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ASSESSMENT OF BIOLOGICAL HAZARDS IN THE MINING ENVIRONMENT ON THE EXAMPLE OF THE PREPARATORY WORKS DIVISION

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Purpose: The presented article is empirical in nature and deals with the proposal of biological risk assessment in the mining work environment in connection with the imposition by the Parliament of the European Union and the Polish Ministry of Health on employers of this assessment also in the face of unintentional biological factors accompanying business activities. Its purpose is to draw the attention of the management of coal mines in Poland to the biological hazards accompanying the technological processes associated with coal mining, which may have an impact on the deterioration of the health of mining crews, and the obligations that fall on the employer and occupational health and safety services in connection with the need to comply with the provisions of Article 207 of the Labour Code (Labour Code) and the changing European legislation (Directive of the Commission (EU): 2019/1833 of October 24, 2019 and 2020/739 of June 3, 2020) as implemented into the Polish regulatory framework (Regulation of the Minister of Health of December 11, 2020 - Dz.U. 2020 item 2234).
Design/methodology/approach: The risk assessment of biological hazards accompanying the technological process in mining conditions in the preparatory works division of a coal mine was carried out based on the assumptions of the descriptive method of occupational risk assessment according to the guidelines of the Institute of Occupational Medicine in Lodz (Kozajda, Miśkiewicz, 2022). To identify biological hazards in the mining work environment, a group of available research methods was used based on: interview, site visit combined with environmental and laboratory tests, and analysis of available literature on biological hazards.
Findings: The study showed that there are many more biological hazards accompanying the coal mining process in the mining environment than the mine health and safety services had previously assumed. The increase in biohazards increases with the depth of mining and the deterioration of working climatic conditions. In the mining environment there are also biological factors classified as group 3 human hazard, which could not be detected by the procedures used by mines to identify biological hazards and quantitative methods of occupational risk assessment. It is therefore advisable to implement new solutions and research methods described in the article that allow to increase the safety of miners' work in terms of biological hazards.
Research limitations/implications: Harmful factors present in the mining work environment that can affect the health of coal mine workers hard coal is a sensitive issue and one that is reluctantly raised by mine management, union organizations and the workers themselves. Miners hide their ailments for fear of losing their jobs and are reluctant to undergo diagnostic tests. Therefore, a condition of conducting environmental studies at the mine in question and

compiling data for the purposes of the above article was to guarantee the complete anonymity of the subjects and the workplace. The obligation to protect the source of the data stems from Order No. 54/2022 of the Rector of the Silesian University of Technology dated March 1, 2022 on the introduction of the Book of the Educational Quality Assurance System (Legal Monitor of the Silesian University of Technology, 2022, item 154) and the cooperation agreements between the Silesian University of Technology and individual business entities.

Practical implications: The descriptive method of risk assessment for biological hazards in the mining work environment presented in the article can be directly implied for practical use not only by the health and safety services of mines and mining plants, but also by the health and safety services of other business entities.

Social implications: Biological agents found in the work environment are a growing social problem. Its effect is an increase in the number of workers exposed to biological agents also in branches of the national economy in which they have not previously been identified. This phenomenon raises the social costs associated with the loss of working capacity of an increasing number of workers diagnosed with occupational diseases of biological origin and the need to treat those infected. A proper procedure for identifying and assessing biological hazards in the work environment can reduce this phenomenon by indicating more effective prophylaxis against biological agents in workplaces.

Originality/value: The article is directed to the management of coal mines and occupational health and safety services, to whom it points out the places of possible occurrence of biological hazards in the mining environment, as well as ways of assessing these hazards and directions for taking more effective preventive measures to reduce health risks for miners.

Keywords: mine, preparatory works department, biological hazards, risk assessment, preventive measures.

Category of the paper: Original work (scientific - research).

1. Introduction

Biological hazards, although often associated primarily with medicine, diagnostic laboratories, the food industry, agriculture, animal husbandry or waste management, are also found in many other work environments that at first glance are not directly associated with biological hazards. Their presence may not be obvious, and yet pose a real risk of infections, allergies or other occupational diseases. Therefore, according to the new guidelines contained in the Decree of the Minister of Health of December 11, 2020. - OJ. 2020 item 2234 (ISAP 2020), every employer is required to update the assessment of occupational risks to which an employee is or may be exposed, even if biological risks are not due to the nature of the work itself, but may be present in the work environment incidentally or unintentionally.

The indicated regulation, following the position of the European Commission in Directives: 2019/1833 and 2020/739 (EUR-lex 2019, 2020) updated not only the list of biological agents and the list of work exposed to them, but also strengthened the obligation to assess biological risks in a comprehensive manner. According to §6(1) of the regulation: "The employer, taking into account the type, degree and duration of the employee's exposure to biological agents and the risks to health or life, shall assess the occupational risks associated with the employee's exposure to these agents".

These regulations are not limited only to jobs where biological agents are recognizable and identified, but also include all workplaces where there is a possibility of their presence, even if they are not part of the basic technological process.

Examples of non-obvious jobs where biological risks due to working conditions, environment or auxiliary materials should be assessed include:

1. Work in the construction industry - when working in old buildings, contact with mold (e.g., *Aspergillus*, *Penicillium*), soil bacteria or animal feces (e.g., pigeons) can occur, which are sources of respiratory infections or zoonoses.
2. Work in the wood and paper industry - when handling organic raw materials in a soggy environment, there is a risk of exposure to fungal toxins (mycotoxins) and microorganisms that develop in cellulosic materials.
3. Storage and transportation work - organic products (e.g., grains, wood, foodstuffs) can biodegrade under conditions of improper storage, becoming a source of bacterial and fungal growth.
4. Office work in soggy or poorly ventilated buildings (so-called sick building syndrome) - possible presence of *Legionella pneumophila* bacteria in air conditioning and fungi that cause allergic reactions.
5. Work in the mining and quarrying industry-where there are, among other things, fecal bacteria (e.g., *E. coli*, *Salmonella*), viruses and parasites residing in contaminated mine waters, or ubiquitous molds and fungi (e.g., *Aspergillus*) developing in ventilation ducts or on wooden parts of the mining casing.

The amendment to the regulations on harmful biological agents, introduced in 2020, has already been reflected in the statistics of the Central Statistical Office (Auksztol et al., 2024), which noted a recent jump in the number of people exposed to biological agents in mining from 2 forfeitures in 2019 to 1,064 in 2023, ranking this industry of the economy in 6th place in terms of the number of people employed in conditions threatened by biological agents (Table 1).

The threat of non-obvious biological factors accompanying the mining process in mining, as indicated by the inspection of inspectors of the State Sanitary Inspectorate carried out at some coal mines, may be even greater, as there is still insufficient knowledge and awareness among employers, health and safety services, trade union organizations and workers themselves about potential exposure to biological factors in the workplace and related health problems. The inspectors of the State Sanitary Inspectorate also point out that the occupational health and safety services of coal mines have problems with the identification of biological hazards and their assessment, for in estimating occupational risks they use quantitative methods which, in the absence of hygienic standards for individual groups of biological hazards and their nonspecific effects on workers, often give false results. It is therefore advisable to look for new methods of assessing biological risks and their identification, which is the subject of this paper.

Table 1.
Employed in conditions of risk of biological agents by section in 2019-2023

Section of economic activity PKD	2019	2020	2021	2022	2023
Health care and social assistance	3811	7396	10786	9859	5792
Industry	4672	3292	2727	4341	4687
• Water supply; sewage and waste management; reclamation	2485	2283	1544	2953	2283
• industrial processing	1991	992	965	1274	1261
• mining and quarrying	**2**	**6**	**154**	**54**	**1064**
• generation and supply of electricity, gas, steam and hot water	194	11	63	60	79
Agriculture, forestry, hunting and fishing	1422	1673	1874	1619	1153
Trade; repair of motor vehicles	263	601	278	746	204
Construction	314	265	477	449	679
Transport and warehouse management	82	156	100	305	186
Professional, scientific and technical activities	24	100	76	152	102
Education	52	176	331	28	31

Source: own compilation based on CSO (Auksztol et al., 2024).

2. Assessment of biological risks in the workplace

Biological risks in the work environment have been the subject of many foreign studies for years (Alter et al., 2007; Eduard, 2009; Fromme et al., 2016; Green, Beezhold, 2011; Montano, 2014; Rim, Lim, 2014; Tiong, 2021) and Polish scientists (Dutkiewicz et al., 2011, 2015, 2016; Wójcik-Fatla et al., 2020, 2022; Zukiewicz-Sobczak et al., 2013, 2013a), government agencies such as the European Agency for Safety and Health at Work (EU-OSHA 2009, 2017, 2018, 2019, 2019a, 2019b, 2019c), the National Institute for Occupational Safety and Health, USA (NIOSH 2020) and international organizations among which the largest is the World Health Organization (WHO, 2014, 2018). These studies show that biological factors not only in the work environment, but also in everyday life, have a significant impact on the health of workers and public health more broadly. According to the latest data, it is estimated that around 320000 workers worldwide die annually from work-related infectious diseases, about 5000 of them in the European Union countries (EU-OSHA 2020), and more than a billion people worldwide are exposed to them on a daily basis. Statistical data on occupational morbidity in individual countries of Europe and the world as well as ongoing scientific research (Szymanska, 2007, Fijan, Šostar Turk, 2012; Dulon et al., 2015, Shereen et al., 2020, EU-OSHA, 2019c) indicate that health care workers are among the most vulnerable occupational groups. In this group, the most common risks are bloodborne infections such as HIV, hepatitis B and C, as well as tuberculosis and influenza. Infections mainly occur through needlestick injuries or contact with infected biological material. These risks affect doctors and nurses as well as support staff, such as cleaners and temporary workers, who are often not properly trained and equipped with personal protective equipment. Biological hazards, however, as research shows, are not just the domain of one occupational group. Biological agents also cause occupational diseases among farmers (Spankie, Cherrie, 2012; Pearson et al., 2015; Cano-Jiménez et al., 2016; Schlosser et al., 2018; EU-OSHA, 2019a), waste and wastewater workers (Kuijer, Sluiter, 2010; Anzivino-Viricel et al., 2012; Duquenne et al., 2014), animal professionals: veterinarians, abattoir, slaughterhouse, laboratory or animal husbandry workers (Yilmaz et al., 2013; Feary, Cullinan, 2016; Zamfir et al., 2019). In the scientific databases Web of science, Scopus, MDPI, Google Scholar, CrossRef, there are also many comprehensive studies on biological hazards in the work environment and their impact on the health of workers also in other occupational groups in which biological exposure is not as obvious as in the occupations mentioned earlier (Liebers et al., 2007; Dutkiewicz, 2011; Duquenne et al., 2013; Walser et al., 2015; EU-OSHA, 2017, 2020f). All of these studies clearly indicate that biological hazards are today a growing challenge for employers and occupational health and safety services in their identification, risk assessment and planned preventive measures. A limitation in this regard pointed out by many experts (Brun, Milczarek, Roskams, 2007; Crook, 2007; Eduard et al., 2012; Carducci et al., 2013; Burzoni et al., 2020) is the lack of uniform, widely accepted assessment standards.

Workplace biological risk assessment is a key element in ensuring the health of workers in the face of rapidly changing biological hazards. Despite the growing importance of this field, the process of biological risk assessment is fraught with numerous methodological, organizational and cognitive difficulties. As pointed out as early as the late 1990s (Seedorf et al., 1998), the diversity of biological factors and the lack of standardized measurement methods hinder the comparability of data across sectors. Qualitative approaches dominate over quantitative ones (Douwes et al., 2003), which in practice results in a high dependence of results on subjective assessments by experts. In addition, biological agents, i.e. viruses, fungi parasites, can be present in the environment as well as generated as part of industrial processes (Burzoni et al., 2020) which makes a real risk assessment require taking into account not only the presence of the agent, but also its infectious dose, stability in the environment and routes of transmission - a point supported by the work of (Crook, Burton 2010), who point to the need to integrate microbiological data with exposure assessment. Crook, in his publications discussing problems with biological risk assessment, also points to insufficient epidemiological data and the lack of clear exposure standards for many pathogens. On the other hand (Eduard et al., 2012), points out that measuring actual worker exposure (exposure) is a challenge when assessing biological risk, as exposure factors are often aerosol in nature and difficult to detect using traditional environmental monitoring methods. Moreover, measuring the presence of microorganisms does not always correlate with the risk of infection - exposure assessment models based on epidemiological and toxicological data are therefore needed (Schlosser et al., 2009).

As a result of the difficulties identified, the concept of Quantitative Microbial Risk Assessment (QMRA) is increasingly emerging in the literature. Rose et al. (2013) present QMRA as an approach involving four main steps: hazard identification, exposure assessment, dose-response assessment, and risk characterization. This structure allows for a more precise prediction of health effects resulting from exposure to a specific biological agent. For example, Carducci et al. (2016) used the QMRA method to assess the risk of adenovirus infection in water and wastewater management facilities. The analysis made it possible to estimate the probability of infection depending on the type of work performed and the personal protective equipment used. Similarly, Paccha et al. (2016) modeled the risk of zoonotic influenza infection among swine farm workers. Burzoni et al. (2020) in their publications proposed a model for a comprehensive approach to biological risk assessment that integrates hazard identification, exposure assessment, health effects analysis and implementation of control measures. These assumptions coincide with the guidelines of the Institute of Occupational Medicine in Lodz (Kozajda, Miśkiewicz, 2022) on occupational risk assessment of harmful biological agents consisting in replacing the method of occupational risk assessment presented in the Polish Standard PN-N-18002 (PKN 2011), which is commonly used by workplaces in Poland, with a descriptive method involving the collection of all relevant information about the work environment, identification of biological factors posing a risk at individual workplaces, identification of the highest risk group among the biological factors present or potentially present, and proposing on this basis the most effective set of risk-reducing preventive measures.

The discussion presented above shows that the assessment of biological risks in the work environment, as opposed to measurable factors, is a complex process, which is influenced not only by the biological conditions of the work environment, the individual personal sensitivity of employees, but also by the current legal requirements of the country and safety culture. Therefore, employers and occupational health and safety services concerned about the safety of their employees should focus not only on developing effective tools for risk assessment, but also on educating employees and the professional community about risks and health policies, because only in this way can biological factors present in the work environment be effectively countered.

3. Research methodology

Coal mines are working environments with a higher degree of risk, not only natural, physical, chemical or mechanical, but also biological. However, biological risks in modern mines compared to other obvious mining hazards as a side element of the main technological process associated with mining have been underestimated by employers and health and safety services. Meanwhile, as the examples of other industries presented in Chapter 2 of this paper show, it can be an important element affecting the health of workers and the operation of mining facilities. Thus, the assessment of biological risks in coal mines in Poland required a comprehensive approach that takes into account the specifics of underground work, a humid and warm environment, limited ventilation, contact with mine waters and also contact with a crew of several thousand people, who may be carriers of various disease phenomena.

The quantitative methods of assessing harmful factors used so far are based on the Polish Standard PN-N-18002:2011 (PKN 2011) in which risk (R) is defined as a function of the probability of occurrence of an event (P) and its potential effects (S) related to the value of exceeding the norm of a given harmful factor (formula 1):

$$R = f(P, S) \tag{1}$$

and the Risc Score method (Krause, 2011) in which the risk (R) is determined as the product of the probability of activation of the hazard (P), exposure to the hazard (E) and the probable effects of the hazard (S), expressed by formula (2) prove to be unsuitable in the case of biological agents that do not have hygienic norms and reproducible limit values. As a result, the health and safety services of the mine under investigation were not able to conduct a proper assessment of biological risks and identify all relevant biological agents at workplaces, which was emphasized in their post- inspection reports by the inspectors of the State Sanitary Inspectorate who inspected the mine.

$$R = P \times E \times S \tag{2}$$

Therefore, a qualitative (descriptive) method adapted to non-standard exposure conditions based on the guidelines of the Institute of Occupational Medicine in Lodz (Kozajda, Miśkiewicz, 2022) was used for practical assessment of biological risks in the preparatory works department of the coal mine under study, the course and result of which are presented below in the diagram shown as Figure 1.

3.1. Workplace characterization and identification of potential sources of pathogens

Characterization of the workplace consisted of conducting a site visit and collecting information from the mine's technical and health and safety services about:

1. The location of the selected mine division (explant or excavation site, mining level, type of mining deposit).
2. Environmental parameters:
   - humidity and air temperature (measured with hygrometers and Assman PM-8211 Psychrometer).
   - Air velocity and direction (anemometers) - influence on the spread of suspended particles.
   - Natural and technical hazards (especially machinery and equipment used ways to monitor hazards).

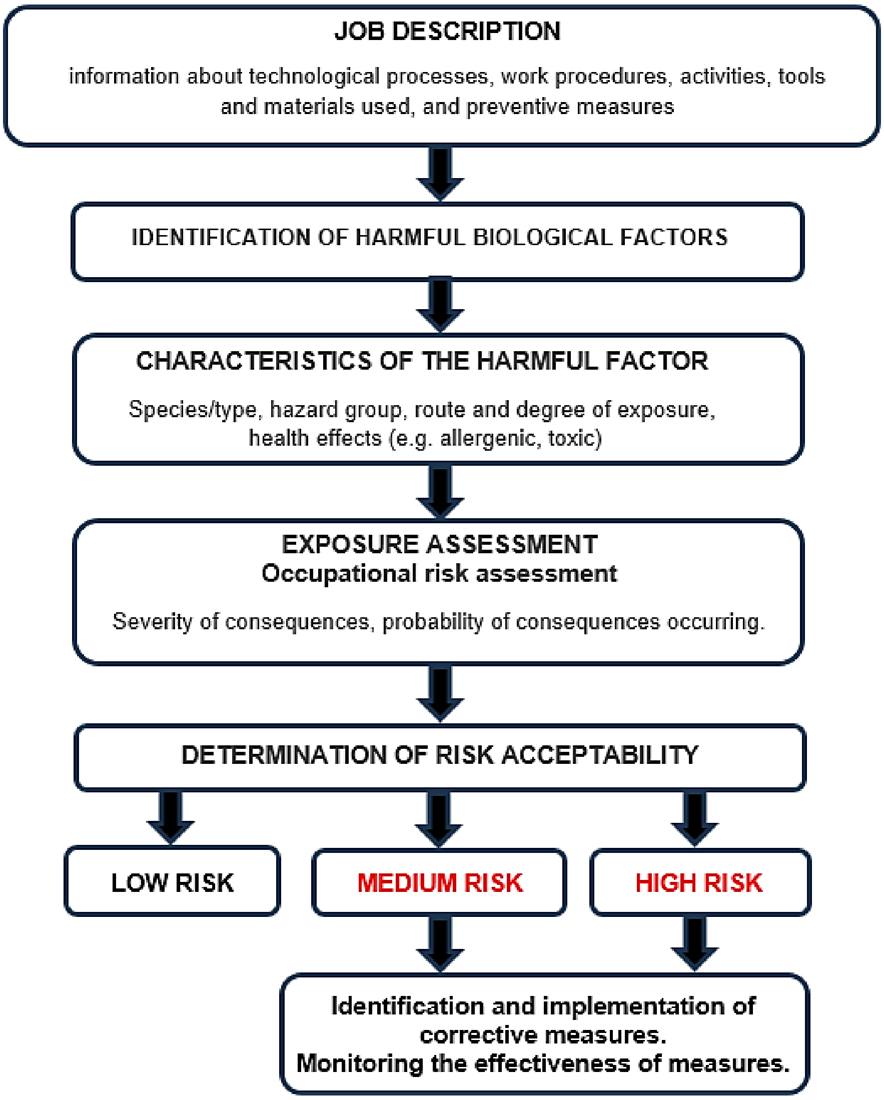

Figure 1. Stages of occupational risk assessment in exposure to harmful biological agents.

Source: own elaboration based on (CIOP, 2022).

Sources of biological agents ie:

- mine water: water samples were taken from various points, e.g. shafts, main drainage pumps, watercourses, pressure installation, fire pipelines);
- rock surface and structures: swab samples were taken, e.g., from the surface of the excavation and from the sides, pipes, conveyor belts, wooden elements of the casing, i.e., those places where fungi and bacteria can grow;
- air in the excavation: aerobiological measurements were taken using the impactor method to determine the concentration of bioareosols (e.g., fungal spores);
- free-living rodents in mine workings: live traps designed to capture mice and rats were set in selected locations of underground mine workings for laboratory analysis to assess the health of rodents and the threat from them as reservoirs of pathogens. Animals were caught in accordance with the principles of humane treatment and biosecurity rigor;

- social and hygienic spaces of the mine, i.e.: baths, locker rooms and storage areas for work clothes. Particular attention was paid to damp and soiled clothes, and the floor of the bathhouse, areas that could be potential habitats for fungi, bacteria and biological allergens.

The information obtained allowed a thorough understanding of the research facility and the identification of potential sites of existing biohazard in both underground mine workings and employee welfare rooms located on the surface, which had to be subjected to detailed microbiological analysis and evaluation

3.2. Sampling and preparation for laboratory analysis

All activities related to the collection of samples for laboratory testing and the testing itself were performed by the staff of an accredited laboratory cooperating with the coal mine under study in accordance with the applicable standards (PKN 2002, 2005, 2007) and so:

1. Water sampling:
   a) sterile bottles of volume usually 1 l, transport in a refrigerator (4 °C), delivery to the laboratory within 24 hours;
   b) in the laboratory:
      - Culture on liquid and solid media (e.g., TSA agar for aerobic bacteria, Sabouraud agar for fungi).
      - Aerobic-anaerobic testing (incubation under anaerobic conditions for detection of absolutely anaerobic bacteria).
2. Collection of sediment and swab samples:
   a) Sterile tubes, refrigerated transport.
   b) Serial dilutions from 10^{-1} to 10^{-6}, culture on various media:
      - McCartney agar (for Gram-positive and Gram-negative bacteria).
      - Specialized media (e.g., medium for Mycobacterium sp. if tuberculous pathogens are suspected).
3. Air sampling:
   a) Impactor (Andersen) with multi-hole discs, allows to classify the number of colonies according to particle size (e.g. 1-5 μm, >5 μm).
   b) After collecting filter or plate with medium: incubation at 25-30°C (fungi) or 35-37°C (bacteria) for 3-7 days.
4. Analysis of captured rodents:
   a) Live traps allowing live rodents to be transported to the laboratory within 24 hours.
   b) In the laboratory:
      - Initial assessment of the physical condition of rodents, collection of biological samples (blood, oral and anal swabs, as well as internal organs after euthanasia under laboratory conditions).

- Bacteriological culture (including identification of Leptospira, Salmonella, Yersinia, Escherichia coli).
- PCR methods (to detect genetic material of pathogens, including hantavirus and internal parasites).
- Serological methods (determination of the presence of antibodies against specific zoonotic pathogens).
- Parasitological analysis: stool and gastrointestinal tract sections were also tested for the presence of parasites (including nematodes, tapeworms, protozoa).

5. Social and hygienic spaces of the mine:
   a) Sterile tubes, refrigerated transport.
   b) In the laboratory:
      - Microbiological testing of material samples taken from soiled and damp protective clothing, showing the presence of fecal bacteria, staphylococci and molds that can cause skin infections and allergic reactions in workers.
      - The cultures were performed on selective and differential media for Gram-positive and Gram-negative bacteria, as well as mold and yeast-like fungi.
      - The concentration of the total number of microorganisms was also determined, including the most common genera: *Aspergillus, Penicillium, Cladosporium, Candida, Staphylococcus, Bacillus*.

The described procedure made it possible to ensure the reliability and representativeness of the samples collected for laboratory analysis. Thanks to the use of standard procedures and the work of qualified personnel from an accredited laboratory, it was possible to maintain sterile conditions for the collection and transport of samples of water, sediment, air, rodents and materials from social and hygienic spaces. Appropriate culture and incubation techniques, as well as the use of PCR, serological and parasitological methods, made it possible to effectively identify potential microbiological and parasitological hazards in the mine's working environment.

3.3. Laboratory analysis and species identification

An analysis of the available literature on biological hazards (Dutkiewicz et al. 2007a, 2007b, EU-OSHA 2017) and the results of laboratory tests of collected samples were used to identify biological agents in the preparatory works department of the coal mine under study:

1. Colony morphology:
   - Color, shape, consistency, growth rate, characteristic features (e.g., green coloration of *Aspergillus* colonies).

2. Microscopy:
   - Gram staining (bacteria) and hyperpigmentation (fungi).
   - Evaluation of the shape of cells, spores, filaments - allows preliminary classification into genus.
3. Biochemical tests (bacteria):
   - Catalase, oxidase tests, API (Analytical Profile Index) or automated systems (e.g., VITEK).
4. Molecular methods (optional):
   - PCR using universal primers for 16S rRNA (bacteria) or ITS (fungi).

The described procedure allowed for the effective identification of biological agents present in the preparatory works department of the mine under study and the combination of literature analysis and laboratory results, which enabled an accurate assessment of microbiological risks. Meanwhile, the use of comprehensive identification methods, including evaluation of colony morphology, microscopy (including differential staining), biochemical tests or molecular techniques such as PCR. It enabled to precisely determine the type and species of microorganisms, which formed the basis for further biological risk assessment

4. Study results and discussion

The subject of research related to exposure to biological agents within the framework of the presented article was a coal mine located in Upper Silesia in southern Poland in the city of Ruda Śląska, in which the region of the coal gangway No. 4 in deck 504 drilled with the AM - 50 shearer towards the future longwall No. 8 by 68 employees of the preparatory works division GRP-1 was selected for detailed environmental studies (Figure 2). The subject of research related to exposure to biological agents within the framework of the presented article was the region of the coal gangway No. 4 in deck 504 drilled with the AM - 50 shearer towards the future longwall No. 8 by 68 employees of the preparatory works division GRP-1 of the X mine located in Ruda Śląska (Figure 2). The excavation with a cross-sectional area of 17.5 m^2 was ventilated by braze ventilation allowing about 850 m^3 of airflow. Due to the difficult climatic conditions (air temperature exceeding 28.8^{o}C and humidity oscillating around 93.0%), tunnelling was carried out in 4 shifts of 6 hours each.

Figure 2. The region of the excavated coal gallery No. 4 in the coal mine under study in seam 504.
Source: own study.

4.1. Stage I - Characteristics of workplaces in the area of the preparatory works division GRP-1 in the studied coal mine

In underground mine workings, exposure to biological agents is not a direct result of employment in a specific job position, but is closely related to the type of activities performed and the characteristics of the work environment. Activities exposing miners to harmful effects of biological agents in the area of the coal gangway No. 4 were, for example:

1. Mechanical mining of coal puddles.
2. The extraction of the bottom by hand mining of loose rock material.
3. Operation of electric, hydraulic and diesel mining machinery and equipment.
4. Manual transport of materials to the face.
5. Installation of elements of sidewalk lining ŁP-10.
6. Execution of the opinion of the roadway excavation or its regeneration.
7. Drainage of mine workings.
8. Installation and extension of brazing ventilation with the progress of the excavation.

In performing these tasks, miners employed at the GRP-1 division were exposed to a number of biological hazards, resulting from the presence of various microorganisms in the working environment. Among them were microorganisms that naturally existed in the ground and crushed rock material, as well as pathogens present in the underground water, such as *Legionella pneumophila* bacilli - responsible for legionellosis - and *Leptospira spp. spirochetes*, which cause leptospirosis. The miners were also threatened by mold fungi, including species of the genera *Aspergillus*, *Penicillium* and *Cladosporium*, which, due to the humidity and high temperature in the pit, thrived intensively on moist surfaces and organic materials. The presence in the mine workings of wild rodents, mainly mice and rats, which may have been a reservoir and vector for many zoonotic diseases (zoonoses), including the aforementioned leptospirosis, as well as salmonellosis and hantaviruses, also appears to be of significance (Table 2).

4.2. Stage II - Identification of biohazards in the GRP -1 branch of the coal mine under study

Identification of biological hazards occurring in the area of hollow coal seam No. 4 of the coal mine under study was carried out in three steps:

- on the basis of an interview based on a created questionnaire - the so-called checklist (Table 3),
- a site visit combined with environmental and laboratory tests performed by an accredited laboratory cooperating with the coal mine under study,
- available literature (Dutkiewicz et al., 2007a, 2007b; EU-OSHA, 2017).

An interview conducted among the employees of the GRP-1 division excavating coal seam No. 4 showed that the miners are poorly aware of the biological factors present at their workplaces or accompanying technological processes. According to them, the employer has so far failed to inform them about this danger at safety training courses outside COVID-19. The miners themselves have become accustomed to hard work in underground conditions, ubiquitous dirt, moisture, dust, and the accompanying wild creatures (mice, rats) that often gorge on their food. Deprived of sanitary facilities in mine workings, they eat their meals on site often with unwashed hands.

On the other hand, they take care of their physiological needs in secluded places not too far from their workstations, dropping feces on coal spoil transported by conveyors. For the most part, miners are unable to break down biological agents, nor do they know what health effects they cause. For many years, the only ailments they were able to recognize in themselves were fungal infections of the feet and nails caused by biological agents, with which, despite the cleaning products and antifungal salves used, they persist. Some miners of the GRP-1 division also complain of skin lesions caused by having to work for several days in dirty clothes and not being able to change them daily.

There is a much greater awareness of biological hazards occurring at the mine, their possible sources and consequences among the employees of the occupational health and safety service, but, as they themselves admit, they did not pay more attention to them than required by the Labor Code and other legal regulations. This state of affairs changed after 2022 and the obligation imposed on the employer to assess risks in the case of biological hazards, so they carefully joined in the development of a procedure for their assessment.

Their joint efforts made it possible, based on laboratory tests and a literature review, to identify and classify biological hazards present at the coal mine under study (Table 4).

Table 2.
Stage I of the occupational risk assessment for harmful biological agents in the area of coal gangway No. 4 of the coal mine under study

<table>
<tr><th colspan="3">OCCUPATIONAL RISK ASSESSMENT</th></tr>
<tr><th colspan="3">Basic information</th></tr>
<tr><td colspan="3">Workplace (name and address):
Hard coal mine, Ruda Śląska, GRP-1 Division, Coal gangway No. 4 in deck 504</td></tr>
<tr><td colspan="3">Position/positions:
Foreman, shearer miner, robber miner, conveyor operator, miner at manual handling, diesel train operator, mine carpenter.</td></tr>
<tr><td colspan="3">Number of persons covered by the risk assessment: 68 including juveniles: 0</td></tr>
<tr><td rowspan="5">Employees covered by the risk assessment from groups particularly susceptible to harmful biological agents:
Enter an "x" next to the groups known to belong to at least one of the workers included in the list of persons covered by the occupational risk assessment.</td><td>1. juveniles (persons between 15 and 18 years of age) - vocational and secondary school students</td><td>-</td></tr>
<tr><td>2. pregnant or breastfeeding women</td><td>-</td></tr>
<tr><td>3. persons aged 65+</td><td>-</td></tr>
<tr><td>4. immunocompromised persons</td><td>X</td></tr>
<tr><td>5. Employees with suspected occupational disease</td><td>-</td></tr>
<tr><td colspan="3">Sources of harmful biological agents present in connection with the work process:
1. Earth, soil fragmented rock mineral formed in the process of excavation of the rock mass containing micro and macroorganisms.
2. Wood, wooden stakes, lumber - used to protect the ceiling and chestnut free spaces, subject to the process of decay and decomposition.
3. Water of natural origin from the rock mass, watercourses and reservoirs containing microorganisms.
4. Process water used in the mining process, technological process, fire-fighting and dewatering installations.
5. Water-oil medium used to power hydraulic cylinders and installations, the side effect of which is oil mist.
6. Mine dust containing crushed particles of rock minerals and organic matter.
7. Humans-Continuous contact with several hundred co-workers who may be carriers of various viruses and bacteria.
8. Rodents: mice, rats living wild in mine workings that can be carriers of biological agents.
9. Human excrement and excreta associated with the lack of sanitary protection in mine workings.
10. Difficult microclimatic conditions conducive to the growth of fungi and bacteria.
11. Soaked work clothes conducive to the development of bacterial flora.</td></tr>
<tr><td colspan="3">List of activities performed that expose the worker to harmful biological agents:
1. Mechanical mining of coal puddles.
2. Collection of the bottom, manual mining of loose rock material.
3. Operation of electric, hydraulic and diesel mining machinery and equipment.
4. Manual transport of materials to the face.
5. Installation of elements of sidewalk lining ŁP-10.
6. Execution of the opinion of the roadway excavation or its regeneration.
7. Drainage of mine workings.
8. Installation and extension of brazing ventilation with the progress of the excavation.</td></tr>
<tr><td rowspan="4">Routes of exposure:
enter an "x" next to the probable routes of infection</td><td>respiratory</td><td>x</td></tr>
<tr><td>oral</td><td>x</td></tr>
<tr><td>contact (skin, mucous membranes, eyes)</td><td>x</td></tr>
<tr><td>blood-borne</td><td>x</td></tr>
<tr><td>Genetically modified microorganisms (GMMs)</td><td>YES</td><td></td></tr>
<tr><td>(YES - present, NO - absent)</td><td>NO</td><td>x</td></tr>
<tr><td>Other relevant information:</td><td>Unintentional exposures to biological agents in the work process</td><td></td></tr>
</table>

Source: own compilation based on (Kozajda, Miśkiewicz, 2022).

Table 3.
Sample questions of the checklist conducted among the employees of the preparatory works division GRP 1 of the coal mine and health and safety services studied

Definition of work area			
Work area	Coal gangway No. 4 deck 504		
Number of employees	68		
Description of the performed activities	Tunnelling of the corridor excavation		
Exposure time	daily		
Information on harmful biological agents	**Yes**	**No**	**Comments**
Are there any factors from hazard group 2?	x		
Are there factors from hazard group 3 present?	x		
Are the factors present likely to enter the body by contact?	x		
Can the factors present penetrate the body through the oral route?	x		
Can the agents present penetrate the body by air?	x		
Do the biological agents present have an allergenic effect?	x		
Information about the course of work and professional activities performed			
What is the source of biological agents? - Is there contact with blood? - Is there contact with other organic material, human secretions? - Is there contact with diseased infected animals?	 x x	 x	
Is the quantity (volume), concentration of the biological agent known?		x	
How often is the work performed in exposure to harmful biological agents?	x		**268 days**
How long can exposure to harmful biological agents last?	x		**5 hrs.**
Is there a possibility of injury?	x		
Have biological agents ever been measured?		x	
Have there been any illnesses among employees related to activities involving exposure to biological agents?	x		**Mycoses cutaneous**
Classification of activities			
Are intentional activities related to the use of SCBs being performed?		x	
Are only unintentional activities related to SCB performed?	x		
Protective measures used			
Are backfills with antifungal agents used prophylactically?	x		
Do employees have the ability to separate work clothes from civilian clothes?	x		
Does the employer provide regular cleaning and replacement of work clothes?	x		
Is there an opportunity to wash hands at the workplace?		x	
Technical measures			
Are mine workings mechanically ventilated?	x		
Are the mine workings air-conditioned?		x	
Is water quality controlled for biological hazards?		x	
Organizational measures			
Is there a procedure in case of injury or accident?	x		
Are immunizations administered at the facility?		x	
Is a procedure defined for disinfection of mine workings, work tools?		x	
Is there a ban on eating in the mine workings?		x	
Preventive measures			
Are clothing, gloves, work and protective footwear used?	x		
Is respiratory protection provided?	x		

Source: own compilation based on (CIOP, 2022).

4.3. Stage III - Estimation of biological risks in the preparatory works division

The estimation of occupational risks associated with exposure to biological agents in the miner's work environment involves a comprehensive assessment of the health risks that may arise from short-term or chronic contact with these agents. The purpose of this process is to determine the likelihood of health effects and their potential severity, in the context of protecting the lives and health of workers. The basis for this assessment was the biological hazards identified in Stage II in the preparatory works division GRP- 1 of the coal mine under study and the applicable classification of biological agents belonging to one of the four hazard groups (ISAP, 2020). The second extremely important aspect in the risk estimation process was to determine the duration and frequency of exposure. This allowed the estimation of exposure doses and thus the determination of the probability of health effects, which was particularly important for epidemiological investigations aimed at confirming a cause-and-effect relationship between exposure and the development of an occupational disease.

In practice, the occupational risk estimates carried out (Table 4) for workers employed in the area of coal seam No. 4, in deck 504 of the coal mine under study, indicate a significant biological risk. The greatest risks for miners of the GRP-1 Division are:

- melioidosis bacilli (*Burkholderia pseudomallei*) and *Rickettsia typhi*, which are spread by rats living in the workings;
- mycotoxins, produced by mold fungi that develop on wooden stamps, as well as on miners' dirty work clothes.

All of these agents belong to the third group of biological hazards, which means that even short-term exposure can lead to serious diseases, such as:

- melioidosis (purulent inflammation of internal organs and lymph nodes),
- endemic typhoid (rat fever),
- mycotoxicosis, involving damage to the liver, lungs or kidneys.

Miners working in the area are exposed to the above factors for up to 268 days a year, which significantly increases the likelihood of occupational diseases and requires the implementation of appropriate preventive measures and monitoring of workers' health.

Table 4.
Stage II and III of the occupational risk assessment for harmful biological factors identified in the area of coal gangway No. 4 of the coal mine under study

OCCUPATIONAL RISK ASSESSMENT											
Identification of harmful biological agents / Risk estimation											
	Risk group		**Name of species/ genus.**	**Antibiotic resistance**			**Duration of exposure**		**Possible health effects**		
				Yes	**No**	**Highly likely**	**mber of days per month**	**Number of days per year**	**Allergic effects**	**Synthesis of sin x o t**	**Diseases or symptoms:**
Bacteria	**Threat group**	**2**	Clostridium perfringens		x		**23**	**268**		x	gas gangrene
			Clostridium tetani			x	**23**	**268**		x	tetanus
			Clostridium spp			x	**23**	**268**	x		Wound malignant edema, enteritis
			Fluoribacter bozemanae			x	**23**	**268**			pneumonia
			Legionella pneumophila			x	**23**	**268**			legionellosis
			Leptospira interrogans	x			**23**	**268**			leptospirosis, Weil's disease
			Mycobacterium kansasii			x	**23**	**268**			pulmonary mycobacteriosis
		3	Burkholderia pseudomallei	x			**7**	**84**			Melioidosis: acute lymphadenitis
			Rickettsia typhi		x		**7**	**84**			endemic rat typhoid fever
		3**	Mycobacterium tuberculosis			x	**7**	**84**			pulmonary tuberculosis
			Salmonella Typhi		x		**7**	**84**			typhoid
Viruses	**Threat group**	**2**	Hepatitis A virus, enterovirus type 72)		x		**23**	**268**			Hepatitis A, gastroenteritis
		3	Dobrava-Belgrade hantavirus			x	**13**	**156**			Hemorrhagic fever with renal syndrome (HFRS)
			Seoul hantavirus			x	**13**	**156**			Hemorrhagic fever with renal syndrome (HFRS)
		3**	Hepatitis B virus (HEPATITIS B, HBV)			x	**23**	**268**			Hepatitis B, a common form of chronic cirrhosis, liver cancer

Cont. table 4.

OCCUPATIONAL RISK ASSESSMENT											
Identification of harmful biological agents / Risk estimation											
	Group of hazard		Name of species/genus.	Antibiotic resistance			Duration of exposure		Possible health effects		
				Yes	No	Highly likely	Number of days per month	Number of days per year	Allergic effects	Synthesis of sin x o t	Diseases or symptoms:
Fungi	Threat group	2	Aspergillus flavus	*x*			*23*	*268*	x		Pulmonary mycosis; bronchial asthma carcinogenic effect.
			Candida albicans		*x*		*23*	*268*			Candidiasis of the skin, nails, oral cavity. AL. - endogenous allergic reactions.
			Candida tropicalis			x	*23*	*268*			Candidiasis of skin, nails, urinary tract infection.
			Epidermophyton floccosum			*x*	*23*	*268*	x		Dermatophytosis (dermatophytosis), allergies.
			Trichophyton rubrum			*x*	*23*	*268*			Dermatophytosis (dermatophytosis), allergies.
		3	Mycotoxins produced by many mold fungi			*x*	*23*		x		Mycotoxicosis poisoning of internal organs mainly liver, lungs, kidneys), carcinogenic effect.
Parasites	Threat group	2	Ancylostoma duodenale		*x*		*13*	*156*			Ankylostomatosis, diarrhea, larvae-induced pneumonia.
		3	Balamuthia mandrillaris		*x*		*13*	*156*			Pneumonia, encephalitis, dermatitis, keratitis.
			Necator americanus		*x*		*13*	*156*			Antilostomosis (tunnel disease), diarrhea pneumonia caused by larvae.
		3**	Strongyloides stercoralis		*x*		7	*120*			Echinococcus, for diarrhea pneumonia, and, less frequently, meningitis.

Source: own compilation based on (Kozajda, Miśkiewicz, 2022).

4.4. Stage IV - Corrective and preventive actions

The result of carrying out an occupational risk assessment of exposure to biological agents in the work environment should be the prioritization of actions aimed at reducing the risk, especially in positions where its level has been assessed as high or very high. The key here is to determine both the type of biological agent and the time, frequency and intensity of exposure.

In cases where exposure to biological agents is the result of their intended use (e.g., in laboratories or biotechnology production), the optimal solution is to replace the hazardous biological agent with a safer counterpart. However, in a working environment such as underground mining, where exposure is unintentional, resulting from the presence of, for example, microorganisms, rats, animal excrement or mold, the use of this method is impossible in practice. In this situation, according to the current regulations contained in the Ordinance of the Minister of Health of March 11, 2024 on harmful biological agents in the work environment and the protection of the health of workers occupationally exposed to these agents (ISAP 2020), the employer is obliged to take all possible measures to eliminate or reduce the exposure of workers to biological hazards. This includes:

- eliminating biological agents from the work environment, if possible,
- controlling technological processes and work organization to reduce contact with harmful agents,
- informing and training employees about biological hazards and proper conduct,
- conducting medical surveillance, especially in cases of infectious diseases or suspected occupational disease.

The biological risk assessment carried out for employees of the GRP-1 Branch working on the excavation of coal seam No. 4 in deck 504 revealed significant biological risks that had not previously been prioritized by the occupational health and safety services. Among the identified factors were:

- mold fungi (mainly Aspergillus and Penicillium),
- Burkholderia pseudomallei bacilli - the etiological agent of melioidosis,
- Rickettsia typhi - transmitted by rats, causing endemic typhoid fever.

Sources of these hazards include decaying organic materials (wood, garbage), moisture and high temperatures in pits, improper storage of work clothes and the presence of free-living rodents.

The assessment showed that:

- most workers had no knowledge of biological hazards or protective measures,
- there was no previous prophylaxis targeting biological agents,
- activities were limited to: provision of work clothes, basic personal hygiene, availability of antifungal soaps and drippings, and general deratization.

The analysis of occupational risk for biological hazards in the area of coal heading No. 4 (seam 504) showed that the existing activities of the occupational health and safety services-according to the guidelines of the Institute of Occupational Medicine in Łódź (Kozajda, Miśkiewicz, 2022) and the Central Institute for Labor Protection in Warsaw (CIOP 2022)-have proved insufficient both in the underground workings and in the surface facilities (baths, changing rooms). Not only were group 2 and 3 pathogens (bacteria, viruses, parasites, fungi) found there, but also cases of diseases such as skin mycosis, nail candidiasis and food poisoning.

Table 5.
Stage IV of the occupational risk assessment for harmful biological agents identified in the area of coal walkway No. 4 of the coal mine under study

OCCUPATIONAL RISK ASSESSMENT			
PREVENTIVE MEASURES			
Substitution of harmful biological agents		**Collective protection measures / Procedures**	
		Technical measures used:	**Procedures used:**
impossible	x	Portable sanitary cabins and toilets	Initial and periodic health and safety training
possible		Mechanical dust collectors	Washing and disinfection of work clothes
If possible, whether it has been done:		Local water sprinklers to reduce dust	Periodic preventive examinations of employees
NO	YES		
if substitution has been made, enter factors before and after substitution:		**Proposal for additional technical measures.**	**Proposal to implement additional procedures**
1.		Ozonators for sanitary rooms	Deratization of mine workings
Replaced:		Bactericidal UV lamps	Health education
2.		Biofilters and biological reactors in water systems	Application of biocides in water systems
Replaced:			Impregnation of wood, stamp lumber

Proposal for protective vaccination	**Personal protective measures:**		
Vaccination against hepatitis B.	Respiratory protection	x	Filter masks of FFP2, FFP3 class.
Vaccination against tetanus bacillus.	Skin protection	x	Cotton work clothes
Vaccination against leptospirosis.	Face and eye protection	x	Safety glasses and goggles
	Leg protection	x	Rubber footwear
	Hand protection	x	Leather gloves
	Cleaning products	x	Soaps, antifungal salves

Source: own compilation based on (Kozajda, Miśkiewicz, 2022).

To significantly reduce workers' exposure to biological agents, it is recommended that the existing package of protective measures (clothing, masks, basic disinfection) be supplemented with the following coordinated preventive measures (Table 5):

- Permanent deratization of mine workings and surface facilities, especially near social areas.
- Use of biocides in water systems and drainage systems - both underground and surface.
- Impregnation of wood used in mine workings (stamps, temporary casings, helmets) with anti-fungal and anti-bacterial preparations.
- Introducing disinfection of social rooms, using ozone or UV-C radiation, scheduled at least once a week.
- More frequent laundering and disinfection of work clothes - daily if possible, or after each shift, with agents to combat spores and mycotoxins.
- Introducing biological decomposition activators for organic waste, including fecal matter and sewage sludge in social facilities and underground water drainage systems.

In addition, due to the unintentional but persistent exposure of miners to group 2 and 3 biological agents, it is necessary to expand preventive medical care:

- inclusion of periodic examinations aimed at early detection of bacterial, viral and fungal infections,
- consideration of immunizations (e.g., hepatitis B, leptospirosis, rabies) based on local epidemiological risks,
- implementation of post-exposure prophylaxis, i.e. procedures for rapid access to medical care, including specialist consultations and implementation of antibioticprophylaxis or antiviral/fungal treatment in accordance with current guidelines.

Such a coordinated program of measures - combining technical, organizational and medical countermeasures - will make it possible to realistically reduce the risk of infections and occupational diseases among miners working in harsh mine conditions.

4.5. Stage V - Informing employees about occupational risks, reviewing and updating the risk assessment

The obligation imposed on the employer to inform employees about biological risks in the workplace is not only a legal requirement, but above all a necessity to protect the health of employees. In light of the Decree of the Minister of Health of December 11, 2020 and EU Directives: 2019/1833 and 2020/739, employers must systematically update the assessment of health risks associated with exposure to biological agents and take preventive measures to reduce existing risks. Such practice contributes to reducing occupational illnesses and building a proactive safety culture in the workplace.

As illustration of the practical implementation of the above requirements, reference can be made to the charter of stage V of the risk assessment for employees of the preparatory works division GRP-1 of the coal mine under study (Table 6), which includes:

- a list of persons familiarized with the results of the occupational risk assessment,
- registered cases of health problems among miners caused by biological factors.
- information on preventive measures taken to reduce the number of illnesses and ailments among the mining crew,
- information on the need to conduct an additional risk assessment, including after disinfecting the wooden casings and wooden lining of coal walkway No. 4.

Thanks to this, both the employer, occupational health and safety services and the employees themselves have the opportunity to control the effects of measures taken to reduce biological risks at workplaces.

Table 6.

Stage V of the occupational risk assessment for harmful biological factors identified in the area of coal gallery No. 4 of the studied coal mine

OCCUPATIONAL RISK ASSESSMENT

Informing exposed workers about the result of the occupational risk assessment:
List with signatures of persons informed of the result of the occupational risk assessment

Date	**Name of the person responsible for informing workers**	**Workers informed about the result of occupational risk assessment**	
yyyy-mm-dd	**Name**	**Name**	**Handwritten signature**
2024.01.02	Branch manager Piotr Muś	Jan Kowalski	**Kowalski**
2024.01.02.	Branch manager Piotr Muś	Adam Nowak	**Nowak**
2023.01.02.	Branch manager Piotr Muś	Karol Wisniewski	**Wisniewski**

Monitoring the effectiveness of preventive measures

Date yyyy-mm-dd	**Description of health problems reported by employees caused by biological agents**	**Number of reports**	**Corrective actions taken**
2024.02.20	Dermatophytosis	7	Disinfection of employee baths, increase frequency of washing work clothes
2024.03.08	Candidiasis of fingernails and foot skin	10	Referred for medical consultation

Accidents and other incidents/incidents involving biological agents

Date of event yyyy-mm-dd	**Description of the incident involving a biological agent**	**Number of injured persons: total**	**Was post-exposure treatment implemented?** **YES**	*If YES what kind?)*	**NO**
2024.04.10	Cut wound of the foot/ Clostridium tetanii	1	**x**	Wound disinfection, vaccination Against tetanus bacillus	

Verification of risk assessment

Date dd-mm-yyyy	**Name of person responsible for verification**	**Is there a need to make changes to the risk assessment?** **NO**	**YES**	**If YES, what changes should be made? As of when they will be implemented** *(enter date* dd-mm-yyyy*)*
2024.03.20	Jan Lis - health and safety inspector	**x**		Carry out deratization of the pit. Until 20.04.2024.
2024.08.11	Jan Lis - health and safety inspector		Yes	Carry out disinfection of the chestnut and wooden opinion in the coal walkway No. 4 by 10.09.2024

Source: own compilation based on (Kozajda, Miśkiewicz, 2022).

5. Conclusions

As shown in the study (stages I to V), the environment of coal mines, characterized by high humidity, elevated temperatures, the presence of organic substances and limited ventilation which creates favorable conditions for the development of microorganisms - bacteria, fungi, viruses and their metabolites (Table 4). As a result, mining workers are exposed not only to physical and chemical hazards, but also to serious biological hazards that can lead to the development of occupational diseases, primarily from the respiratory system and skin

(Cheluszka et al., 2023; Rdzanek et al., 2015), so measures should be taken immediately in mines, not only coal mines, to identify, assess and reduce biological risks.

Unfortunately, despite the growing interest in this problem in research conducted around the world, identification of biological risk factors in mines and accurate assessment of occupational exposure remains a challenge due to the complexity of exposures, lack of legal standards and limited availability of modern detection methods.

The main problem in identifying biological risks in the mine environment is the multicomponent nature of bioaerosols. Thousands of different microorganisms are detected in mine air: saprophytic and pathogenic bacteria, microscopic fungi (mold and yeast-like), actinomycetes, and sometimes viruses and mycotoxins (Wei et al., 2015; Xue et al., 2022). Due to the limitations of classical microbiological methods (culture on agar), a significant proportion of these organisms remain undetectable, leading to underestimation of risk (Montano, 2014).

Studies using molecular methods (PCR, 16S/18S rRNA sequencing, metagenomics) have shown that classical culture tests reveal only a fraction of the microbiome present in dust and mine aerosols (Wei et al., 2015; Cheluszka et al., 2023). High-throughput sequencing can detect potential opportunistic pathogens, such as *Klebsiella pneumoniae*, *Burkholderia cenocepacia*, *Acinetobacter spp.*, *Aspergillus flavus* and *Stachybotrys chartarum*, which can cause infections in immunocompromised individuals (Xue et al., 2022; Sharma, Sumbali, 2019). However, even these advanced methods do not provide a complete picture of exposure - they do not report on the viability of the organisms, infectious doses or toxicity of metabolites.

Another barrier to effective identification and management of biological risks in mines is the lack of uniform international standards for acceptable concentrations of bioaerosols and their components (NIOSH, 2017). In most countries, including Poland and China - where the most research has been conducted - there are no legally binding limits for the number of microbial cells per cubic meter of air in underground working environments (Cheluszka et al., 2023; Wei et al., 2015). Instead, general guidelines for confined environments or interpretation based on literature "warning values" are used.

The complexity of biological risk also stems from the difficulty of establishing a dose-response relationship. There are no precise data on what concentrations of *Aspergillus fumigatus* spores or lipopolysaccharide endotoxins will cause allergy, pneumonia or infection in the average miner (Montano, 2014; Rdzanek et al., 2015). As a result, researchers use the concept of "unit concentration", analyzing the composition of bioaerosol qualitatively and comparatively, without being able to fully assess the quantitative risk (Cheluszka et al., 2023).

Occupational risk assessment of exposure to biological agents in mines is most often based on a combination of qualitative and quantitative methods. Cultures of microorganisms from air and surface samples, identification of organisms by molecular methods, measurement of concentrations of endotoxins, β-glucans or mycotoxins, and environmental assessments (humidity, temperature, presence of organic materials) are used (Wei et al., 2015; Cheluszka et al., 2023).

Metagenomic approaches and QMRA (*Quantitative Microbial Risk Assessment*) models, which attempt to estimate health risks based on exposure data, pathogen characteristics and population susceptibility, are also increasingly being used (Sharma, Sumbali, 2019). However, the availability of such analyses is limited to countries with adequate laboratory and financial facilities.

On a practical level, occupational risk assessment faces numerous difficulties: lack of systematic microbiological monitoring, low awareness of biological risks among employers, health and safety services and workers, and insufficient personal protective equipment (e.g., ineffective dust masks, dust gloves) (Cheluszka et al., 2023). In many cases, there is also a lack of correlation between the microorganisms found and clinical symptoms in workers - epidemiological data are fragmented, and cases of infection are often not reported as occupational (Rdzanek et al., 2015). This state of affairs causes employers and occupational health and safety services to be reluctant to deal with biological hazards, which are a side element of the mainstream production of a mining plant or mine, despite changes in EU and national law.

The descriptive method of biological risk assessment presented in the article, the methodology for conducting the identification of biological hazards presented and implemented on a specific example - the preparatory works department of a coal mine, showed that the process of analyzing and estimating the health effects of exposure to biological agents does not have to be complicated. Having the right pattern of conduct based on empirical and literature data, the services of any workplace where biological hazards occur as a side element of the main manufacturing process should cope with the assessment of biological risks. In addition, the biological risk data collected in this way can be used for further scientific research and practical solutions aimed at:

1. Standardize methods for measuring bioareosols by introducing global protocols for sampling and microbiological analysis to enable data comparisons between countries and mines.
2. Develop occupational exposure standards and establish permissible levels of exposure to the most common microorganisms and metabolites in mine conditions.
3. Expanding the use of molecular and metagenomic methods to detect a wider spectrum of microorganisms and better identify opportunistic pathogens.
4. Conducting detailed epidemiological studies that include combining microbiological data with worker health information (e.g., spirometry results, allergic symptoms) to identify causal relationships.
5. Implementing more effective prevention based on solutions: technical (specialized air filtration systems, drying of clothes, monitoring of microclimatic conditions); organizational (integrated schedule of deratization and disinfection); individual

(ffp3 masks, antibacterial clothing and waterproof gloves) to educational (OSH training and employee education), which should significantly reduce biological risks in the work environment.
6. Protecting the health of workers by using biological risk assessment methods to ensure that working conditions comply with international standards and national regulations.

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