http://medpr.imp.lodz.pl/en

https://doi.org/10.13075/mp.5893.01491

REVIEW PAPER

HEALTH IMPACT OF ENVIRONMENTAL AND INDUSTRIAL NOISE – A NARRATIVE REVIEW

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Abstract

Industrial noise sources are among the environmental noise sources that are ranked second among the causes of ill health in Europe by the World Health Organization. The aim of this paper is to summarize and review of published information focusing on noise annoyance from industrial activities and mining. A search for articles was performed using the bibliographic databases platforms. The epidemiological evidence shows that environmental noise may be associated with cardiovascular and metabolic diseases, impaired cognitive development in children, mental health, post-irritability, and sleep disturbances. As a result of efforts to minimize the effects of industrial noise on human health, the New South Wales Environment Protection Authority published *A Guide to the Noise Policy for Industry* in 2017, which sets out recommended noise levels, methods, and procedures for noise management based on the latest scientific evidence. Social networks can be used to assess the population's noise annoyance and to verify the effectiveness of the measures. The industrial noise sources are typically defined by low-frequency noise. Low-frequency noise has very low attenuation and is only slightly affected by obstacles, therefore it can be a major cause of night noise annoyance. An association was confirmed between exposure to low-frequency noise and sleep disturbance, psychological problems, cognitive impairment, increased social conflicts, anxiety, emotional instability, nervousness, and reduced mental performance – concentration, and visual perception. In view of the long tradition of mining and industry, the assessment of noise from these activities from the perspective of its impacts on human health is an inherent part of legislative processes. Med Pr Work Health Saf. 2024;75(5)

Key words: noise annoyance, health effects, industrial noise, low-frequency noise, environmental noise, sleep disturbance

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Received: November 23, 2023, accepted: July 8, 2024

INTRODUCTION

Environmental noise, including industrial noise, can be considered one of the principal factors in the deterioration of the quality of life in the urban environment [1]. The World Health Organization (WHO) has listed environmental noise to be the second most serious cause of ill health in Europe (after air pollution) [2]. This significant public health problem has been already associated with adverse cardiovascular and metabolic events, impaired cognitive development in children, and impaired mental health [3], as well as with the development of irritability or sleep disorders [4]. In the long term, chronic noise-induced stress can affect homeostasis due to dysregulation, incomplete adaptation, or, on the contrary, high demands on the physiological adaptation of the organism [5]. To know the noise exposure and the actual burden on the population, member states of the European Union (EU) systematically assess environmental noise, including that from industrial sources, in accordance with the European Noise Directive [4]. Although many studies have proved the negative effects of noise annoyance and chronic exposure to noise from road, railway, or air traffic on human health, the effect of industrial sources of noise, including mining, remain largely unexplored [6]. Considering the characteristic physical properties of low-frequency noise, exposure and negative effects of this type of noise must be

Funding: this work was supported by Technological Agency of the Czech Republic (project No. SS05010044 entitled „Methodology for evaluating the exposure-response relationship of persons exposed to mining noise in the environment," and the Ministry for Environment within the scope of the program "Environment for Life," project manager: Ing. Dana Potužníková, Ph.D.) and by University of Ostrava (project No. CZ.02.1.01/0.0/0.0/16_019/0 000798 entitled "Healthy Aging in Industrial Environment (HAIE)," co-financed by the European Union).

also taken into account when evaluating the industrial noise annoyance. This paper aims to provide a review of information on industrial noise annoyance, with a special emphasis on mining activities.

METHODS

The presented narrative review is based on studies investigating the impact of environmental noise sources on human health. The emphasis is put on health effects, annoyance, and sleep disturbance caused by industrial noise sources. Partial attention is also paid to road, rail, and air traffic, and to the health impacts of industrial noise in the working environment. Publications were obtained through automated searches in several major bibliographic databases including Pubmed, Google Scholar, Web of Science, MEDLINE Complete, and Scopus, and through cross-referencing based on references in the relevant journal articles. The combinations of the following keywords were used: noise annoyance, health effects, industrial noise, low-frequency noise, environmental noise, and sleep disturbance. During the selection of studies, special attention was paid to studies evaluating the relationship between the magnitude of noise exposure and health effects. Almost 50 studies published after 2000 were selected for this review. A few older studies published before the year 2000 (e.g., a study describing the body response to noise during sleep from 1960 [7] or another study demonstrating the effect of road traffic noise on the development of hypertension in 1977 [8]) covering the fundamentals of research on the subject or general information on the subject, were also included in the review due to their significant contribution to the field and the need to refer to original sources rather than to the interpretation of their results in the more recent papers. Only studies published in English (or in another language with an English version available) were included.

RESULTS

Industrial noise assessment and management

Industrial noise sources count among the environmental sources of excessive noise exposure, particularly for the general population living in urban areas [1]. The European Environmental Agency report considers these sources to be the least significant contributor to the total environmental noise burden on the population [4], with the greatest proportion of the population affected by industrial noise found in Romania, followed by Cyprus and Latvia [4]. The variability and complexity of environmental noise produced by industrial sources constitute a major problem for the measurement and interpretation of its effects [9]. The used industrial technology is the main driver of the generated noise, increasing its noise emissions with increasing power [10]. In study by Alayrac et al. [9], the proposed approach is set up by type of spectral features and based on a perceptive typology of steady and permant industrial noises comprising 6 categories and investigated the degree of annoyance separately for each category. For each perceptive category, listening tests based on acoustical factors are performed on noise annoyance. Their results predict the level of noise annoyance in a population based on the industrial noise category determined by the spectral composition of the noise. Mining activities are a specific industrial noise source characterized by noise arising during excavation, bucket excavator operations, un/loading and transport of excavated materials (e.g., transport by conveyor belts), etc. [10].

The knowledge on the impacts of excessive (not only) industrial noise exposure on human health has grown considerably over the last years, further promoting research in this field and highlighting the need to search for important answers in the realm of public health [5]. In response to the need for minimizing the effects of industrial noise on human health, the New South Wales Environment Protection Authority (NSW EPA) published *A Guide to the Noise Policy for Industry* in 2017. This guideline sets out recommendations for noise levels and details of methods for noise control based on the latest scientific evidence [11].

Multiple legislative processes are in place for mitigation of the impacts of industrial noise on public health in EU member states. For example, land use planning represents an effective way of ensuring that industrial areas are to be located away from residential areas (in the countries of the EU, this is typically governed by the process of preparing documentation for land use proceedings, in accordance with valid regulations). The construction permit process requires the evaluation of all possible negative impacts on the environment (including noise), taking into account social, economic, and ecological perspectives (tool named Environmental Impact Analysis) [12]. Once production begins, the owner of the industrial facility is responsible for its flawless operation and meeting noise pollution limits. If public health limits are violated, the regulatory authorities are empowered to take action ensuring compliance with legal obligations on the side of the controller of the noise

source [13]. These policies aim to make sure that industrial noise remains at an acceptable level, while not acting prohibitively on industrial activities [11]. Noise policies take into account different types of noise and their effect on the population and weigh these effects against the importance of the noise source for the local population. Such processes should ensure that the industrial noise sources will be proposed in a way emitting the lowest reasonably achievable amounts of acoustic pressure. If measures must be taken to reduce noise emissions, 3 principal strategies are available: noise source abatement (e.g., modernization of the used technologies), noise transmission control (using noise barriers), and noise immission control (e.g., air conditioning systems instead of window opening) [11]. A case study on the Wollar community near Mudgee, NSW, Australia, showed a loss of almost 90% of the local population due to excessive noise annoyance. Evaluation of noise immission in these properties found excessive noise annoyance in a vast majority of these properties [5]. Another case study in the vicinity of the Maules Creek Mine, NSW, Australia, revealed that the original noise analysis submitted to the authorities for a mining permit was incorrect. This was confirmed by the NSW EPA which ordered noise measurements and revealed a drastic underestimation of the noise burden in the original documentation compared to the reality of ≥10 neighbouring properties [5].

Noise annoyance

Annoyance is generally defined as a psychological condition arising when an individual is subjected to circumstances or factors that are perceived negatively because they disturb the individual's privacy, interfere with their activities, or influence the quality of rest. Noise annoyance is then annoyance with noise as the cause. Noise annoyance is the trigger of various reactions and health issues. In some cases, noise annoyance is interpreted as the result of the disturbance, in others as a result of helplessness with regard to the noise source. Noise annoyance must be related to acoustic variables; acoustic characteristics, however, do not play a major overwhelming role in the concept of annoyance [14]. The technical document *Acoustics – Assessment of Noise Annoyance by Means of Social and Socio-Acoustic Surveys* defines noise annoyance as an individual reaction to noise. In the context of this standard, the noise annoyance scale refers to long-term exposure [15]. The reaction to noise is highly individual and it is not possible to predict, which individuals exposed to noise will experience discomfort when exposed to noise and who will not be annoyed by the same level of noise [11]. Although extensive research into noise annoyance has largely begun only in the last few years, noise annoyance is already considered a widespread problem. In a German study, 15 010 participants aged 35–74 were questioned about the level of noise annoyance and <80% of them reported annoyance due to noise from various sources, including industrial noise. The degree of noise annoyance decreases with increasing age and is generally associated with sociodemographic parameters, such as sex, age, socioeconomic status, etc. [16].

Health risks associated with noise annoyance

The response of the cardiovascular system (blood pressure changes, peripheral resistance increase, pathological changes on electrocardiogram) to noise annoyance is one of the most significant responses of human organisms to environmental noise. It can change the respiratory rate and other metabolic functions, such as the production of digestive enzymes, the motility of the gastrointestinal tract, or hormone secretion [17]. According to the WHO Global Burden of Disease Study published in 2020, coronary artery disease is the leading cause of death in developed countries. Among other factors, it is associated also with excessive noise exposure [18,19]. The increase in the risk of developing coronary heart disease, including myocardial infarction, or hypertension in relation to road and air traffic noise has been proven in the past [8,20,21]. So far, however, little evidence has been published where industrial and railway noise are concerned [22]. In 2018, the Gutenberg Health Study proved the association between industrial noise annoyance and the development of atrial fibrillation. Interestingly, the degrees of annoyance were not associated with the changes in the cardiovascular risk factors; in other words, noise annoyance is a binary factor – determining its presence or absence is important, while the degree of existing noise annoyance does not play a role in the development of cardiovascular risk factors [23]. A similar study published in 2022 investigating annoyance by noise from specific sources, demonstrated an increase in the risk of atrial fibrillation in men and women by 21% and 18%, respectively [6].

It has been suspected for many years that cognitive function in children is negatively affected by noise exposure. A study evaluating exposure to aviation noise has demonstrated the negative effects of such noise on reading comprehension and memory in children [24,25]. Exposure to noise during a critical period of a child's

learning could potentially disrupt the child's development, thus affecting lifelong learning and, finally, educational achievements. One of the best studies in this field evaluated the effect of the relocation of the Munich airport on health and cognitive function in 217 children. This study proved a reduction of the deficiency in long-term memory and reading abilities in children living in the vicinity of the original airport after its relocation [26]. The impact of industrial noise on cognitive functions in children is, unfortunately, not well studied, despite, e.g., a study published in 2018 recommending the identification of areas of children's noise exposure, including industrial noise, and suggesting measures to prevent noise exposure in children, particularly in the early stages in their development [27].

Gong et al. [28] studied the influence of noise annoyance on psychological health, revealing a higher risk of depression or generalized anxiety disorder in individuals heavily exposed to noise. It was found that the risk of developing psychological problems increased more than two-fold (by 119%) in individuals exposed to noise (mean number of participants 7427, ranging 1244–19 294 in individual studies) compared to the standard population.

Sleep disorders count among the most common complaints associated with noise exposure that can significantly impact health and quality of life [2]. As the human organism reacts to the surrounding noise even while asleep, it has been proven that noise affects sleep in terms of both acute effects (change of sleep phase, waking up, tossing around, twitching) and long-term effects (chronic sleep disorder) [7]. There is a considerable body of scientific evidence on sleep disturbances associated with excessive noise exposure from industrial sources, including mining activities. The Gutenberg Health Study demonstrated significant sleep disturbances caused by industrial noise sources in a study population of 14 639 individuals [23]. Another case study demonstrated increased levels of sleep deprivation stress in a rural area due to night-time noise annoyance caused by the nearby Warkworth mine, in Great Britain. When exposed to the noise at lower frequencies of 16–25 Hz, which is characteristic of the so-called coal washes, people commonly reported pain or pressure in the ears and head, sleep disturbance, or nausea [5]. The study from Czech Republic focused on the impact of noise from mining activities on subjective health effects, such as annoyance and sleep disturbance, and proposed a methodology for assessing the impact of noise on subjective perceptions using a questionnaire survey. The preliminary results of the survey showed that the residents of the monitored area perceived mining noise as a significant problem. The assessment method proposed by the authors is potentially applicable to assess the impact of other industrial sources [29].

Sleep disturbance by noise has also been scientifically demonstrated for road [30,31], railroad [32] and air traffic [33]. According to the NSW EPA document – *A Guide to the Noise Policy for Industry*, both awakenings and disturbances of sleep stages count among sleep disturbances and need to be taken into account in the assessment of the possible risks when constructing new industrial facilities [11].

Popular social networks can also be used to objectively assess the level of noise annoyance in a selected population. A case study in the United Arab Emirates monitored noise annoyance levels from several sources in 2015 by analyzing publicly available Twitter messages (>8 million). The authors found public sharing of feelings of discontent, fatigue, and sleep deprivation related to excessive noise pollution, particularly from music productions or human activities. Most of such tweets were shared during the night (11 p.m.) or early morning hours (2 a.m.) [34].

Health impacts of low-frequency noise

The effects of noise or sounds on human health depend on its physical characteristics, with frequency being one of the most important ones. In industrial noise sources, including mining, low-frequency noise is typically defined as noise at frequencies of 16–160 Hz, with the upper limit sometimes set to 200 Hz. This type of noise is characterized by very low attenuation and is only slightly affected by obstacles. This makes it one of the particularly problematic types of noise for residents at night [35]. In view of the expected negative effects of low-frequency noise on human health, a recommendation to intensify research focusing on this type of noise has been published as soon as 2004 [36].

The findings of a Portuguese case study assume a relationship between weather conditions and the spreading of low-frequency noise. In the studied sample of the population, as well as according to previous studies, the authors also proved that low-frequency noise, due to its easy spreading in the environment, affects sleep disturbances, psychological problems, cognitive disorders, increase in the intensity of social conflicts, anxiety, emotional instability, and nervousness [37]. Another Portuguese case study evaluated the effects of low-frequency noise within the range of 10–160 Hz on exposed individuals, who reported it to be highly annoying [38].

Yet another study of 193 volunteers found low-frequency noise to negatively affect mental performance, in particular concentration and visual perception [39]. It can be hypothesized that low-frequency noise can affect human brain activity, thus leading to sleep disturbances [35]. Studies focusing exclusively on the health effects and well-being of individuals exposed to low-frequency noise in outdoor environments are relatively rare. One of the main reasons for this lies in the low sensitivity of human ears to these low frequencies and the considerable differences between the exposure to low-frequency noise from indoor/outdoor sources and between rooms in houses or flats [40]. The association between exposure to low-frequency noise in the work environment and health impacts on the workers has been, however, confirmed by many studies [37,41–43].

CONCLUSIONS

In view of the long tradition of mining and industry in many countries of the EU, the assessment of noise from these activities from the perspective of its impacts on human health is an inherent part of legislative processes. Statistics and research results show that noise from road or air traffic is the most significant type of noise pollution from the perspective of affecting the health of the population; the type of noise that is perceived as the most annoying, however, remains an open question. Many studies have shown that chronic noise exposure leads to adverse health effects. The association between noise annoyance and negative effects on health, however, has not been satisfactorily explained yet. Is it more than desirable to investigate and evaluate the exposure-response relationship of persons exposed to industrial noise in the environment which will include the classification of exposure-response function and which will reflect the need to include the frequency characteristics of noise. One of these research activities is a currently underway Czech Project [44]. Within the scope of the project, noise from mining activities will be measured according to the methodological guidance of the Czech Ministry of Health [45] and international ISO (International Organization for Standardization) standards. Noise annoyance and sleep disturbance will be evaluated using social and social-acoustic surveys, associating these results with measured and/or calculated noise levels. The questionnaire, which will be collected at several time points, will be a modification of an international questionnaire *Acoustics – Assessment of Noise Annoyance by Means of Social and Socio-Acoustic Surveys* [15,46].

Author contributions
Research concept: Markéta Stanovská, Hana Tomášková, Hana Šlachtová, Dana Potužníková, Ľubica Argalášová
Research methodology: Ľubica Argalášová
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Statistical analysis: Hana Tomášková
Interpretation of results: Hana Tomášková
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Publisher: Nofer Institute of Occupational Medicine, Łódź, Poland