Noise in the Mining Work Environment - Causes, Effects and Threats

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Abstract. According to the reports, the European Agency for Safety and Health at Work, millions of employees in Europe are exposed daily to industrial noise and all risks associated with it. About 7% of employees suffer from a hearing problem and noise-induced hearing damage is the most common occupational disease in Europe because it accounts for about one-third of all work-related diseases and is more common than skin and respiratory diseases. The industries with the highest noise emissions in the work environment include heavy industry, mining and construction, although the noise is also increasingly appearing in other sectors of the economy. The research issues discussed in the article introduce the issue of noise in the mining work environment of Polish hard coal mines and identify its causes, effects and threats. The article presents the results of hearing screening tests conducted in 2019 using the Mobile Hearing Diagnosis Center among over 3,000 employees of 37 hard coal mines located in the Slaskie and Malopolskie voivodships and describes the effects of exposure to noise among employees. The article also identifies noise sources and presents the level of their emissions in connection with the operation of machinery and equipment used in Polish hard coal mining. The obtained results of the measurement of the sound intensity of mining machines and devices point to repeatedly exceeding the permissible hygienic standards of Polish and European noise emission. The results of the research presented in the article indicate the urgent need to take action to constantly control the noise level at the workplace and introduce solutions that will enable its reduction and allow better protection of employees against its disastrous consequences. The article is an interesting case study of research conducted in a natural industrial environment that allows you to start a broad discussion on harmful factors in the work environment and look for solutions that increase the level of employee safety during work.

1. Introduction
Noise is one of the most common threats in the world and the workplace around us. According to reports from the European Environment Agency (EEA) and the European Agency for Safety and Health at Work (EU-OSHA), over 113 million Europeans are exposed daily to environmental noise around the clock at a minimum of 55 decibels. These statistics are additionally supplemented by nearly 40 million Europeans exposed daily to noise levels at work in excess of 85 dB and all related risks.

Published reports [1] show that over 22 million people are exposed to high levels of railway noise every day, 4 million are exposed to high levels of noise generated by aircraft, and more than 60 million are exposed to traffic noise. It is estimated that prolonged exposure to environmental noise...
causes 12,000 premature deaths and contributes to 48,000 new cases of coronary heart disease annually in Europe. As a result of excessive noise, up to 22 million people suffer from chronic high exacerbation, 6.5 million struggle with sleep disorders and nearly 12.5 thousand students suffer from learning disabilities.

However, the most common health problems caused by noise are among Europeans exposed to noise at work. According to EU-OSHA, 1/3 of all working Europeans complain of heavy noise during work. Over 13 million employees in Europe suffer from hearing problems [2]. Hearing loss due to noise is one of the most recognized occupational diseases in the EU [3], and employees' hearing loss occurs in almost every branch of the national economy of the Member States of the European Union. Noise is also the cause of numerous accidents at work, e.g. as a result of masking of audible warning signals or jamming of machines and industrial equipment.

In Poland, according to the data of the Central Statistical Office in 2018, among the factors related to the work environment, the biggest threat was the noise, which was threatened by 193.6 thousand persons (59.5% of all persons employed in hazardous conditions related to the work environment; calculated as many times as to which factors they were exposed). The number of employees exposed to noise was more than three times higher than the number of employees threatened by the second most common harmful factor in Poland - dust, to which 50.2 thousand people were exposed (15.4%). The largest number of people exposed to noise was recorded in the mining and quarrying section (the highest value was recorded in the hard coal and lignite mining section) and industrial processing (mainly in the production of metal products) [4].

Due to the scale of noise hazard in hard coal mining, as part of scientific research conducted by the Silesian University of Technology (Politechnika Slaska), it was decided to investigate this phenomenon more closely, explore its causes and effects as well as present the results of the research.

2. Impact of noise on an employee's body
Excessive noise impairs hearing - causes a temporary or permanent shift of hearing threshold (hearing loss), and in special situations - with long exposure to noise and after exceeding certain thresholds - a person can lose hearing completely and have recognized deafness. At the same time, this factor affects the whole body causing systemic disorders and ailments in individual human systems, among others:

a. in the circulatory system: changes in capillaries and the heart muscle. Increases in blood pressure, cardiac arrhythmias, most commonly increased heart rate, extrasystoles, decreased cardiac output, narrowing of small blood vessels and reduced blood flow in tissues.

b. in the blood: moderate anemia, increased ESR and eosinophilia.

c. in the digestive tract: increased gastric acid secretion, especially more frequent in the case of ulcer and duodenal ulcer.

d. in the endocrine system: adrenal function increases, hyperthyroidism increases, metabolism increases.

e. in the central nervous system: increase in intracranial pressure; occurrence of pathological changes in the eeg curve. Particularly noteworthy are the frequently occurring changes in the psyche, such as disturbance of mental balance expressed as fatigue, irritability, and argumentation. It is not uncommon for noise to cause fear and anxiety, attention deficit disorder, disturbance or difficulty in full and peaceful rest and sleep.

f. changes in the hearing organ: they can be functional, such as temporary dullness of hearing, or limited hearing, such as hearing loss and even deafness. These types of damages usually occur under the influence of intense noises, while the degree of damage hearing depends on the intensity and duration of a given noise on the human body.
The presented systemic changes depending on the duration, frequency, intensity or psychological preparation of a person for the appearance of noise may be more or less significant. Most often these changes are functional, and in more severe cases there are organic changes.

The scale of systemic disorders caused by noise varies, depending on age, sex, "sensitivity" of the hearing organ, well-being, health, type of work, nature and duration of the noise. Noise annoyance may occur even in the case of barely audible noises [5].

The research of the Polish Institute of Occupational Medicine in Lodz shows that as a result of many years of exposure to noise exceeding 85 dB in industrial conditions, symmetrical receiving hearing loss occurs in employees, in particular high frequencies, especially in the range of 3-6 kHz, which in the early period of hearing damage may go unnoticed by an employee. The main reason for this is that the first changes to sound reception problems relate to frequencies higher than the speech band. The dynamics of hearing damage caused by industrial noise is relatively fast during the first 10 years of exposure, after which it slows down. After 15 years of work in abnormal noise, the first cases of hearing damage involving lower frequencies, i.e. <2 kHz, are already recognized. In turn, 30 years of exposure to noise can cause total deafness. Figure 1 [6].

![Figure 1. Tonal audiometry - progression of hearing damage caused by occupational exposure to noise [6]](image)

Despite these facts, an employee rarely can see the effects of a pernicious noise, because the person affected by hearing loss is gradually getting used to it, and the hearing loss is compensated by the brain for a long time, so in the first phase of hearing disorders there are almost no difficulties in everyday life. Often it happens that the environment (family, friends, co-workers) recognizes hearing problems earlier than the affected person who persistently repeats: "I hear normally!". It is also very common for hearing-impaired workers who are aware that they no longer hear perfectly, in fear of losing their job or having to change jobs to less noisy and less paid, often hide their disability for a long time and take no action. They use the arguments "Somehow I manage!", "Maybe nobody will notice", "Others also can't hear" and postpone the performance of comprehensive hearing tests, or if such tests already occur, e.g. during periodic employee tests, they try to fake them.

3. Research methodology

3.1. Hearing screening

To meet the described problems of excessive exposure to noise in the extraction of hard coal and lignite section. Scientists from the Silesian University of Technology in Gliwice, the Faculty of Mining, Security Engineering and Industrial Automation attempted to recognize the scale of the
problem, its causes and effects. To this end, it was decided to carry out hearing screening tests on a representative group of miners from each of the mines located in the Slaskie and Malopolskie voivodships. In order to avoid controversy related to the research methodology and ensuring the same laboratory conditions for each group of mine employees surveyed, hearing screening was decided to be carried out using Mobile Hearing Diagnosis Centers - the so-called Sluchobusow company ACSluchmed sp. z o.o from Lublin. Miners' hearing screening tests were conducted for a period of 4 months from August to the end of November 2019 by specialized diagnostic teams, which included a hearing care professional or ENT specialist, driver of the Mobile Hearing Diagnostic Center - Listenbus and scientist of the research team from the Silesian University of Technology. The team had two Peugeot Boxer cars with registration number WI 026ET and LU 204GU (Figure 2) equipped with a silenced cabin, Interacoustics type AD 226 audiometer with appropriate approvals and certificates as well as necessary medical equipment.

The research was carried out according to a predetermined schedule in which hard coal mines and mining plants were divided into five research groups due to their location and functionality. Extramural students of GIG (mining and geology) of the Silesian University of Technology working on a daily basis in hard coal mines were also selected for the sixth group of respondents. The tests were carried out between 10 am and 4 pm in Mobile Hearing Diagnosis Centers, which, with the consent of the management of mines and mining plants, stood directly in front of the mine entrance or in the parking lot of the mining clinic. As part of the hearing screening tests, the study also covered nearly half (45.5%) of the staff of Brzeszcze Mining Plant (Zakład Górnictwy Brzeszcze). Mobile Hearing Diagnostic Centers conducted 24-hour tests at this mine for five days.

The scope of hearing screening included:

- Initial interview with the patient - the purpose of which was to familiarize himself with the personal data of the examined person, such as: date of birth or telephone number enabling subsequent contact, as well as with the needs, fears and expectations of the patient.
- Medical history - enabling familiarization with the patient's medical history. Such information was important for the hearing diagnostician and ENT specialist, as additional patient diseases may change his hearing periodically and affect the result of the hearing test.
- Environmental interview - the purpose of which was to obtain information on what the patient is currently doing. Is it exposed to high levels of noise? What kind of work he does professionally and how he spends his free time (yearly concerts, discos, sporting events) and in which situations the patient has the biggest problems with hearing and understanding speech.
- Colonoscopy of the patient's ears - the purpose of which was to check the condition of the external auditory canal and eardrum before proceeding with audiological tests. During the tests, if a cork was
found which made it impossible to diagnose the patient, he was directed to clean the ear canal to the ENT office.

- hearing screening using a silence booth and an audiometer - it consisted in giving audiometric headphones in a muted room a sound of different frequency and signaling by the patient of sound recognition (hearing threshold). By pressing the button, the patient signaled the moment when he began to hear the tones given to him, the frequency of which was successively increased. The aim of the study was to extract from a given population those people who have specific diseases, e.g. hearing impairment, deafness. If the results of the screening indicated a hearing loss, the prosthetist informed the patient what steps should be taken to prevent the worsening of hearing loss and referred the patient to comprehensive tests to the nearest place of residence of the patient's ENT office or hearing prosthetics company ACSłuchmed Sp. z o.o.
- total audiometry - was performed in one of the prosthetic offices of the company ACSłuchmed Sp. z o.o., to which patients with suspected hearing impairment or diagnosed hearing impairment diagnosed as a result of screening were referred. The tests carried out in the office were aimed at verifying the degree of hearing impairment in the patient based on, among others air and bone audiometry.

3.2. Surveys
As part of the screening of hearing, employees of hard coal mines also took part in an anonymous survey, which aimed to find out the subjective assessment of employees about:
- sources of noise occurrence in mines,
- daily exposure of employees to noise,
- noise reduction solutions used in mines,
- the effectiveness of preventive examinations in the field of hearing physiology and pathology,
- knowledge of changes in the ear due to excessive noise,
- the extent and duration of employees' exposure to noise outside occupational exposure.

The survey included 30 questions in three thematic blocks: working conditions at the mine in noise, hearing condition, spending free time.

3.3. Underground noise measurement
Obtained knowledge from surveys also enabled the commencement of work related to noise measurements in octave bands in the range from 31.5 Hz - 8000 Hz of machines and devices working in mining excavations, at the mechanical processing plant, in the power and mechanical department. Mines will not carry out such measurements although they are necessary to determine exceedances of noise for individual frequencies, and thus determine its harmful effects on the hearing organ. The measurements were carried out in accordance with the provisions of the PN-EN ISO 9612: 2011 [7] and PN-N-01307: 1994 [8] standards. The study measured sound intensity L_Aeq emitted by hand tools, mining machinery and equipment as well as maximum sound level A - L_Amax, and peak sound level C - L_Cpeak. The integrating sound level meter DLM -101 from P.P.U.H Sonopan Sp.z.o.o. was used for the measurements. This meter has a first accuracy class and meets the requirements of PN-EN 61672-1: 2014 [9]. It is a meter enabling measurement of sound intensity both at workplaces and in the environment. The meter allows you to work at temperatures from -10 °C to 50 °C and up to 90% humidity, without the results of distorted measurements. The measuring range of the meter is 24 - 135dBA and 45 - 137dBC. The basis for assessing the noise level were the results of three measurements at each test stand during individual technological processes.

4. Research results
4.1. Screening results
A group of 3,265 active and former employees of 37 hard coal mines currently operating as independent, combined or decommissioning mines participated in hearing screening using the Mobile Hearing Diagnosis Center (Figure 3). The study involved miners who have not yet found an
occupational disease associated with hearing loss. The majority of respondents were professionally active men 89.6%. The surveyed women 11.4% are mainly employees of the coal processing plant and the power engineering department servicing the main mine fan stations. The research covered employees from each age group, whose average seniority in mining was around 16 years. This condition is undoubtedly caused by the generational change that took place in Poland in connection with the mining reform in 2015 and the departure for mining or retirement of older employees.

Figure 3. Examples of places of hearing tests conducted among employees of Polish mines

The largest group of respondents 32.4% was employees between 31-40 years old, the smallest 5.2% employees over 50 years old. The largest group among the surveyed were employees employed in such positions as a miner - 26.6% of respondents, supervisors of various departments - 11% of respondents, reworkers - 8.1%, rescuers - 8.0% and locksmiths 7.7%. The research included representatives of virtually all mining departments, and their number in individual groups correlates with the actual level of employment in individual departments (Figure 4).

| No. | Position       | Department | Left ear [Hz]/[dB] | Right ear [Hz]/[dB] |
|-----|----------------|------------|-------------------|--------------------|
| 1.  | Miner          | Mining     | 250 500 1k 2k 4k  | 250 500 1k 2k 4k   |
| 2.  | Roadheader     | Mining     | 10 20 25 15 20 18 | 5 10 10 5 10 8    |
| 3.  | Locksmith      | Preparatory| 5 10 20 50 20 21 | 10 15 30 15 25 19 |
| 4.  | Electrician    | Mechanical | 45 55 70 45 50 53 | 30 35 40 50 60 43 |
| 5.  | Blasting worker| Preparatory| 60 70 80 80 80 74 | 30 30 65 70 70 53 |
| 6.  | Rescuer        | Ventilation| 5 5 10 0 5 5 5   | 5 10 10 5 5 5 8   |
| 7.  |                |            |                   |                    |

Signature of the researcher:  
Signature of the survey supervisor:

Figure 4. Example of hearing screening report
For people associated with the industry, it is no secret that employment in mining and exploitation and preparation departments is the largest, and the second most important in terms of employment are the departments: power engineering and ventilation. Hearing screening and total audiometry studies have shown, however, that it is not these professional groups that are most affected by the effects of excessive exposure to noise in the mine. Most often, injuries and impairment of the organ of hearing occur among the shots. Nearly half (46.0%) of them had hearing loss or deafness.

A similar phenomenon of high intensity occurs at the stand of plumbers operating high pressure pumps, compressor sets and main drainage systems (41.2%). A significant risk of hearing impairment is also recorded in employees associated with the operation of belt conveyors both in underground conditions and on the surface in a coal processing plant, where the increase in noise emissions is additionally intensified by ring crushers, vortex mixers or enrichers. The percentage share of respondents according to positions is presented in Table 1. This table also shows the percentage of people diagnosed with final cases of hearing impairment at individual workplaces.

| No. | Position                      | Percentage of respondents surveyed by position | Hearing impairment in the given group | No. | Position                      | Percentage of respondents surveyed by position | Hearing impairment in the given group |
|-----|-------------------------------|-----------------------------------------------|--------------------------------------|-----|-------------------------------|-----------------------------------------------|--------------------------------------|
| 1.  | Miner                         | 26.6%                                         | 13.2%                                | 12. | Carpenter                    | 2.5%                                         | 34.1%                                |
| 2.  | Roadheader Driver             | 1.6%                                          | 21.2%                                | 13. | Processing worker            | 2.6%                                         | 18.8%                                |
| 3.  | Conveyor service              | 5.1%                                          | 36.9%                                | 14. | Power engineer               | 1.9%                                         | 12.9%                                |
| 4.  | Driller                       | 2.1%                                          | 4.3%                                 | 15. | Electrician                  | 6.0%                                         | 19.5%                                |
| 5.  | Rescuer                       | 8.0%                                          | 11.2%                                | 16. | Linie operator               | 2.1%                                         | 30.4%                                |
| 6.  | Methane operator              | 2.3%                                          | 8.1%                                 | 17. | Blasting worker              | 2.7%                                         | 46.0%                                |
| 7.  | Filler                        | 1.6%                                          | 23.1%                                | 18. | Geologist                    | 0.5%                                         | 0.00%                                |
| 8.  | Conservator                   | 2.4%                                          | 23.1%                                | 19. | Signaller                    | 8.1%                                         | 35.0%                                |
| 9.  | Driver                        | 1.3%                                          | 24.4%                                | 20. | Lab worker                   | 0.5%                                         | 0.0%                                 |
| 10. | Locksmith                     | 7.7%                                          | 25.4%                                | 21. | Inspector                   | 0.3%                                         | 11.1%                                |
| 11. | Plumber                       | 3.1%                                          | 41.2%                                | 22. | Supervisor                   | 11.0%                                        | 18.6%                                |

Employees of the following departments: shooting, energy-mechanical and mechanical coal processing also belong to those mine branches where the most people with hearing impairment meet (Table 2), so presumably the emission of industrial noise in these branches is significant and exceeds the applicable hygiene standards.

Normal hearing was found by 2,587 people. By 216 people, during the initial (sight-glass) examination, earwax plug was prevented from conducting the audiometric test and they were referred to an ENT specialist. After repeated examination, 94 out of this group of patients were diagnosed with hearing loss. Symptoms of hearing impairment were also diagnosed in 598 other people, of whom 311 people by 31/03/2020 volunteered for additional tests to indicate hearing care prosthetics companies of AC Słuchmed Sp. z o.o. Among 98 people surveyed from this group, a significant (over 40%) hearing loss was identified, which qualified employees to apply for an occupational disease benefit. The global epidemic of coronavirus COVID-19 and restrictions introduced in Poland made it impossible to temporarily carry out further detailed research on the degree of hearing impairment among miners examined who were diagnosed as a result of hearing impairment by screening.
The obtained results of hearing screening tests confirm the data of the Central Statistical Office of Poland as to the conclusion that noise in the mining work environment of hard coal mines is very high. However, the results also show that the consequences of this exposure are greater than expected because as a result of the impact of noise in the mining work environment, more than 20% of respondents (20.9%) have a hearing impairment and 3% of them are significant. These results confirm previous observations that miners, in fear of losing their jobs, partly hide their ailments.

### Table 2. Found hearing loss among employees in individual departments

| No. | Department                  | Percentage of respondents by department | Hearing disorders found in a given department |
|-----|-----------------------------|----------------------------------------|---------------------------------------------|
| 1.  | Mining                      | 37.1%                                  | 17.5%                                       |
| 2.  | Mechanical                  | 28.0%                                  | 25.7%                                       |
| 3.  | Mechanical processing       | 9.1%                                   | 34.0%                                       |
| 4.  | Blasting Techniques         | 3.2%                                   | 47.6%                                       |
| 5.  | Ventilation                 | 16.2%                                  | 13.4%                                       |
| 6.  | Collapse                    | 2.4%                                   | 3.8%                                        |
| 7.  | Energetic                   | 2.1%                                   | 14.5%                                       |
| 8.  | Materials management        | 0.4%                                   | 7.7%                                        |
| 9.  | Measurement and geological  | 0.8%                                   | 0.0%                                        |
| 10. | Environmental protection    | 0.7%                                   | 0.0%                                        |

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#### 4.2. Survey results

A total of 3,265 employees from all 37 mines participated in the survey. The research allowed to identify the main sources of the password on the mines to which miners were or are exposed during the performance of their duties and to identify activities performed by miners, which may be accompanied by excessive noise. Thanks to them, it was also possible to identify the customs and activities of miners outside work, which may be accompanied by noise in everyday life. As it turns out, about 22% of miners, especially young ones up to 30 years old, are also exposed to noise outside the workplace. The main source of this threat is noise emitted by devices such as mobile phones, smartphones, playing equipment and TV. Young miners also use pubs and restaurants go to discos and rock concerts where they come into contact with high-intensity noise. This exhibition, however, is not permanent and does not cause too much change in the hearing organ, which is confirmed by audiometric tests. Only less than 1.5% of respondents from the 18-30 age group were diagnosed with hearing loss symptoms.

The results of the survey, however, have brought other remarks and observations, important from the point of view of noise pollution in the work environment. This information relates to activities undertaken by mining companies in Poland to reduce noise in the work environment. It turns out that practically all available solutions limiting the level of noise emission in the work environment are used at the mines in Poland. Starting from organizational activities related to e.g. staff rotation at noisy jobs, through collective protection measures, medical examinations, and ending with individual protection measures (Table 3). The research and opinions of employees show that the main problem with protective measures and their effectiveness lies in the fact that this equipment is incorrectly selected for the existing working conditions and the specifics of the activities performed. When assessing
occupational risk, OHS services focus on employee protection and select individual and collective noise protection equipment depending on daily exposure to the average noise level. Meanwhile, high-power mining machines and equipment used to generate very high noise levels for 24 hours in various octave bands. 43.8% of respondents give up, so often the use of hearing protectors, especially individual because they interfere with communication and make it difficult to identify other mining hazards, especially natural hazards in technological processes such as cracking the rock mass. 71.3% of miners surveyed also believe that the hearing protectors used do not protect them well against noise.

Table 3. Sample survey responses

| No. | What noise reduction measures are / were you using in your mine? | Percentage of response | No. | Do you use hearing protectors at work? | Percentage of response |
|-----|---------------------------------------------------------------|------------------------|-----|----------------------------------------|------------------------|
| 1.  | earmuffs                                                     | 17.5%                  | 1.  | Yes                                    | 56.2%                  |
| 2.  | earplugs                                                     | 51.4%                  | 2.  | No                                     | 27.6%                  |
| 3.  | soundproof booth                                            | 3.2%                   | 3.  | I don't know / sometimes               | 16.2%                  |
| 4.  | staff turnover in a noisy workplace                         | 2.3%                   |     |                                        |                        |
| 5.  | acoustic screens                                            | 0.3%                   | 1.  | Yes                                    | 28.7%                  |
| 6.  | noise suppressors                                           | 12.2%                  | 2.  | No                                     | 56.4%                  |
| 7.  | none                                                        | 13.1%                  | 3.  | I don't know / sometimes               | 14.9%                  |

4.3. Measurement results of sound intensity emitted by mining machines and devices
To identify the scale of noise pollution in the mining work environment. Measurements of noise emitted by mining machinery and equipment were carried out at three selected hard coal mines. $L_{Aeq}$, $L_{Aeq,\delta}$, $L_{Cpeak}$ i $L_{Amax}$ sound intensity measurements were made during the normal operation of mining machinery and equipment in the mining and processing operation. In the preparatory, maintenance, energy-mechanical, blasting and ventilation works. Summary results, sound intensity emitted by individual tools, mining machines and devices are summarized in Table 4.

Table 4. Sound level measurement values for selected mining tools, machines and equipment

| No. | Hand tools, device                                             | Range of average sound level $L_{Aeq}$ [dB] | Maximum sound level $L_{Amax}$ [dB] | Peak sound level $L_{Cpeak}$ [dB] | The average value of exceeding the normative |
|-----|---------------------------------------------------------------|---------------------------------------------|-------------------------------------|-----------------------------------|---------------------------------------------|
| 1.  | Longwall shearer                                              | 91-99                                       | 105.8                               | 119.4                             | 10                                          |
| 2.  | Roadheader                                                    | 88-102                                      | 106.2                               | 123.2                             | 10                                          |
| 3.  | Windlass                                                      | 90-120                                      | 120.4                               | 136.8                             | 100                                         |
| 4.  | Diesel-powered floor railway                                 | 92-104                                      | 109.1                               | 125.3                             | 20                                          |
| 5.  | Scraper conveyor                                              | 85-95                                       | 102.1                               | 118.7                             | 3.2                                         |
| 6.  | Belt conveyor                                                 | 88-97                                       | 104.6                               | 119.2                             | 5.6                                         |
| 7.  | Power drill                                                   | 86-101                                      | 101.4                               | 109.8                             | 7.1                                         |
| 8.  | Pneumatic drill                                               | 98-126                                      | 118.6                               | 130.1                             | 501.2                                       |
| 9.  | Pneumatic hammer drill                                        | 102-130                                     | 114.6                               | 131.2                             | 1258.9                                      |
| 11. | Hydraulic drilling machine                                    | 83-89                                       | 89.1                                | 93.3                               | 1.3                                         |
| 12. | Pneumatic drilling rig                                        | 105-130                                     | 118.6                               | 130.1                             | 1778.3                                      |
| 13. | Hydraulic drilling rig                                        | 82-86                                       | 96.3                                | 100.4                             | 0.8                                         |
| 14. | Pressure pump                                                 | 89-98                                       | 103.4                               | 112.6                             | 7.1                                         |
| 15. | Air compressor                                                | 90-106                                      | 108.2                               | 122.7                             | 20                                          |
| 16. | Oil compressor                                                | 86-95                                       | 107.6                               | 120.1                             | 3.5                                         |
| 17. | Filling station                                               | 88-94                                       | 106.6                               | 118.1                             | 4                                           |
| 18. | Multistage horizontal pump                                    | 92-108                                      | 109.4                               | 125.3                             | 31.6                                        |
| 19. | Submersible pump                                              | 94-106                                      | 107.3                               | 118.6                             | 31.6                                        |
In this table, in addition to average sound level A, maximum sound level A, peak sound level C, the average values of exceeding hygiene standards for each machine are also given and devices according to standards in force in Poland (85dB for 8 hours of exposure time). These data show that mine employees are constantly exposed to a high level of noise emissions in mining excavations, especially when using pneumatic tools that emit noise exceeding the allowable norms by several dozen to several hundred times. The nominal working time in the vicinity of machines with high noise emissions at the current level of protection, according to the measurements carried out, should last from a few seconds to a maximum of several minutes. Meanwhile, employees operate noisy machines and devices for several dozen minutes or even several hours a day.

The research shows that entrepreneurs not only in the mining industry should pay more attention to the noise generated by the machinery and equipment used in their plants and choose noise protection measures appropriate to the level of sound they produce, and only then assess the threat from attention to his exposure. The exposure parameter is a soft element of occupational risk assessment and does not always reflect the actual level of risk, which in the case of noise was shown by the results of hearing screening tests and the percentage of employees diagnosed with hearing impairment.

5. Conclusions
The research shows that:
- Industrial noise is a common phenomenon that occurs in the production process of any hard coal mine. As shown by the results of screening tests among 3265 people and total audiometry among 311 miners, excessive noise in the mining environment caused significant health changes in 20.9% of miners tested.
- Among 98 of the surveyed people, a significant (over 40%) hearing loss was identified, qualifying employees to apply for an occupational disease benefit, despite the fact that they had never had such symptoms before.
- The documented and presented results of a survey conducted among 3265 people confirm the prevalence of noise in the mining environment.
- The research also showed ineffective selection and disposal of noise protection measures, although mining companies use all commercially available noise reduction solutions.
- Poor effectiveness of preventive measures is related to the incorrect estimation of occupational risk at individual workplaces and the concentration of attention of OHS services on employee exposure to noise, and not establishing actual values of sound level emitted by mining machines and equipment. This approach is undoubtedly a mistake because errors in the diagnosis of danger lead to damage to the hearing organ among employees.
- Due to the significant noise values occurring in the mining environment but also in other industrial plants, there is a justified need to conduct further research on the possibility of introducing an industrial noise monitoring system in mining and introducing new hearing protectors, which can improve the level of occupational safety and reduce noise in appropriate octave bands the frequency of the emitted sound.
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