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STRATEGIES FOR INDUSTRY: ENGINEERING SOLUTIONS IN NOISE CONTROL AND RISK MANAGEMENT

Selena Samardžić[1] *[0000-0003-2578-7412]*, *Robert Lakatoš*[2] *[0000-0002-8206-7692]*

Abstract

Implementing comprehensive noise management plans in every organisation is not just a task; it is also a responsibility to maintain a productive and healthy atmosphere in the work environment. By upholding minimal noise exposure levels, we directly contribute to safeguarding workers' health and well-being, a mission that should drive our every action. Many studies have confirmed that, nowadays, exposure to noise at the workplace is, in most cases, above the proposed level. On the other hand, employees are also exposed to other physical stressors whose minimal variations affect productive capacity, social relations and employee health. In the context of Industry 5.0, it is crucial to adopt strategies that prioritise the well-being and comfort of employees. This human-centred approach enhances potency and fosters a sense of added value for workers, making them an integral part of an organization which improves resilience and a broader focus on sustainability. The paper analyses noise across 13 different industries, particularly emphasising the excessive sound pressure levels experienced by workers. It also delves into the critical values of 1/3 octave frequency that might harm different aspects of workers' health. In addition to this, worker satisfaction in standard and open-plan offices will also be considered. Particular emphasis will be placed on exploring diverse engineering solutions to minimise noise exposure, alongside conducting risk assessments in scenarios where preventive protection measures are not implemented for specific reasons.

Key words*: noise, industry, frequency analysis, engineering, well-being, risk.*

[1] University of Novi Sad, Faculty of Technical Sciences, Serbia, selena@uns.ac.rs
[2] University of Novi Sad, Faculty of technical Sciences, Serbia, laki@uns.ac.rs

1. Introduction

Throughout the years, an evolving framework has been aimed at protecting workers from hazardous workplace noise while emphasising employer responsibility towards ensuring a safe acoustic environment.

The first significant publication on noise exposure at work was in 1963, followed by the Code of Practice for Reducing Noise in 1972. The Noise at Work Regulations were implemented in 1989, setting out employer duties and action levels for daily personal noise exposure. In 2005, the Control of Noise at Work Regulations introduced updated guidance to prevent and reduce hearing loss due to workplace noise. These regulations outlined specific action levels requiring interventions from employers to minimise potential harm from excessive noise exposure(Courtislow, 2024).

Noise is a pervasive challenge in industrial settings, posing potential risks to workers and operations. The clamour of machinery, equipment, and processes can reach high decibel levels, detrimentally affecting employees' hearing and overall well-being (Metidieri et al., 2013). Prolonged exposure to excessive noise can result in permanent hearing loss, stress, reduced productivity, and communication difficulties.

On the other hand, the service sector is experiencing an expansion in its workforce, particularly within office environments. This is coupled with a trend of technological systems assuming an increasing number of low-skilled tasks (Roelofsen, 2008). Therefore, organizations must prioritize establishing conducive, comfortable work environments to facilitate uninterrupted employee productivity and the achievement of organizational objectives, both short-term and long-term.

Industry 5 focuses on technological innovations that improve production and work processes through intelligent technologies such as automation, artificial intelligence, and the Internet of Things. This approach also considers the impact of noise on working conditions, which is essential to improving productivity and preserving the employee's health.

It is well known that high noise levels can cause stress, fatigue, decreased concentration and increased nervousness among employees. Different countries have varying criteria for determining the risk of noise damage, typically within the range of 85-90 dB(A). However, any sound level that is bothersome or exceeds 75 dB(A) may be classified as noise.

A crucial first step in improving working conditions is reducing noise levels, such as by using insulating materials, implementing technological solutions to reduce machine noise, or providing personal noise protection. Also, using sound-absorbing materials, creating designated quiet zones, and implementing noise control policies can result in significant benefits. Evaluating noise hazards in the workplace typically entails gauging noise levels to ascertain employees' exposure to excessive noise. This can be accomplished through specialized measuring instruments and routine monitoring. After the measurements, the findings and risk assessment should be carefully examined to gather information about the potential

impacts of noise levels on employees' well-being. Human resource management in industrial settings presents a complex challenge, necessitating deploying engineering solutions to achieve optimal outcomes for employees and employers.

1.1 Materials and Methods

The study was conducted across thirteen distinct processing sectors: printing, chemical, automotive, metal, meat, plastic, rubber, wood, shoe, flooring, textile, furniture, and energy. Notably, three of these industrial facilities are under foreign ownership, specifically in the automotive industry's textile, flooring, and plastic and rubber parts production. Each industry's noise levels were measured, focusing on the machine type or the specific workstation. As per the Serbian guidelines on workplace protection measures and standards (Official Gazette, 2019), the equivalent L_{eq} values with filter A should be assessed over the effective daily duration of a worker's exposure to noise to determine the daily noise exposure level, Lex,8h (Directive 2003/10/EC, 2003). Sound pressure level was measured within the range of frequencies between 25 Hz and 10 kHz using a TES 1358A Sound Level Meter (SLM) with the RS-232 connection, which complies with the IEC 651 Type 1 standard.

The second part of the research involves conducting questionnaire surveys (NAWOP23) with fifty employees who work in 4 banks with open-plan offices. Noise measurements were also taken. The banks were chosen based on the type of open-plan workspace they have. For data analysis, the statistical software IBM SPSS Statistics 20 was used. Frequency analyses were applied to display the structure of the sample, and questionnaire item reliability was investigated using Cronbach's alpha.

2. Results

The noise levels were assessed in thirteen manufacturing facilities for all types of machinery and work positions within the production areas of the factories. Figure 1. illustrates that the recorded L_{eq} values in industrial processes typically range from 70 to 100 dB(A) (Luburic et al., 2020), aligning with findings by other researchers (Al-Dosky, 2014; Yang et al., 2016). The average value is calculated to be 83.28 (8.22) dB(A), and the highest mean value of 118.56 (1.30) dB(A) is observed during metalworking procedures involving the use of a hammer in the metal industry. The highest recorded noise levels were in the sawmill and furniture industries, surpassing the 85 dB (A) threshold value (Figure 1). These specialised workshops employ around twenty workers, aiming to expand their production. The average noise level in the sawmill is L_{eq} = 92.05 (1.37) dB (A), and in the furniture factory, L_{eq} = 92.82 (6.19) dB (A). There are several issues of concern here. All the machinery produces high noise levels, further worsened by their proximity. This means the workers are constantly exposed to unpleasant noise during work hours. It is also well-established that more noise sources lead to higher noise levels.

Consequently, increased noise levels pose a significant risk of negatively impacting the health and well-being of employees in this type of work environment.

Based on the presented results, it can be concluded that close to 40% of the industry generates noise above the sufficient value for 8 hours of work, while 70% generates noise above 80 dBA.

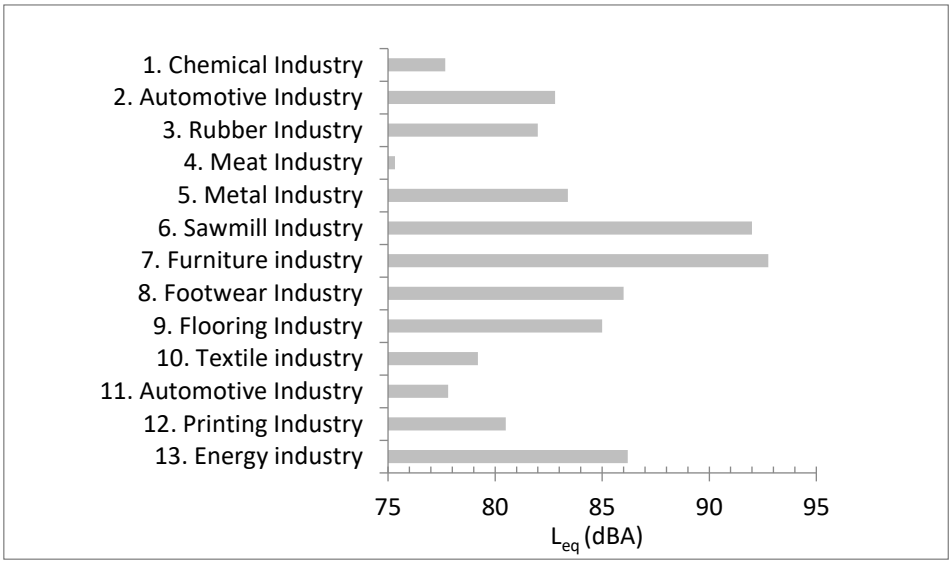

Figure 1. Representation of mean noise levels L_{eq} in investigated industries

Noise was also measured in open-plan offices. According to Serbian guidelines, the permissible noise level for tasks involving mental focus and regular verbal or telephone communication is 50 dBA, while for office work, the level is 45 dBA. The recorded average noise L_{eq} levels measured in four banks with open-plan offices ranged from 58 dBA to 61 dBA, surpassing the recommended thresholds, as seen in Table 1.

Table 1. Average values for L_{eq}, L_{max} and L_{min}

No.	L_{Aeq} [dB]	L_{Amax}[dB]	L_{Amin}[dB]
1	58.38(1.20)	66.40 (0.99)	47.5 (0.91)
2	59.26(0.58)	66.44(2.42)	50.2(0.42)
3	60.72(1.88)	79.92(2.04)	49.5(1,63)
4	58.42(1.14)	68.18(2.43)	48.7(1.45)

2.1 Questionnaire survey and statistical analysis

Conversely, Table 2. summarizes subscale scores (15-item questionnaire) for 66 employees who work in investigated open-plan offices. Subjects had the highest mean scores for the psychophysical changes and ability to perform the work

subscales, which indicates that noise can generally affect psychophysical health and negatively affect productivity.

Table 2. Descriptive statistics for noise effects on employees using a 5-point Likert scale

	N	AS	SD
Stress	66	2.95	1.531
Psychophysical changes	66	3.71	2.252
Ability to perform work	66	3.75	2.493

3. Discussion

Based on the research findings, noise is a significant contributor to workplace pollution. It significantly affects people's well-being and substantially impacts work productivity and overall job satisfaction. Therefore, management and governing bodies are responsible for ensuring a healthy work environment. One potential solution to this issue is integrating engineering solutions into the design of workspaces.

To improve the acoustic quality, several authors suggest installing divider panels between workstations and using sound-absorbing materials for the roof (Esfandiari et al., 2021). According to Chetoni et al. (2016), different frequencies affect room elements differently. For example, windows significantly transmit noise at low frequencies, while the ceiling is a significant source at higher frequencies. To reduce noise levels in noisy rooms, high-impedance floor coverings like acoustic metamaterials with excellent sound absorption coefficients in the 602-1287 Hz range can be used (Yang et al., 2022). Additionally, Čudina et al. (2016) recommend using art paintings with specific color combinations (predominantly pastel colors with green, blue, and grey) to mitigate the effects of background noise in an open-plan office.

The noise level generated in industrial processes is affected by various factors, such as the nature of the process, operating speed, and the materials used. Studies suggest that the age of the machinery has a minimal impact on the noise produced. Machines such as pneumatic power tools, compressors, pumps, metal and wood forming machines, and turbo generators produce high noise levels. A global acoustic quality index has been proposed to help evaluate machinery noise (Pleban, 2010). In foreign-invested factories, noisy machines are either enclosed with modular acoustic panels or located in separate rooms, and this practice is recommended for general implementation. Furthermore, these factories have established protocols for workers and visitors to adhere to protective measures to minimize excessive noise exposure. It is essential to prioritize noise control and practical strategies, as some research questions the effectiveness of hearing protection as a long-term substitute for noise control (Groenewold et al., 2014). Standard protective equipment includes user-friendly earplugs and earmuffs, but workers often do not use them. Some authors (Reddy et al., 2012) note that workers believe noise is an acceptable and unavoidable part of the job.

4. Conclusions

Noise control is an essential aspect of risk management in the workplace, as excessive noise can lead to a range of health issues and impact productivity. Employers must implement measures to reduce noise levels, such as using sound-absorbing materials, installing barriers or enclosures around noisy equipment, and providing employees with hearing protection. Additionally, regular monitoring and assessment of noise levels in the workplace are crucial to identify areas where interventions may be needed. By effectively managing noise-related risks, organizations can ensure their employees' well-being while improving overall work environment quality and performance.

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