liebherr), with the newer machines producing values 7-8 dB(A) lower on average. This conclusion aligns with that of Lee et al. (2012), who reported that acoustic insulation, advanced cooling systems, and electronic engine power control lead to a significant reduction in noise emissions. Thus, it was empirically demonstrated that modernizing equipment directly and quantifiably reduces the risk of OHS, a finding not previously demonstrated in laboratory studies. On the other hand, some results do not entirely agree with those reported by Babazadeh et al. (2025), who concluded that machine age does not significantly affect noise levels. Still, the decisive factors are the soil type and the mechanical load. Our results, on the contrary, demonstrate a clear correlation between machine age and increased noise, confirming the need for regular maintenance and equipment modernization as basic preventive measures. With this result, our work can help explain previously contradictory findings in the literature and clarify the causal effect of technical obsolescence on acoustic load.

Although the noise levels measured were mostly within the legally permitted limits, the results indicate the need to improve the noise exposure management system further. Based on all the results and from an organizational perspective, there is a clear absence of an adequate management framework that converts measured noise parameters (L_{eq}, L_{Cpeak}, Dose %) into actionable decision-making procedures on construction sites. To fill this gap, this study proposes the Noise Risk Management Framework, a two-component operational model illustrated in Fig. 3 and Fig. 4 and consolidated in Table 9. The framework enables construction site managers to translate any set of measured acoustic parameters directly into a prescribed set of management decisions, covering work organization, machine selection, maintenance scheduling, hearing protection requirements, and emergency response thresholds.

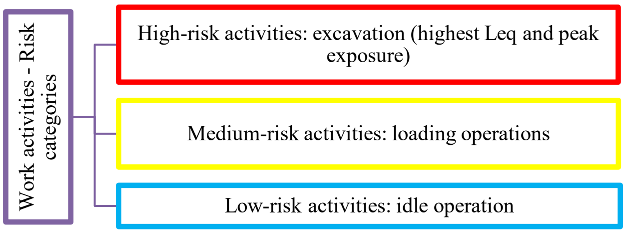

Figure 3: Component I of the Noise Risk Management Framework — Risk Level Classification Based on Measured Acoustic Parameters (L_{Er}, L_{cpeak}, Dose %)

The classification presented in Fig. 3 forms the first component of the proposed Noise Risk Management Framework. Each combination of activity and machine type is assigned to one of four risk levels (Low, High, Critical) based on three simultaneously measured acoustic parameters: the equivalent continuous noise level (L_{eq}), the C-weighted peak sound pressure level (L_{Cpeak}), and the cumulative noise dose as a percentage of the permissible daily limit (Dose %). The second component (Fig. 4) specifies the operational response procedures for each risk level. Together, these two components form a complete management cycle: measure → classify → decide → act. Table 9 consolidates this logic into a practical decision matrix for construction site managers (Ministry of Labour and Social Policy, 2019; Ministry of Labour and Social Policy, 1992).

The manager does not draw conclusions based on a single parameter, as prescribed by the regulation, but rather according to a hierarchy. Management decisions must be based on the conservative principle — that is, decisions made according to the most unfavorable (highest-risk) scenario. When measurement data reveals a discrepancy (as in this pilot research), such as a relatively low L_{eq} alongside an elevated L_{Cpeak}, the management response must be anchored to the most hazardous parameter. This is the dominant parameter principle: whichever measured value poses the greater physiological risk governs every subsequent decision, regardless of how favorable the other indicator appears. Based on the measurements, the management framework operates as a closed loop across six phases. It begins with data collection, combining a personal dosimeter worn throughout the shift with an SLM capable of capturing instantaneous peak levels. These two instruments complement each other — the dosimeter integrates exposure over time, while the SLM captures transient impulse events that the dosimeter alone may underrepresent. Decision-making translates that finding into three categories of action: technical measures (damping impulsive noise sources, maintaining machinery, evaluating material handling that generates impact noise), organizational measures (restricting time in the excavator zone, demarcating risk perimeters), and personal protection (mandatory hearing protectors, routine checks of HPD compliance, worker health surveillance). Implementation puts those decisions into practice, and continuous monitoring closes the loop by feeding new data back into the next measurement cycle. The framework is self-correcting: as conditions change, the dominant parameter shifts, and the decisions evolve accordingly.

Table 9: Noise Risk Management Decision Matrix — From Measured Parameters to Operational Management Actions

Regulatory Threshold	L_{eq} [dB (A)]	L_{Cpeak} [dB (C)]	Dose [%]	Required Management Actions
Lower Action Level	≤80	≤135	≤10	– Routine monitoring, voluntary HPD, periodic machine maintenance, standard work schedule – Employer shall make hearing protection devices available – Information and training of workers is required
Upper Action Level	80-85	135-140	10-50	– Mandatory HPD, – Work rotation every 1h, preference for newer low-emissions machines, – Documented risk assessment, – Relocation from high-noise tasks, – Engineering controls (enclosures, barriers), scheduled maintenance of older machines, management review, – Noise reduction program shall be established, – Health surveillance required
Limit Value	≥85	>140	>50	– Immediate work stoppage pending engineering intervention, – Mandatory HPD, – No continued exposure without corrective action, urgent machine maintenance or replacement, formal incident report, or regulatory notification

Scientific Contribution

The principal scientific contribution of this study relative to existing literature is threefold. First, it is the first empirical study to simultaneously deploy a Sound Level Meter and a personal dosimeter under real, dynamic construction site conditions for hydraulic excavator operations. This dual-instrument approach reveals a systematic underestimation of exposure when only stationary SLM measurements are used: for the same machine and shift, the personal dosimeter recorded L_{eq} = 82.9 dB(A) versus 75.0 dB(A) by SLM, a discrepancy of 7.9 dB(A) that carries direct regulatory and risk classification implications. Second, the study empirically quantifies the effect of machine age on noise emission under actual operating conditions (Pearson r = 0.68, p = 0.005; Cohen's d = 0.86), resolving contradictory findings in the literature — notably those of Babazadeh et al. (2025), who found machine age to be non-significant under controlled conditions — and establishing technical obsolescence as a quantifiable and manageable occupational risk factor. Third, and most distinctively, this research moves beyond exposure documentation to propose an operational Noise Risk Management Framework that translates measured acoustic parameters (L_{eq}, L_{Cpeak}, Dose %) into specific management interventions via a structured decision matrix. No previous study identified in the literature review provides this level of operational closure between measurement evidence and construction site management practice. The scientific contribution of this study is further reflected in the empirical confirmation of the methodological difference between two measurement approaches — a stationary sound level meter and a personal dosimeter — under real construction site conditions, with quantification of deviations that may have direct implications for occupational risk assessment. The results indicate that assessing workers' noise exposure should prioritize personal dosimetry, particularly in dynamic working environments, since measuring Leq values alone (with a sound level meter) can systematically underestimate actual risk. Furthermore, the study points to the need for systematic introduction of personal dosimetry into research and occupational safety practice, thereby contributing to the improvement of occupational safety and health management systems in the construction sector.

Theoretical and practical implications

Theoretically, the findings verify the principles of ergonomics and human factors theory (Masterson and Themann, 2025; Oyekunle et al., 2025), according to which long-term exposure to noise leads to cumulative consequences, not only physiological, but also cognitive. These results are consistent with the conclusions of Yang et al. (2025), who found that continuous noise affects workers' attention and risk perception. Still, our research aligns with and supports existing evidence that the frequency range of 500-8000 Hz may simultaneously affect hearing and communication efficiency. In this way, it was confirmed that noise not only puts physical health at risk but also impairs interpersonal coordination and team efficiency, aspects that were generally not included in previous studies' interpretations. Theoretically, the research contributes to expanding scientific knowledge of noise as a multidimensional phenomenon that links the technical, physiological, and organizational components of the work process. The methodological contribution lies in the empirical support for the combined measurement approaches, while the practical contribution is the development of an applicable model for continuous noise monitoring and control.

On a practical level, the results confirm that the application of combined technical and administrative measures yields the best reduction in noise exposure. Analysis of conditions at the location in Subotica shows that systematic machine maintenance, the use of more modern equipment, planned breaks, and employee rotation reduce average exposure to below 85 dB(A). This finding is in line with the recommendations of Azimi et al. (2024), which point out that organizational measures have an equally important effect as technical innovations, but differ from their approach in that the synergy of both aspects in a real environment is confirmed in this work. In other words, the combined action of technical and administrative measures is more sustainable than the application of individual approaches. This finding has not yet been quantified. The practical implications of the research are reflected in the noise monitoring, which combines an SLM and a personal dosimeter, and in the integration of measurement results into the management approach. It is recommended that combined measurements be introduced as a mandatory practice on construction sites and incorporated into national occupational safety standards. This opens the possibility of developing "smart" security systems in accordance with the concept of sustainable and humane industrial practice.

Based on the collected data and the literature review, it is suggested that the assessment of workers' noise exposure be primarily conducted using personal noise dosimeters, as the pilot research showed that personal dosimetry provides more reliable information about daily exposure than stationary sound-level meters. In addition, results also showed an urgent need to reshape occupational safety management in construction. A structured noise risk management approach based on preventive measures prescribed by the Ministry of Labour and Social Policy (2019) has been developed and shown in Fig. 4. The mentioned approach would enable a transition from passive noise management to proactive noise management, consistent with modern principles of sustainable, preventive occupational safety practice.

Managerial Implications

For project managers and site supervisors, the primary implication of this research is that noise risk cannot be adequately managed solely based on periodic stationary SLM measurements. The results demonstrate that an SLM can underestimate actual worker exposure by up to 8 dB(A), potentially leading to incorrect risk classification and the omission of mandatory protective measures.

Personal dosimetry is therefore recommended as a minimum standard for monitoring compliance with Directive 2003/10/EC and national legislation (Rulebook 96/2011) (European Parliament and Council, 2026). This recommendation has direct consequences for site monitoring protocols, record-keeping requirements, and the designation of noise-exposed workers.

From the perspective of work organization and shift planning, the results support a risk-tiered scheduling approach. During High and critical-risk activities (excavation and loading with older machines), rotation intervals should be reduced to 60 minutes, and exposure should be limited to the smallest possible number of workers. Managers should schedule high-noise activities at the beginning of the shift to minimize cumulative dose accumulation. For equipment procurement and fleet management, the data confirm that newer excavator models produce on average 7.5 dB(A) less noise, justifying investment in modernization as a quantifiable OHS cost-reduction measure. For maintenance scheduling, the significant positive correlation between machine age and noise level (r = 0.68) indicates that noise-level trend monitoring can serve as a proxy for overall mechanical degradation, supporting predictive maintenance decisions.

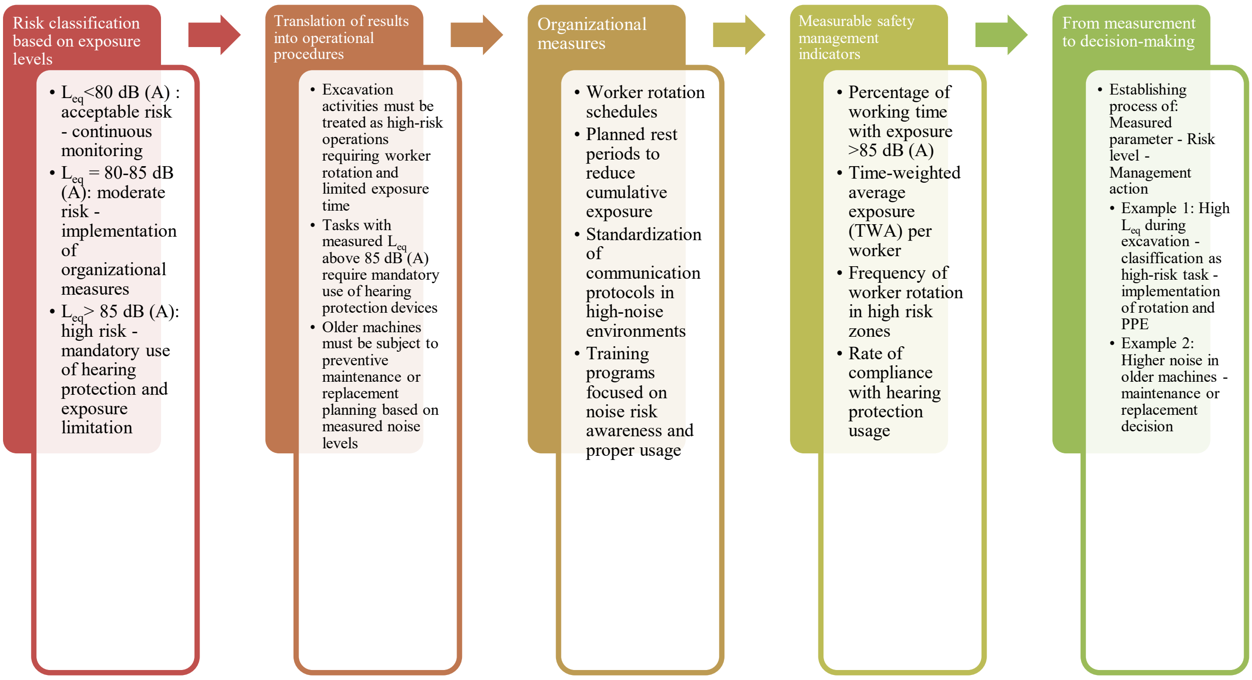

Figure 4: Component II of the Noise Risk Management Framework – Operational Decision-Making Procedures for Construction Site Managers

CONCLUSION

The research provided a comprehensive understanding of actual noise exposure conditions in the construction sector, confirming that the intensity and type of noise emitted by hydraulic excavators are influenced by several factors, including machine type and age, technical condition, and the nature of the activity performed. The results indicated that during excavation and loading, the permitted limit values were exceeded. At times, the impulse levels reach levels that can lead to hearing damage and psychophysical exhaustion of workers. The simultaneous monitoring of environmental and personal exposure, achieved by applying the SLM and a personal dosimeter, represents a methodological advancement and contributes to the development of combined models for the assessment of acoustic risk in real working conditions. This method can serve as a foundation for future standardization of noise measurements and for the development of procedures for systemic worker protection.

The analysis of the research results provides clear evidence that modernizing machines, proper maintenance, and integrating technical and organizational measures play a significant role in reducing noise levels below 85 dB(A), thereby reducing health risks and improving work efficiency. In newer excavator models, emissions of harmful substances decreased considerably due to optimized construction, improved soundproofing, and increased energy efficiency, which directly attest to the influence of technical development on improving work conditions. These results suggest that noise management is not only a safety issue but also a sustainable industrial practice that embraces the human, technical, and organizational dimensions of work. In direct response to the research questions posed, R.Q.1 was confirmed – statistically significant differences in noise levels were found both between excavator activities ($F(2,13) = 5.76$, $p = 0.016$), with excavation identified as the highest-risk activity, and between machine manufacturers ($F(3,12) = 6.32$, $p = 0.008$). R.Q.2 was also confirmed, and machine age was found to have a significant positive effect on noise emission ($r = 0.68$, $p = 0.005$; Cohen's $d = 0.86$), with newer excavator models producing, on average 7.5 dB(A) less noise than older ones.

Limitations and suggestions for future studies

However, the study has some limitations that suggest the need for empirical validation. The sample represented a small number of construction sites and machine types, which may impact the generalizability of the findings. Measurements were performed at limited time intervals and on a daily transition basis, and seasonal and microclimatic variations that can significantly influence the acoustic characteristics were not examined. Also, psychophysiological parameters of the workers were not included in the research, so the effects of noise on cognitive and emotional functions could be concluded only indirectly. Future studies should include longer time spans, different climatic conditions, and a larger number of working scenarios to get a more extended and long-term exposure assessment.

Further development should include the digitalization of this area and the introduction of automatic measurement and monitoring systems, such as IoT sensors, artificial intelligence, and predictive algorithms, to enable continuous monitoring and automatic identification of exceedances of permissible values. One of the greatest challenges of the research is to integrate acoustic measurements with workers' biometric and psychophysiological parameters to establish a clear link between noise, productivity, and subjective workload. Further, it is essential to develop economic models that quantify the correlation between investment in equipment modernization and cost savings in health care costs, absenteeism, and reduced work ability. Such cross-disciplinary subject matter would provide the foundation for the development of a multi-systems acoustic safety approach that links technological innovation, worker health, and sustainable development principles.

This research substantiates that effective noise control should be part of the modern concepts of safety and sustainability in construction. Good acoustic risk management contributes not only to maintaining employees' health and productivity but also to the long-term sustainability and social responsibility of organizations, as well as to organizational efficiency and productivity. Thus, this paper is a key theoretical and practical contribution to the development of standards in a safer, healthier, and more sustainable working environment.

FUNDING

The first author (Željana Kužet) is a scholarship holder of the Ministry of Science, Technological Development and Innovation of the Republic of Serbia.

ACKNOWLEDGEMENT

This research has been supported by the Ministry of Science, Technological Development and Innovation (Contract No. 451-03-34/2026-03/200156) 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 2026" (No. 01-3609/1), Institute for Safety and preventive engineering – BPI, from Novi Sad (providing us with personal dosimeter), Konsalting „Semantika – Comm" DOO and „FIBAC" DOO from Subotica, „Graditelj NS" (providing construction sites for measurements).

REFERENCES

Anees, Anees, M. M., Qasim, M., & Bashir, A. (2017). Physiological and physical impact of noise pollution on the environment. *Earth Science Pakistan, 1*(1), 8–11. https://doi.org/10.26480/esp.01.2017.08.10

Azimi, H., Tabibzadeh, S. M., Khalilpour, A., & Akbaribazm, M. (2024). Rare oto-tricho-tussia/tinnitus: A case report. *Clinical Case Reports, 12*(1), e8412. https://doi.org/10.1002/ccr3.8412

Babazadeh, N., Teizer, J., Bargstädt, H. J., & Melzner, J. (2025). Predictive simulation of construction site noise emissions from heavy equipment. *Smart and Sustainable Built Environment, 14*(3), 715–739. https://doi.org/10.1108/SASBE-08-2023-0226

Barkokébas, B., Jr., Vasconcelos, B. M., Lago, E. M. G., & Alcoforador, A. F. P. (2012). Analysis of noise on construction sites of high-rise buildings. *Work, 41*(Suppl. 1), 2982–2990. https://doi.org/10.3233/WOR-2012-0553-2982

Blevins, R. D. (2015). Formulas for dynamics: Acoustics and vibration (1st ed.). Wiley.

Chen, K. H., Su, S. B., & Chen, K. T. (2020). An overview of occupational noise-induced hearing loss among workers: Epidemiology, pathogenesis, and preventive measures. *Environmental Health and Preventive Medicine, 25*(1), 65. https://doi.org/10.1186/s12199-020-00906-0

Chen, L. J., Saraswat, S., Ching, F. S., Su, C. Y., Huang, H. L., & Pan, W. C. (2025). Development and implementation of EcoDecibel: A low-cost and IoT-based device for noise measurement. *Ecological Informatics, 85*, 102968. https://doi.org/10.1016/j.ecoinf.2024.102968

Chis, T. V., Cioca, L. I., Badea, D. O., Cristea, I., Darabont, D. C., Iordache, R. M., & Barsan, V. A. (2025). Integrated noise management strategies in industrial environments: A framework for occupational safety, health, and productivity. *Sustainability, 17*(3), 1181. https://doi.org/10.3390/su17031181

Choi, J., Kang, H., Hong, T., Baek, H., & Lee, D. E. (2021). Automated noise exposure assessment model for the health of construction workers. *Automation in Construction, 126*, 103657. https://doi.org/10.1016/j.autcon.2021.103657

Dinamarca, M. A., Ibacache-Quiroga, C., González-Pizarro, K., Plaza González, I., Kiseľák, J., Barraza-Morales, B., & Stehlík, M. (2025). Non-standard ANOVA-like statistical analysis of Cobetia marina MM1IDA2H-1 biofilm formation behavior at different temperatures. *Stochastic Analysis and Applications, 43*(4), 533–552. https://doi.org/10.1128/mra.00611-20

Ding, D., Manohar, S., Kador, P. F., & Salvi, R. (2024). Multifunctional redox modulator prevents blast-induced loss of cochlear and vestibular hair cells and auditory spiral ganglion neurons. *Scientific Reports, 14*(1), 15296. https://doi.org/10.1038/s41598-024-66406-1

European Parliament and Council of the European Union. (2003). *Directive 2003/10/EC: On the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (noise)*. Official Journal of the European Union. https://eur-lex.europa.eu/eli/dir/2003/10/oj

González, A. E. (2014). What does "noise pollution" mean? *Journal of Environmental Protection, 5*(4), 340–350. https://doi.org/10.4236/jep.2014.54037

Hakimian, S., Bouzid, A. H., & Hof, L. A. (2025). Corrosion type identification in flanged joints using recurrent neural networks on electrochemical noise measurements. *npj Materials Degradation, 9*(1), 88. https://doi.org/10.1038/s41529-025-00638-y

Hou, L., Easthope, H., & Burgess, M. (2025). Measurement and assessment for child-related noise in apartments: A systematic review. *Building and Environment*, 113837. https://doi.org/10.1016/j.buildenv.2025.113837

Institute for Standardization of Serbia. (2021). *SRPS EN 352:2021: Štitnici za sluh: Opšti zahtevi [Hearing protectors: General requirements]*. Institute for Standardization of Serbia. https://www.iec.ch/publication/5708

International Organization for Standardization. (2017). *ISO 1996-2:2017: Acoustics: Description, measurement and assessment of environmental noise: Part 2: Determination of environmental noise levels*. ISO.

Ismail, N. R. M., & Sahid, S. (2024). Analyzing Form 3 students' intentions to choose business subject as an SPM elective: A study using t-test and ANOVA. *International Journal of Academic Research in Business and Social Sciences, 15*(2), 552–561. https://doi.org/10.6007/IJARBSS/v15-i2/24594

Jain, G., Gupta, V., & Pandey, M. (2016). Case study of construction pollution impact on environment. *International Journal of Emerging Technologies in Engineering Research, 4*(6).

Latorre-Arteaga, S., Gil-González, D., Vives-Cases, C., & La Parra Casado, D. (2017). Vision and hearing health inequities in the Roma population: A national cross-sectional study in Spain. *Journal of Immigrant and Minority Health, 19*(6), 1304–1314. https://doi.org/10.1007/s10903-016-0489-9

Lee, L. K., Kim, J. H., Kim, B., & Kim, J. (2012). Analysis of occupational noise for the healthy life according to the job characteristics. *Health, 4*(10), 897–903. https://doi.org/10.4236/health.2012.410137

Liu, G., Fan, X., Wang, C., Zhao, X., Meng, L., Hu, Q., & Li, Y. (2025). Study on the pitting corrosion behavior of X65 steel in supercritical and dense-phase CO_2 based on in-situ electrochemical noise measurement. *Process Safety and Environmental Protection, 197*, 107060. https://doi.org/10.1016/j.pmatsci.2025.101526

Lu, Y., Gong, P., Tang, Y., Sun, S., & Li, Q. (2021). BIM-integrated construction safety risk assessment at the design stage of building projects. *Automation in Construction, 124*, 103553. https://doi.org/10.1016/j.autcon.2021.103553

Masterson, E. A., & Themann, C. L. (2025). Prevalence of hearing loss among noise-exposed U.S. workers within the construction sector, 2010–2019. *Journal of Safety Research, 92*, 158–165. https://doi.org/10.1016/j.jsr.2024.11.005

Ministarstvo rada i socijalne politike. (1992). *Pravilnik o merama i normativima zaštite na radu od buke u* *radnim prostorijama [Rulebook on measures and standards of occupational safety against noise in workspaces]*. Službeni list SFRJ, br. 21/92. https://www.scribd.com/doc/43136356/Pravilnik-Zastita-Od-Buke

Ministarstvo rada i socijalne politike. (2011). *Pravilnik o preventivnim merama za bezbedan i zdrav rad pri izlaganju buci*. Službeni glasnik RS, br. 96/2011 i 93/2019. https://www.paragraf.rs/glasila/rs/sluzbeni-glasnik-republike-srbije.html

Movahed, N., & Ravanshadnia, M. (2022). Noise exposure assessment in construction equipment operators in Tehran, Iran. *Journal of UOEH, 44*(1), 43–52. https://doi.org/10.7888/juoeh.44.43

Nelson, D. I., Nelson, R. Y., Concha-Barrientos, M., & Fingerhut, M. (2005). The global burden of occupational noise-induced hearing loss. *American Journal of Industrial Medicine, 48*(6), 446–458. https://doi.org/10.1002/ajim.20223

Ouis, D., Hassanain, M. A., Alshibani, A., & Ghaithan, A. M. (2025). Noise from heating, ventilation, and air conditioning (HVAC) systems: A review of its characteristics, effects, and control. *Journal of Building Engineering, 113770*. https://doi.org/10.1016/j.jobe.2025.113770

Oyekunle, F., Ogunsusi, S., Aiyewalehinmi, E. O., & Amoko, K. (2025). Assessment of occupational health and safety risks in selected construction sites in Oyo State, Nigeria. *International Journal of Engineering and Applied Physics, 5*(1), 1152–1167. https://ijeap.org/ijeap/article/view/243

Papadimitriou, E. A., Papageorgiou, G. P., Alamanis, N., & Diakosavva, T. N. (2020). Road noise levels in urban environment compared to specification limits: The case of the City of Larissa, Greece. *Periodica Polytechnica Civil Engineering, 64*(4), 964–974. https://doi.org/10.3311/PPci.14868

Patel, V., Chesmore, A., Legner, C. M., & Pandey, S. (2022). Trends in workplace wearable technologies and connected-worker solutions for next-generation occupational safety, health, and productivity. *Advanced Intelligent Systems, 4*(1), 2100099. https://doi.org/10.48550/arXiv.2205.11740

Praščević, M., & Mihajlov, D. (2018/2019). *Instrumenti za merenje buke [Instruments for noise measurement]*. Faculty of Occupational Safety, University of Niš. https://www.znrfak.ni.ac.rs/serbian/010-STUDIJE/MAS/PREDMETI/IZZS/I%20GODINA/110-BUKA%20U%20ZIVOTNO%20SREDINI/PREDAVANJA/2018-19/Instrumenti%20za%20merenje%20buke.pdf

Prayogo, A., Teophilea, H. S., Nugraha, P., Sunindijo, R. Y., Maharani, C. F., & Yang, K. (2025). Noise disturbance increases negative emotions and unsafe behavior among construction workers. *International Journal of Construction Management, 25*(8), 932–939. https://doi.org/10.1080/15623599.2024.2389591

Rahardja, U., & Aini, Q. (2025). Evaluating the effectiveness of digital marketing campaigns through conversion rates and engagement levels using ANOVA and chi-square tests. *Journal of Digital Market and Digital Currency, 2*(1), 26–45. https://doi.org/10.47738/jdmdc.v2i1.27

Salvendy, G. (2012). *Handbook of human factors and ergonomics (4th ed.)*. John Wiley & Sons.

Samara, P., Athanasopoulos, M., Markatos, N., & Athanasopoulos, I. (2024). From sound waves to molecular and cellular mechanisms: Understanding noise-induced hearing loss and pioneering preventive approaches. *Medicine International, 4*(6), 60. https://doi.org/10.3892/mi.2024.184

Sørensen, M., Pershagen, G., Thacher, J. D., Lanki, T., Wicki, B., Röösli, M., Vienneau, D., Cantuaria, M. L., Schmidt, J. H., Aasvang, G. M., et al. (2024). Health position paper and redox perspectives: Disease burden by transportation noise. *Redox Biology, 69*, 102995. https://doi.org/10.1016/j.redox.2023.102995

Sripaiboonkij, P., Chairut, S., & Bundukul, A. (2013). Health effects and standard threshold shift among workers in noisy environments. *Health, 5*, 1247–1253.

Tánczos, K., Markovits-Somogyi, R., & Török, Á. (2007). Noise annoyance and willingness to pay of inhabitants exposed to transport noise. *Periodica Polytechnica Transportation Engineering, 35*(1–2), 75–84.

Yang, J., Liu, Q., Ye, G., Du, Q., Bai, L., & Yue, H. (2025). Mediating mechanism of construction noise on workers' safety behavior: Evidence from EEG data. *Journal of Construction Engineering and Management, 151*(10), 04025148. https://doi.org/10.1061/JCEMD4.COENG-16651

PROFESIONALNA IZLOŽENOST BUCI NA GRADILIŠTIMA: POSLEDICE PO UPRAVLJANJE BEZBEDNOŠĆU

Ova studija analizira izloženost građevinskih radnika buci koja nastaje prilikom rada sa hidrualičnim bagerima na gradilištima u Novom Sadu i Subotici, zasnovana na 16 merenja pomoću merača nivoa zvuka (Sound Level Meter – SLM) i jednog celosmenskog merenja ličnim dozimetrom. Primena ovakve metodologije omogućila je identifikaciju najčešćih aktivnosti bagera i njihovih

proizvođača koji generišu buku u realnim uslovima rada. Rezultati ukazuju na značajne razlike u nivoima buke koje proizvode bageri, u zavisnosti od proizvođača i aktivnosti koje obavljaju. Dobijeni rezultati potvrđuju značaj kombinovanja merača nivoa zvuka (SLM) i ličnog dozimetra, budući da lična dozimetrija pruža pouzdanije informacije o izloženosti tokom osmočasovne radne smene u odnosu na stacionarni SLM. Pored toga, rezultati ukazuju i na hitnu potrebu za redefinisanjem upravljanja bezbednošću i zdravljem na radu u građevinarstvu. Osnovni naučni doprinos rada predstavlja novi Okvir za upravljanje rizikom od buke (Noise Risk Management Framework), koji direktno prevodi izmerene akustičke parametre u operativne upravljačke odluke namenjene menadžerima gradilišta.

Ključne reči: Buka; Građevinarstvo; Bageri; Lični dozimetar; Merač nivoa zvuka.