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Environmental working conditions versus occupational diseases in the hard coal mining branch

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Abstract

In the article major factors exerting an adverse impact on the comfort of work have been characterised. Mining plants engaged in the process of coal mining and their working conditions have been characterised. Selected examples of hazards influencing the incidence of occupational diseases have been presented. The results of investigations carried out at selected workstations in a mine, both overground and underground, have been presented. Solutions and measures aimed at reducing the existing threats have been proposed.

Introduction

In the legal system of Poland the basis for employees' health protection against an adverse influence of a working environment is provided for in the following regulations:

- Labour Code;
- Occupational Medicine Service Act;
- secondary legislation for these acts.

The Labour Code has among others imposed on the employer and employee the obligation to have preventive examinations performed, as well as to provide other forms of preventive treatment necessary due to working conditions.

The regulations of the Occupational Medicine Service Act have supplemented the provisions of the Labour Code by specifying structures and rules to be created in order to provide preventive health care over employees.

Hard coal mining remains one of the major industry branches as it is the basis of our energy security.

Advances in the technology of minerals extraction and processing have not reduced risks related to the incidence of occupational diseases among mining plant employees. The activity of coal mines belongs to the most dangerous branches of economy. This is caused by very difficult natural conditions and accumulating threats, which influence the health and safety of employees. The work performed by a miner requires him to assume a forced body posture, to stay in the conditions of artificial lighting and changeable temperature, to breathe in various dusts and gases, to inhale air with a reduced content of oxygen, as well as other harmful and dangerous substances influencing his health at work. This adverse environment exerts impact on the miner's health also for many years after he finished working.

General characteristics of mining plants in Poland

Mining activity includes works related to searching, identifying, extracting and processing of minerals. The methods of minerals mining have not changed, hence the division remains the same. It distinguishes the following manners of exploitation:

- underground exploitation;
- opencast mining;
- bore-hole mining.

At this point it cannot fail to mention the future forms of mining – marine mining or biotechnology-based mining [1].

Supervising bodies for all kinds of mining activity include the President of State Mining Authority, Directors of Regional State Mining Authorities, as well as Directors of Specialist Mining Authorities

[2]. State Mining Authority supervises mining plants – currently 320 plants extracting basic minerals are subject to its control and supervision.

Among the mining plants subject to the control and supervision of WUG (State Mining Authority) are:

- 42 underground mining plants, such as:
  - hard coal mines;
  - copper ore mines;
  - zinc and lead ore mines;
  - ceramic clay mines;
  - gypsum, anhydrite and salt mines;
- 9 plants engaged in underground works based on the mining technology;
- 201 opencast mines, including:
  - brown coal mines;
  - sulphur mines;
  - rock minerals mines;
- 68 bore-hole mining plants, such as:
  - salt extraction plants;
  - sulphur extraction plants;
  - oil and gas extraction plants;
  - plants engaged in the extraction of spring waters, thermal waters, brines;
  - plants extracting methane from coal beds;
  - underground gas storage plants;
  - landfills.

Mining plants employ over 210,000 people. Moreover, mining plants are provided with services by more than 1,800 companies employing nearly 38,000 workers.

Mining plants in Poland are characterised by very difficult geological and mining conditions, accompanied by numerous threats, which increases the risk of occupational diseases incidence among the employees and has a direct impact on their work safety.

Natural hazards in Polish underground mining are characterised by high dynamics and intensity. Major natural threats include:

- rock bumps – a phenomenon caused by a rock mass shock;
- methane – a phenomenon related to the occurrence of methane in a rock mass and its release as a result of exploitation;
- coal dust explosion – most frequently caused by the mining process;
- eruption of gas and rock – related to the gas-geodynamic phenomenon;
- fire – most frequently endogenic;
- fall of roof – unintentional dislocation of rock or rock mass and minerals from the side wall or roof;
- water hazard – a sudden inflow of water, brine, lye to the excavations.

Hazards existing in opencast mining include:

- eruption hazard – caused by the searching, making available and extraction of oil and natural gas deposits (boreholes at considerable depths);
- hydrogen sulphide hazard – a release in the process of harmful hydrogen sulphide compounds eruption.

Harmful and hazardous factors in a working environment

Major measures of hygiene conditions in a working environment include:

- working conditions;
- incidence of occupational diseases;
- number of natural deaths.

Harmful factors in the miner's work environment are very aggressive and tend to accumulate due to the fact that they occur in one place. Basic types of material working environment factors [3] have been presented in a diagram (Fig. 1).

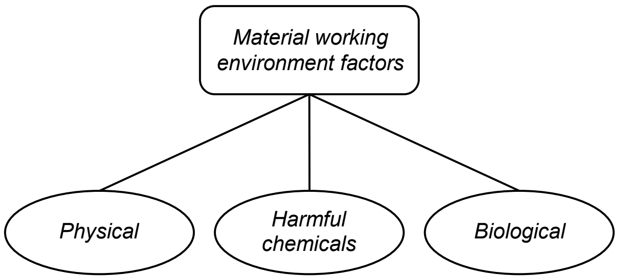


Fig. 1. Types of material working environment factors

In terms of causes and the nature of action, harmful and hazardous factors in a working environment fall into the following categories [4]:

- physical – noise, vibrations, ionizing, optical and laser radiation, microclimate, industrial dusts, electromagnetic field, electrostatic field;
- chemical – caustic, irritating, allergy-inducing, toxic, flammable, mutagenic, carcinogenic, explosive and oxidizing substances;
- biological – plant and animal micro- and macro-organisms (bacteria, viruses, fungi, protozoa);
- psycho-physical – physical and mental strains.

Physical factors

One of the main physical factors exerting an adverse influence on environmental working conditions is noise. The order issued by the Minister of Economy (the Journal of Laws 157, item 1318 as of 5th August 2005) defines noise as: …. "each kind of adverse sound which may be arduous or harmful to health or which may increase the risk of accident at work" [5]. Figure 2 presents the effect of noise on the human body and the working environment.

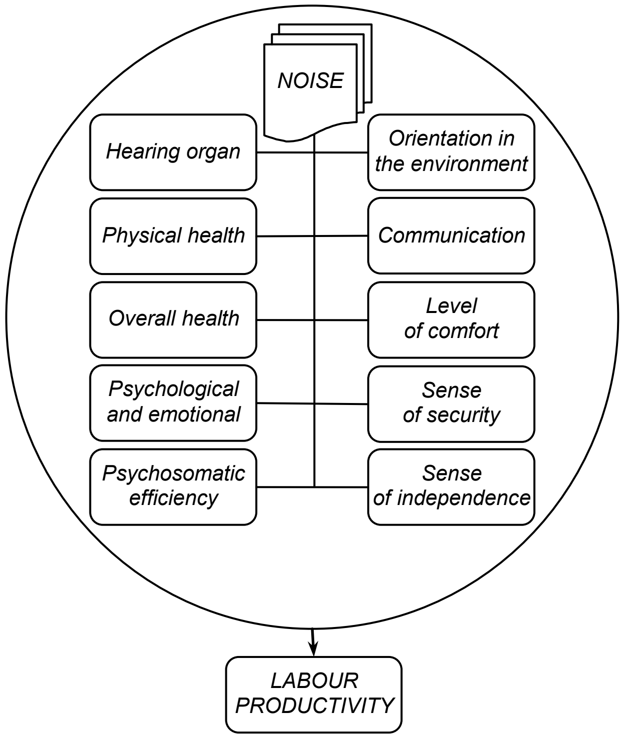


Fig. 2. The effect of noise on man

Noise has an adverse effect on the hearing organ and the central nervous system. Work in an environment where one has to deal with noise results in:

- damage to the hearing organ;
- fatigue;

as well as the so-called noise syndrome, which gives the following symptoms [6]:

- reduced readiness to work;
- stomach and intestine disorders;
- increased sweating;
- headaches and vertigoes;
- sleeping disorders;
- increased neural excitability.

Vibrations – transmission of mechanical vibrations from a solid body to particular tissues or the whole human organism. A vibration is defined as a pendular movement of a resilient medium [6]. Depending on the way of transmission, it distinguishes the following vibrations:

- general – affecting the trunk via the legs, pelvis, back – most frequently this process takes place via a seat;
- via upper limbs.

The adverse influence of vibrations on the human body manifests itself in the effect on:

- circulatory system;
- osteoarticular system;
- nervous system;
- system of muscles and tendons;
- alimentary system;
- general metabolic system;
- skin diseases.

Dust is a fragmented solid body suspended in the air or in another gaseous form [7]. It distinguishes:

- total dust – all particles surrounded by air in a specific volume;
- respirable dust – particles having an aerodynamic diameter of 3.5±0.3 μm which have reached respiratory tracks;
- respirable fibres – fibres having a length of more than 5 μm and a maximum diameter of 3 μm.

In a working environment occur the following kinds of dust:

- organic (plant-associated, animal-associated, synthetic);
- inorganic (mineral, metal);
- mixed.

Notions such as: fine dust, dust, powder, fine powder are frequently considered equivalent. They have one feature in common, i.e. they refer to a fragmented solid body in a form of small grains, which are often called particles. Dusts are solid body particles produced in mechanical processes, which are carried away and dispersed in gases, especially in the air.

This notion is also commonly applied when referring to solid particles precipitated from the gaseous phase and settling on the surface. In this case the term „settled dust" is used [8]. It has been assumed that the size of dust grain can be characterised by one value – its diameter. The nature of dust hazard depends on the size of grain – this fact has been experimentally confirmed [9]. The above dependence has been presented in figure 3 [10].

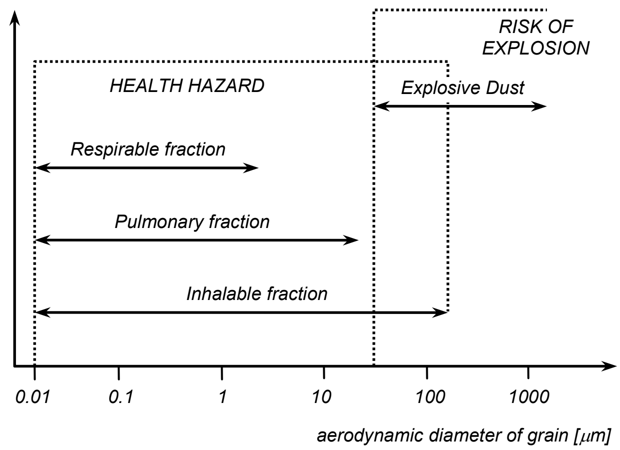


Fig. 3. The nature of dust hazard depending on the size of dust grains

Microclimate – it is quite common in the mining industry. In underground mining it results from descending to ever-increasing depths, while in the opencast mining it is related to year-long work in the open air. The thermal environment of a workplace affects the physical and mental state, health, work efficiency, as well as the safety and hygiene of work.

Radiation – is chiefly the effect of electromagnetic fields where the main sources are various kinds of machines and devices, as well as electric wiring. Moreover, underground mining is characterised by threats related to the ionizing field effect. This results from gamma and alpha radiation, mainly due to the occurrence of radon in mineral deposits and underground waters.

Chemical factors

A chemical factor is an element or a chemical compound in its own form or in a mixture, in the state in which it occurs in nature, as well as in the state in which it is produced or applied or released in a working environment, irrespective of whether it is produced on purpose or whether it is/it is not placed on the market.

Admissible doses of hazardous / harmful chemical factors in a working environment have been defined in the order concerning the highest admissible concentrations and intensities of substances harmful to health in a working environment issued by the Minister of Labour and Social Policy on 29th November 2002 (the Journal of Laws No. 217, item 1833, with subsequent changes) [11]. The order distinguishes:

- MAC – maximum acceptable concentration;
- MIC – maximum instantaneous concentration;
- MCC – maximum ceiling concentration.

Table 1. Chemical substances and their effects

<table>
<tr><th colspan="4">Chemical substances</th></tr>
<tr><th>Occurrence of contamination</th><th>Absorption ways</th><th colspan="2">Effects</th></tr>
<tr><td>Air pollution:
– solid;
– liquid;
– gaseous;</td><td>respiratory system;
skin surface;
eyes;</td><td>respiratory system irritation;
skin sensitization;
eye watering;</td><td rowspan="4">carcino-genic</td></tr>
<tr><td>Water pollution</td><td>skin surface;
alimentary system;</td><td>skin sensitization;
alimentary system disorders;
poisoning;</td></tr>
<tr><td>Soil pollution</td><td>alimentary system;</td><td>alimentary system disorders;
poisoning;
skin sensitization;</td></tr>
<tr><td>Food contamination</td><td>alimentary system;</td><td>poisoning;
alimentary system disorders;
skin sensitization;</td></tr>
</table>

Table 1 presents harmful chemical substances, their occurrence, location, the ways of absorption as well as their effects on the human organism [4].

An employee's exposure to harmful and hazardous chemical substances in a working environment may affect a part or their whole organism and can be acute or chronic. A directive of the European Community as of 1992 contains a division of substances or preparations according to their toxicity [12].

Biological factors

The occurrence of biological factors in a working environment can result in hazards manifesting themselves in a form of various kinds of infections, allergies and toxic effects.

Conditions in underground mines favour the development of bacteria, fungi and parasites, which pose a threat to the human body. Moreover, there is a risk of the occurrence of rodents, which may be carriers of many contagious diseases. In opencast mines there have also been cases of lyme disease caused by ticks.

Harmful biological factors in terms of their pathogenic effects are divided into the following groups [7]:

- factors causing contagious and invasive diseases (viruses, fungi, bacteria);
- biological allergens;
- biological toxins and compounds having a similar effect;
- carcinogenic factors;
- biological vectors, i.e. arthropods transmitting germs of communicable diseases (ticks, mosquitoes).

Depending on the possibility of causing a human disease biological factors fall into four groups. The division looks as follows [4, 13]:

- group 1 – factors which are unlikely to cause diseases;
- group 2 – factors which may cause diseases dangerous for employees, but their dissemination is unlikely – there are effective preventive measures and treatment methods;
- group 3 – factors which may cause serious human diseases, are dangerous for employees and their dissemination is highly probable – there are no effective preventive measures or treatment methods.

Psycho-physical factors

Psycho-physical factors in a working environment include:

- physical strain (physical work);
- mental and physical strain.

Physical strain in the human body is defined as functional changes related to enhanced metabolism. Physical activity can be expressed in a dynamic or static effort [14]. A dynamic effort involves physical activity – a high energy expenditure. Static strain is caused by prolonged tension of muscles caused by keeping one's body or holding objects in the same position (especially a forced one) for a longer period of time.

Mental strain involves intense concentration, engagement of the mind and human nervous system. It may result from the work itself, its character and conditions in which it is performed (responsibility, promptness, arduous external conditions etc.), as well as from personality features of the work performer, his emotional state and attitude to the performed works (prejudice, the lack of faith in his own powers, nervousness, the lack of motivation etc.). Both kinds of strain are practically hard to distinguish from each other. For this reason it usually talks about psycho-physical strain.

In mining plants we deal mainly with physical exertion (both static and dynamic), which does not mean however that mental strain is absent.

Physical exertion is related chiefly to the procedures of machine operation, the loading of mined rock, transport of materials over long distances, as well as to the employees' moving from one workstation to another.

By physical and mental efficiency we understand a biological criterion of a system's working potential [14].

Mental strain at work is mainly related to:

- the manner and conditions of receiving information by an employee;
- decision-taking conditions (consequences of these decisions, responsibility);
- conditions and the manner of carrying out particular procedures.

Apart from the above factors another important aspect is fatigue and work monotony. Fatigue is a transitory functional state of the organism which is characterised by a reduced capacity to work [14]. Fatigue can also be defined as a subjective symptom of deterioration in activity and reluctance to continue it. It is mainly due to the performance of the same work and monotonous environment. This is a dangerous phenomenon as it reduces vigilance, thereby resulting in errors, which may cause accidents.

Occupational diseases

The definition of an occupational disease has been contained in the Labour Code regulations (art. 235) and reads as follows:

"An occupational disease is considered to be a disease included on the list of occupational diseases if as a result of working conditions assessment it can be stated that the disease has been indisputably or with high probability caused by the effect of harmful factors in a working environment or in connection with the manner of performed work, referred to as occupational exposure".

An occupational disease in an employee or a former employee can be identified during his employment in occupational exposure or when he finished work in such exposure provided that disease symptoms which appeared in a period specified in the list of occupational diseases are documented. In order to find that a disease has been caused by occupational exposure, that is to say by the effect of harmful and dangerous to health factors existing in a working environment, or by the manner of performing work, it is necessary to evaluate occupational exposure at a given workstation.

The list of occupational diseases is an attachment to the order concerning occupational diseases issued by the Council of Ministers on 30th June 2009.

Occupational diseases in Poland

The total number of occupational diseases in Poland in the years 2000–2010 on the basis of data provided by the Institute of Occupational Medicine has been presented in table 2 [15].

Table 2. Occupational diseases in Poland in the years 2000–2010

Year	The number od cases			Ratio per 100,000 employed		
	total	men	women	total	men	women
2000	7339	3965	3374	73.9	77.0	70.3
2001	6007	3516	2491	63.2	72.1	53.8
2002	4915	2972	1943	53.6	63.5	43.3
2003	4365	2654	1711	46.6	54.5	38.0
2004	3790	2306	1484	41.0	47.7	33.6
2005	3249	2021	1228	34.8	40.9	27.8
2006	3129	1855	1274	32.8	36.8	28.3
2007	3285	1889	1396	33.5	36.3	30.3
2008	3546	2075	1471	34.7	38.4	30.6
2009	3146	1906	1240	29.9	34.1	25.1
2010	2933	1990	943	28.3	36.4	19.2

Analysis of the data contained in the table shows that the incidence of occupational diseases has a downward trend – this applies to both, men and women.

When analysing the incidence of occupational diseases according to Polish Classification of

Activity in the year 2010, it may be found that 50% incidence of occupational diseases was observed in two kinds of activity: in industrial processing and mining (Fig. 4) [16].

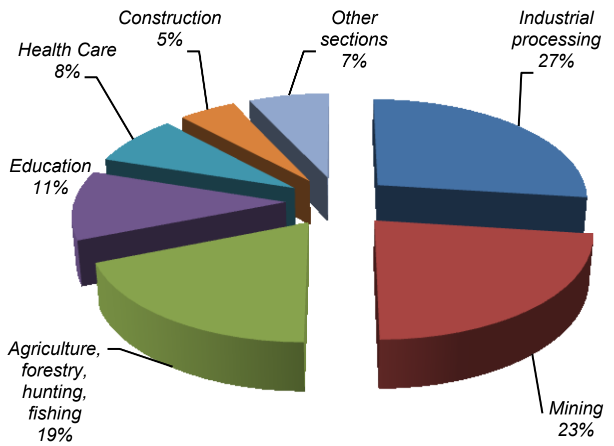


Fig. 4. Occupational diseases according to PKD

Occupational diseases in hard coal mining – selected issues

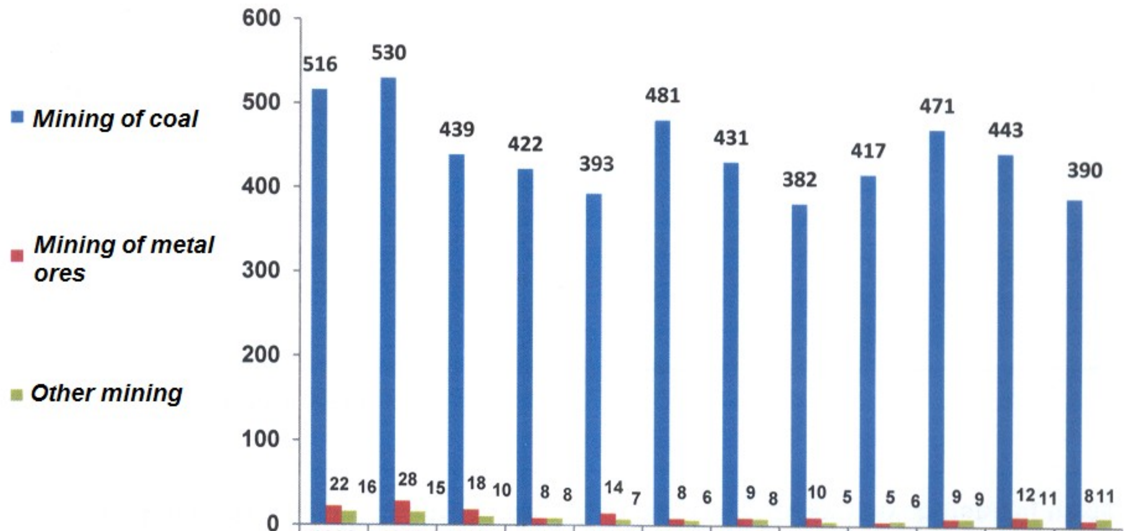
Pneumoconiosis of miners in hard coal mines

Practically, underground mining has always been considered the most dangerous branch of industry. An inherent product of mechanical rock mining is coal mine dust, which apart from the risk of explosion is a cause of occupational disease – pneumoconiosis.

Pneumoconiosis among miners working in hard coal mines results from inhaling practically omnipresent coal mine dust, the main component of which is coal dust. The content of silica in coal dust usually ranges from 2 to 10%. Moreover, this dust contains aluminosilicates and other mineral components, such as sulphur, beryllium, selenium, copper and cobalt. The highest exposure to coal-induced pneumoconiosis is observed among miners working in longwalls and headings, as well as among people engaged in shaft sinking. In the process of explosives blasting the concentration of dust in their vicinity grows rapidly and persists for approximately 20 minutes. The size of dust particles and its respirable fraction also increase. An equally high exposure to coal dust accompanies works related to the loading of mined rock and coal handling in transport.

The highest incidence of pneumoconiosis in Polish mining industry has been noted in hard coal mines. Such a situation has been persisting for many years. Compared to other types of mining activity in the year 2009 the share of pneumoconiosis incidence in hard coal mines reached 95%, which is illustrated in figure 5 showing the structure of pneumoconiosis incidence in the mining industry. The structure of occupational diseases incidence in hard coal mines for a long time has been characterised by the dominant position of pneumoconiosis.

The fact that such high incidence of pneumoconiosis persists while mines take a wide range of preventive measures proves the insufficient effectiveness of the latter. Each case of pneumoconiosis is a failure of the preventive system existing in a coal mine. Therefore, the effectiveness of preven-



	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Mining of coal	516	530	439	422	393	481	431	382	417	471	443	390
Mining of metal ores	22	28	18	8	14	8	9	10	5	9	12	8
Other mining	16	15	10	8	7	6	8	5	6	9	11	11

Fig. 5. Incidence of pneumoconiosis in particular types of mining [17]

tive measures depends on correct diagnosis and efficient elimination of the weakest links of this system [17]. Despite using respiratory system protective equipment and technical means which reduce dust concentration, the effectiveness of these measures is not sufficient.

The conviction that the level of pneumoconiosis incidence among miners depends solely on technical equipment such as dust collectors or sprinklers, as well as on the provision of respiratory system protective equipment is fallacious. Apart from the working environment itself, the possible incidence is also influenced by employees themselves. The lack of awareness among workers results chiefly from insufficient education, personality features and organisational culture. Another important factor is the lack of clear action on the part of the management in view of the employees' ignorance in the process of using respiratory system protective equipment.

On the basis of observations it has been found that major problems related to general reluctance to use respiratory system protective equipment include:

- Equipment which is badly adjusted to a workstation. In a working environment with high dust concentration the working staff are provided with half-masks. In the conditions of high humidity and high dust concentration (and such conditions exist in a sprinkled environment with a high concentration of dust) half-masks quickly lose their initial properties and the breathing process soon becomes harder.
- Equipment ergonomics. A problem related to the application of half-masks and masks is the fact that they are used together with other kinds of protective equipment at a workstation.
- The lack of the awareness of hazards. Awareness is making it possible for an employee to perform the target work which, basing on imagination, prediction of consequences and results of processes in a working environment, allows him to adopt particular behaviours on his own. Awareness is based on education, it should comprise knowledge and skills related to processes in the human body, the knowledge of risks but also the knowledge of preventive measures.

Noise hazard

Hard coal mines are characterised by a high number of workstations with exceeded allowable noise standards. The scale of the problem is proved by the fact that in the year 2009 as many as 27,000 employees of hard and brown coal mining were exposed to work in the conditions of noise hazard (Fig. 6), whereas 69 employees and former employees were found to suffer from occupational disease manifesting itself in permanent hearing loss.

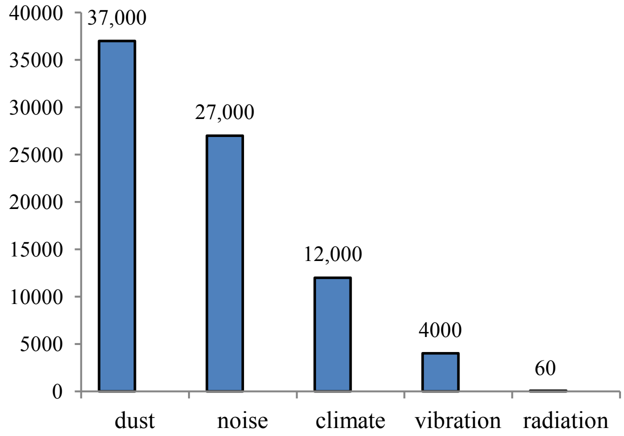


Fig. 6. The approximate number of workers employed in hazardous conditions in the mining industry in 2009

The hearing loss is irreversible and in great measure limits one's working capabilities.

In underground mining we deal with a high number of noise sources. Practically, at each production workstation directly related to the mining process or raw material processing an employee is exposed to noise. This is often a low-frequency noise, particularly difficult to muffle – collective and personal protective equipment is characterised by low effectiveness.

Despite introducing modern machines, devices and the automation of mining processes, the problem of noise is still common, leading to the incidence of occupational diseases and hearing loss. It causes approximately 10% of all occupational diseases in Poland.

Moreover, investigations have been carried out at six workstations in three different departments of the Coal Mechanical Processing Plant (ZPMW) in one of the mines belonging to JSW SA. These departments are placed on a few levels, in three separate buildings of ZPMW. In order to differentiate the results, the research was done during work, during breaks, as well as at the time when the employees were staying in cabins or in refreshment rooms.

Evaluation of the compliance of work with requirements to be met at selected workstations allows stating that the maximum noise level (L_{Amax}) and the peak noise level (L_{Cpeak}) do not exceed the admissible value, while the level of exposure to noise during an 8-hour work time ($L_{ex,8h}$) exceeds the allowable value at each of the six analysed workstations in the Coal Mechanical Processing Plant (Fig. 7).

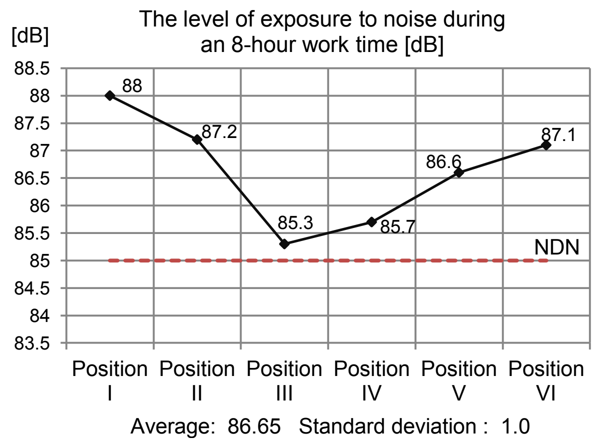


Fig. 7. An analysis of noise level $L_{EX,8h}$ compared to the admissible standard (MAI – maximum admissible intensity) at ZPMW workstations

Conclusions

Complete elimination of the sources of excessive dust concentration and noise from the premises of a coal mine is not technically feasible. In order to change this state of affairs, a number of technical and organisational measures are taken, aiming to reduce the level of dust concentration and noise, as well as to limit the number of employees exposed to this factor and reduce the risk of occupational diseases incidence. The main task for mine supervision services and the OSH department should be to ensure appropriate personal equipment for respiratory system and hearing protection. Such equipment should be selected on the basis of operational parameters and comfort of use. The usability and ergonomics of equipment may encourage employees to use it. The most beneficial effects can be achieved by taking into consideration the feelings and experiences of employees in the process of equipment selection so that they will more readily apply it on their own. The problem of the comfort of use is so important that the mine management should not underestimate it, as its negligence may in a large measure result in the employees' reluctance to use personal protective equipment.

An example might be modernisation of mine traffic control systems, consisting in the removal of staff from workstations particularly exposed to health hazard. This program should be geared chiefly towards activity within the following scope:

- cataloguing the source of dust concentration and noise in a working environment;
- specification of workstations exposed to abnormal dust concentration or noise;
- permanent monitoring of workstations where dust concentration or noise level standards are exceeded;
- specification of various risk groups;
- increasing the awareness of employees with regard to health;
- increasing the level of preventive teams competence;
- periodical assessment of the implemented programme effectiveness.

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