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MINING DUST AS A HEALTH THREAT TO EMPLOYEES OF EXTRACTION DEPARTMENTS OF COAL MINES

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Purpose: The presented article is empirical in nature and deals with the issue of human resource management in the mining work environment in the face of health risks for workers exposed to the harmful effects of coal mine dust at the workplace. Its purpose is to draw the attention of the management of coal mines in Poland to the growing problem of the increase in the incidence of pneumoconiosis among miners and the obligations that fall on the employer and management in connection with the need to fulfill the provisions of Article 207 of the Labour Code (Labour Code) and the changing European legislation (Directive of the European Parliament and of the Council (EU) 2017/2398 of December 12, 2017). The article presents the results of a health study of miners employed in the mining divisions of mine X exposed to the risk of harmful dusts and SiO_2 chemicals contained in mine dust. The impetus for the study in question was the increasing incidence of occupational diseases among workers in Polish coal mines in recent years, among which new cases of pneumoconiosis predominated. In 2022, pneumoconiosis of miners accounted for 92.1% of all diagnosable occupational diseases in the PKD's economic activity section B - mining and quarrying. The second factor prompting the research topic was the amendment of the regulation on chemicals, their mixtures, agents or technological processes with carcinogenic or mutagenic effects in the work environment introduced on January 24, 2020, including crystalline silica - the respirable fraction formed during work - among the agents with carcinogenic or mutagenic effects.
Design/methodology/approach: A study of the assessment of the prevailing dust hazard and the frequency of respiratory lesions among workers in the mining departments of mine X exposed to the harmful effects of mine dust as a by-product of the manufacturing process was carried out using the following methods: individual dosimetry, infrared spectrometry, directional interview, diagnostic tests and spirometry.
Findings: The results made it possible to identify the workplaces with the highest exposure to harmful effects of coal dust and to recognize the effects of this action in the form of respiratory lesions in 28.6% of the miners of mine X examined, who had not previously reported health complaints.
Research limitations/implications: Health examinations of coal mine workers are a sensitive issue and one that is reluctantly raised by mine management, union organizations and the workers themselves. The inadequacy of Polish legislation, which, in the event of the diagnosis of symptoms of an occupational disease, guarantees an employee to keep his or her previous salary as a result of transfer to another job for only 6 months (Article 230 of the Labor Code), causes employees to hide their health status until they are eligible for retirement and are reluctant to undergo earlier diagnostic examinations. The condition for making the data

available for the purposes of the above article was to guarantee the complete anonymity of the subjects and the workplace, which is in line with the policy of the Silesian University of Technology, which guarantees the anonymity of the data obtained in circular letters addressed to the Mining Companies.
Practical implications: Recognized new cases of pneumoconiosis incidence among surveyed employees of mining divisions indicated the necessity of changing the current approach of employers and managers to the issue of measuring harmful factors at workplaces and the necessity of expanding preventive examinations of miners to include capillary blood gasometry, peripheral blood morphology, low-dose high-resolution computed tomography allowing scrinig of lung cancer. The proper approach of mine management and health and safety services to miners' health issues should improve the financial condition of mining companies and mines by reducing the occupational morbidity of the protection of employees, who are the pillar of the company's efficiency.
Social implications: A review of the literature and the results obtained show that the problem of the incidence of pneumoconiosis among coal mine miners not only in Poland is again a growing social problem, resulting in an increase in occupational morbidity rates and incurred social costs related to the loss of physical ability to perform work by miners and the need for their treatment. On the other hand, the consequences of long-term exposure of workers to harmful factors leads to occupational diseases, the consequence of which is often a change of job and loss of part of the workers' wages, so it would be advisable to consider public consultations in this area in order to develop new legal regulations to increase worker protection.
Originality/value: The article is directed to the management of coal mines and health and safety services. It presents the results of environmental measurements and diagnostic tests of miners carried out in real time, to which access is difficult. In addition, the article presents solutions for early diagnosis of respiratory health disorders and better management of human resources and protection of miners' health as a superior value.

Keywords: mine, mining division, pneumoconiosis, mine dust, occupational disease, diagnostic testing, spirometry.

Category of the paper: Research paper.

1. Introduction

Pneumoconiosis is one of the most commonly diagnosed occupational diseases caused by harmful agents found in the workplace. In 2022, in terms of the frequency of newly diagnosed occupational diseases, pneumoconiosis ranked second, right after infectious and parasitic diseases, among which COVID-19 was by far the most prevalent, with 1,053 cases. According to data from the IMP in Lodz (Swiatkowska, Hanke, 2023), in 2022 the number of diagnosed occupational pneumoconiosis in Poland amounted to 466 cases (17.6% of total occupational pathologies), of which coal miners' pneumoconiosis accounted for 254 cases (54.5% in this group). For years, it has been among the most commonly diagnosed pneumoconiosis of occupational etiology next to asbestosis and silicosis. Due to the specific nature of employment in a particular industry and exposure to mine dust (stone and coal dust), coal workers' pneumoconiosis is more common in men (99.6% of cases) than in women (0.4%). By virtue of the number of people working in conditions of exposure to fibrosing dust, 19215 out of a total of 22802 (Akusztol et al., 2022), pneumoconiosis is the most commonly diagnosed occupational disease in the socio-economic sector that includes mining and quarrying (Section B), where 351 cases of pneumoconiosis were found in 2022. Equally determinant risks in the mining and quarrying sector are carcinogenic dusts containing the respirable fraction of crystalline silica SiO_2 that cause lung cancer. Of the 19834 people exposed to carcinogenic dusts in 2022, as many as 11 out of 47 such cases in the mining industry were diagnosed in Poland. And since the inclusion of crystalline silica as a carcinogen in 2022, there have already been 42 such cases. Analysis of cases of pneumoconiosis by age groups shows that the number of decisions issued declaring an occupational disease in the form of pneumoconiosis increases with the age of the worker. In the case of the PKD section of mining and quarrying, more than 92.3% of the established cases of pneumoconiosis are diagnosed in workers who are already retired, and most often in the advanced stage of this disease that bodes poorly for the health future of former miners.

What is worrying, therefore, is not only the continued increase in the number of cases of pneumoconiosis among miners, but the fact of late diagnosis of these conditions, especially since they are often chronic diseases that significantly affect health, and can take years to develop. Therefore, early detection of disease symptoms and prompt initiation of treatment have the greatest impact today on the course of the disease and its possible consequences. Too late recognition of the patient's ailment carries very serious and irreversible consequences not only for the miner himself, but also for his family and society as a whole. Therefore, such an important element in the fight against miner's pneumoconiosis, lung and bronchial cancers caused by exposure to mine dust (stone and coal dust) is that employers and managers take appropriate preventive measures to limit the occurrence of dust in the workplace and cover employees at risk of fibrosing dust with medical prophylaxis appropriate to the risk. This is particularly important, especially in mines and coal mining plants, where most technological processes are still based on the physical labor of miners.

Human resource management in coal mines should therefore view "people as a valuable source of the company's success and treat them as a fixed asset, which should be provided with the best and safe working conditions and opportunities for the full development of their abilities" (Koziol, Piechnik-Kurdziel, Kopeć, 2000). In turn, labor efficiency depends not only on the numerical state of the workforce, but at the same time on its qualitative state, i.e. on the characteristics of its composition, i.e. the structure of employment according to certain criteria, as a rule, interdependent, as well as aspects of work safety and health of employees, who are the pillars of the company's efficiency (Figure 1).

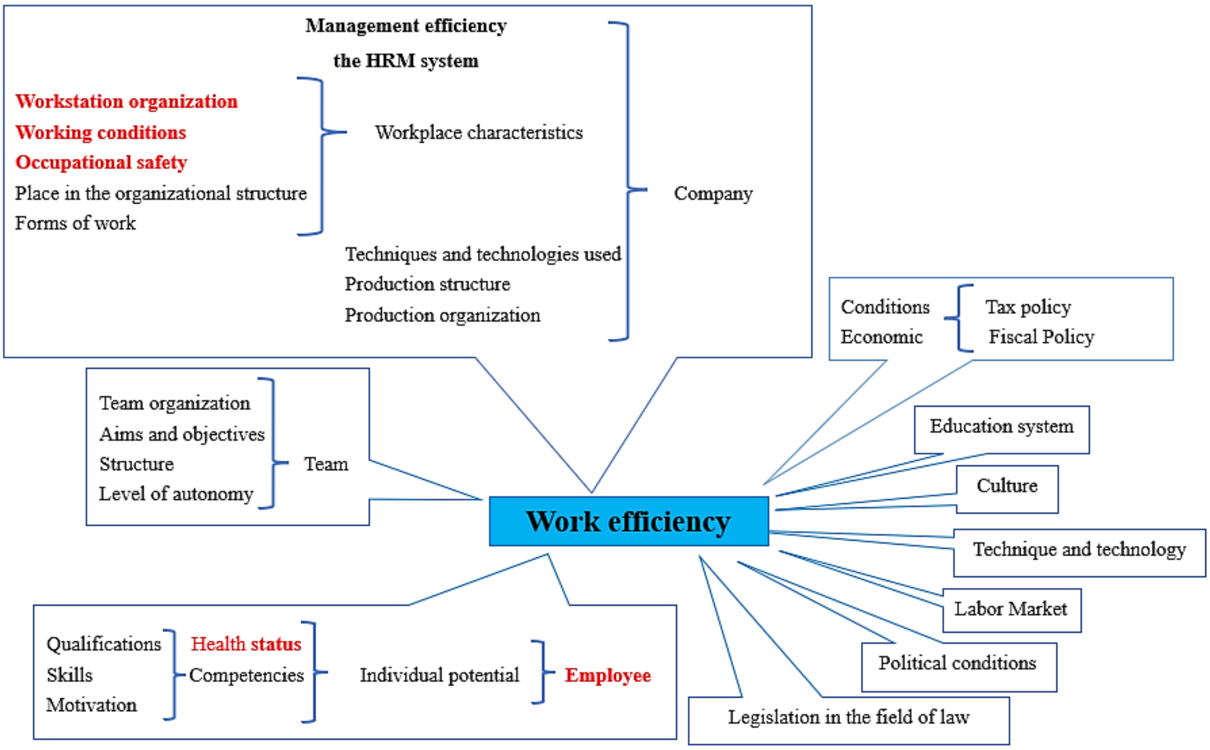

Figure 1: Determinants of labor efficiency.

Source: own compilation based on Mocek, 2021, pp. 118-135.

The purpose of the study, in the first place, was: to assess the actual state of the risk of fibrous and carcinogenic dusts in the mine workings of the mining divisions of the X mine located in Ruda Śląska in light of the amended 2020 legal regulations regarding the counting of the respirable fraction of free crystalline silica to carcinogenic dusts, and to assess the actual state of health of active coal mine miners. In the second place, to remind employers of their obligations under the provisions of Chapter X of the Labor Code, which states, among other things, that the employer is obliged to:

a) be responsible for the state of health and safety at the workplace,
b) protect the health and lives of employees by ensuring safe and sanitary working conditions,
c) conduct tests and measurements of factors harmful to health in the work environment,
d) assess and document the occupational risks associated with the work and apply the necessary preventive measures to reduce the risk,
e) Inform employees about the occupational risks associated with their work and the principles of protection from hazards,
f) respond to the needs for ensuring occupational health and safety and adjust the measures taken to improve the existing level of protection of the health and life of workers, taking into account the changing conditions of work performance.

2. Literature review and hypothesis development

Despite the many international efforts and actions taken (López-Campos, Soler-Cataluña, Miravitlles, 2020; Blackley, Halldin, Laney, 2018; Blackley et al., 2016). to reduce coal mine workers' exposure to harmful dusts generated in the mining process (Blackley et al., 2016; Weissman, 2022; Liu, T., Liu, S.H., 2020) still tens of thousands of miners worldwide are exposed to their harmful effects (Laney, Weissman, 2014; Perret et al., 2017, Perret et al., 2020). The result of this exposure is pneumoconiosis, which is common among miners (Cohen et al., 2022; Barber, Fishwick, 2016), with acute-fibrosis and chronic-failure (Han et al., 2018; Antao et al., 2005; Almberg et al., 2018), which for years have been the subject of research and scientific publications by many researchers from Columbia (Rey et al., 2015), the Czech Republic (Tomášková et al., 2017), Poland (Brodny, Tutak, 2018), Asia (Perret et al., 2017), Australia (Zosky et al., 2016), the United States of America (Hall et al., 2019) and other industrialized countries of the world. In all of these countries, recent years have seen a renewed increase in the incidence of pneumoconiosis especially of the silicosis type manifested in its most severe form associated with rapid massive fibrosis of lung tissue. Studies in Asia and the United States indicate that the incidence among miners has more than doubled since the end of the 20th century (Shi et al., 2020; Suarthana et al., 2011). The main reason for the increase in morbidity among miners today is believed to be improvements in mining equipment and raw material processing technologies that have enabled the cost-effective recovery of thin coal seams. The mining of thin seams also entails the extraction of large amounts of surrounding rock layers excavated with the coal, which may contain crystalline silica. Studies conducted by various researchers show that in some mines the rock layers occupy more than 50% of the total volume of extraction carried out from thin seams which generates almost twice as much respirable dust compared to the coal seam itself (Cohen et al., 2016; Sarver, Keles, Afrouz, 2021; Johann-Essex et al., 2017; Trechera et al., 2022).

In order to reduce this danger, various technical solutions are being introduced in the mine workings of coal mines to reduce the amount of dust produced or to deprive it of its volatile properties. Among the most effective technical solutions are:

- Dust collection devices (Xu, Wang, 2021; Kuczera, Ptaszynski, 2019).
- Sprinkler systems mounted on the heads of mining machines (Balaga et al., 2016; Lutynski, 2020).
- Hydration of the rock mass (Chao et al., 2022; Liao et al.).
- Water curtains installed in mine workings (Balaga, 2019; Peng et al., 2022).
- Ventilation systems (Balaga et al., 2015; Ji et al., 2016).

Considering the above, it should be stated that taking care of the health and life of employees is one of the basic duties of the employer resulting directly from the Labor Code Act (ISAP, 2018) and other international (EUR-Lex, 2017; EUR-Lex, 1989) and industry regulations. This means that for the **respirable fraction of crystalline silica generated during coal mining,** all obligations related to carcinogens under the regulation (ISAP, 2020; ISAP, 2021 i.e.):

- Include silica in the register of work whose performance makes it necessary to be in contact with chemicals, their mixtures, agents or technological processes with carcinogenic or mutagenic effects.
- Include workers exposed to silica in the register of workers exposed to chemicals, their mixtures, agents or technological processes with carcinogenic or mutagenic effects.
- Conduct periodic training of employees taking into account the topics contained in paragraph §9 item. 2 of the Ordinance (ISAP,1997), as well as appropriate preventive examinations.
- Every year, by January 15, send information in this regard to the relevant state provincial sanitary inspector and the relevant district labor inspector.
- Regularly conduct occupational risk assessments of workers exposed to crystalline silica, the respirable fraction generated during work, and other fibrous dust.

3. Research Methodology

Volume Assessment of health risks for employees of selected mining divisions of Mine X due to long-term exposure to mine dust (coal-dust) was carried out by employees of the Department of Safety Engineering of the Silesian University of Technology in cooperation with employees of the Central Laboratory for Work Environment Research "Stanisław Bielaszka" in Jastrzebie Zdroj and physicians in the field of pulmonology. As part of the research conducted in accordance with the regulations in force in Poland (ISAP, 1997; ISAP, 2011; ISAP, 2018a), were carried out:

1. Measurement of dust concentrations of inhalable and respirable fractions at the workplace.
2. Measurement of chemical concentrations at workplaces.
3. Preventive diagnostic testing of the respiratory system of employees of selected mining divisions.

Workplace sampling was used to determine the concentration of inhalable and respirable fraction dust at the workplace based on:

- PN-Z-04008-7:2002 "Protection of clean air - Sampling - "Principles of air sampling in the working environment and interpretation of results".
- PN-G-04035:2002+Az1:2005 "Protection of air purity in underground mines. Measurement of air dust concentration and determination of free crystalline silica content in dust".

For sampling of harmful substances (dust), the method of individual dosimetry was used using individual pumps that allow sampling of air in the worker's breathing zone continuously for a period at least equal to 75% of the duration of the work shift.

Studies of the respirable and inhalable fraction of dust were based on standards:

- PN-91/Z-04030.06 "Determination of respirable dust at workplaces by the filter-weight method",
- PN-91/Z-04030.05 "Determination of total dust at workplaces by the filter-weight method".

The basis for determining the concentration of crystalline silica was infrared spectrometry (Maciejewska, 2012):

Prior to the survey, a site visit was made and information was collected on:

- The location and naming of the workstation.
- The type and course of technological processes.
- types of machinery and equipment and activities performed.
- harmful factors characteristic of the technological processes in question.
- the duration of exposure to harmful health factors (exposure time).

Apparatus

Individual aspirators of SKC's type 224-44MTX were used for air sampling at workstations, which are subject to checking each time before and after measurement with a rotameter of type ROS-06 with factory number 079902, which has a calibration certificate issued by OUM in Poznan accredited at PCA (No. AP 085) - Figure 2.

The doughnuts used for the measurements were dried to a constant mass in a desiccator, after which they were weighed on a RADWAG AS60/220.R2 balance with serial number 508222, which has a certificate of legalization and calibration issued by "TOPS" S.C. Mass Measurement Laboratory accredited by PCA (No. AP 093).

Each siphon was assigned appropriate holders (inhalable fraction) and cyclones (respirable fraction).

Figure 2. Type 224-44 MTX individual aspirators used in environmental studies.

Source: own study.

In order to determine the concentration of chemicals at workplaces, tests and measurements were carried out at workplaces based on: PN-Z-04008-7:2002 and PN-Z-04008-7: 2002r/Azl December 2004. "Principles of air sampling in the work environment and interpretation of results".

Based on the determined concentration values in the dust and/or chemical samples, the average concentration by weight was determined formula (1) and (2) and the exposure rates W_E were calculated for the entire work shift formula (3):

- for samples taken by individual dosimetry based on formula (1):

$$C_w = \frac{C_1 \cdot t_1 + C_2 \cdot t_2 + C_3 \cdot t_3 + \cdots + C_n \cdot t_n}{t_1 + t_2 + t_3 + \cdots + t_n} \quad (1)$$

where:

C_1, C_2, ..., Cn - concentrations obtained from the determination of individual samples [mg/m^3],

t_i - time of taking individual samples [min],

n - the number of samples.

- for samples taken by the stationary method based on formula (2) and (3):

$$\bar{X}_{gw} = \frac{\bar{X}_{g1} \cdot t_1 + \bar{X}_{g2} \cdot t_2 + \bar{X}_{g3} \cdot t_3 + \bar{X}_{gk} \cdot t_k}{t_1 + t_2 + t_3 + \cdots + t_k} \quad (2)$$

where:

X_{g1}, X_{g2} ..., X_{gk} - concentrations obtained from the determination of individual samples [mg/m^3],

t_{123}, ..., t_k - duration of individual measurement periods in minutes,

k - the number of measurement periods,

$$W_E = C_W \cdot \frac{T_e}{T_o}, \text{ or } W_E = \bar{X}_{gw} \cdot \frac{T_e}{T_o} \quad (3)$$

where:

C_W $X_{,gw}$ - weighted average concentration of a specific type of dust/chemical, expressed in [mg/m^3],

T_e - time of exposure during the working shift, expressed in minutes,

T_o - reference time for 8-hour working time, or 480 minutes,

W_E - exposure indicator,

Working conditions are considered safe if the calculated exposure index did not exceed the NDS for the substance, and the exposure index W_N is less than or equal to 1 formula (4).

$$W_N = \frac{W_E}{NDS} \leq 1 \quad (4)$$

where:

W_N - exposure-indicator,

W_E - exposure index for total or respirable dust or chemical substance, expressed in [mg/m^3],

NDS - the maximum permissible concentration for total or respirable dust or chemical substance, expressed in [mg/m^3].

For sampling of harmful substances (chemical agents), the method of individual dosimetry was used using individual pumps that allow sampling of air in the breathing zone of the worker continuously for a period at least equal to 75% of the duration of the work shift

Apparatus

SKC's type 224-44 MTX individual aspirators were used to collect air samples for testing the concentration of chemicals at workstations, which are subject to checking each time before and after measurement with a type ROS-06 rotameter with serial number 079901, which has a calibration certificate issued by OUM in Poznan accredited at PCA (no. AP 084).

The doughnuts used for the measurements were dried to a constant mass in a desiccator, after which they were weighed on an AS60/220.R2 balance from RAD W AG, factory number 508222, which has a certificate of legalization and calibration issued by "TOPS" S.C. Mass Measurement Laboratory accredited by PCA (No. AP 093).

Chemical analysis was performed on the following equipment:

- Crystalline silica: FT-IR Spectrum TWO spectrophotometer from Perkin Elmer Factory No. 97389 - calibration certificate for polystyrene film issued by the General Office of Measures - infrared absorption spectrophotometry method.

Preventive diagnostic examinations of employees of selected mining divisions of mine X were carried out based on the miner's interview, physical examination and spirometry.

4. Results and Discussion

The most important organizational structure of any deep coal mine is the Mining Branches, whose primary task is to exploit (mine) the accessed coal seam or deposit between two parallel galleries (Figure 3). The roadways transport the material necessary for the production process (subwall roadway) and collect the worked coal from the longwall (headwall roadway). The basic equipment of a longwall is a mechanized casing, which protects the crew from uncontrolled rock fall, a scraper conveyor, which transports the processed coal, and a longwall shearer, whose task is to mine the coal body. The length of longwalls ranges from 60 to 250 meters, and their runway from several hundred meters to several kilometers. The height of the coal face varies from 1.5 to 4.0 meters.

The processed and transported to the surface coal extracted from the coal face by mining divisions is the main raw material sold by coal mines.

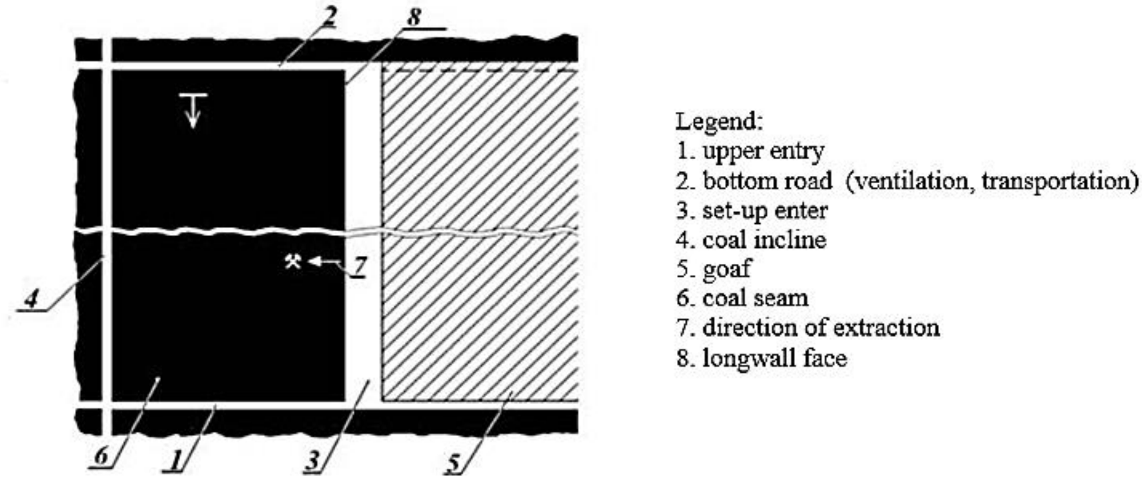

Figure 3. Overview diagram of the excavations around the coal face.

Source: own elaboration based on Honysz, 2011.

Figure 4. Dust in the coal face area of the G-1 mining division of X Mine.

Source: own study.

In the process of mining a coal seam by a longwall shearer, the greatest dusting of air occurs, which miners breathe for most of their working shift Fig. 3. Due to the limited spatial dimensions of the mine workings and the coal face itself, as well as the limited ventilation capacity and technological processes used, the mine air may contain other minerals including free crystalline silica in addition to crushed coal and stone particles.

As part of the study, air dust measurements were carried out in two mining divisions: G-1 - which conducts works in seam 405/1 with a thickness not exceeding 1.7m by a longwall system with shearer cavities, and G-2 - which conducts works in seam 507 with a thickness of 2.5 m by a longwall system without cavities.

The results of dust measurements at selected positions of the mining divisions of mine X are shown in Table 1, and the chemical substances in Table 2. The following numbers were assigned to the individual workstations: shearer - 1, shearer's helper - 2, sectional - 3, miner in transport - 4, conveyor operator - 5, miner in the shearer's bay - 6, blasting miner - 7, robber - 8.

Table 1.
Results of measurements of mine dust (coal-dust) air dust at individual workstations of mining divisions by the dosimetric method

Ward	Position	Dust concentration range, in the fraction [mg/m^3]		Indicator W_E [mg/m^3]		NDS		W indicator $_N$ (multiples of the NDS)	
		inhaled	respirabled	inhaled.	respirabled.	inhaled.	respirabled.	inhaled	resp.
G-1	1	0,60-37,54	0,38-18,52	35,62	16,32	10	2	3,6	8,2
	2	0,56-35,43	0,36-17,25	33,24	15,41	10	2	3,3	7,7
	3	0,55-33,12	0,30-15,48	30,42	13,25	10	2	3,0	6,6
	4	0,40-21,36	0,15-7,63	19,70	5,80	10	2	2,0	2,9
	5	0,46-26,70	0,28-15,33	24,44	13,46	10	2	2,4	6,7
	6	0,65-38,66	0,32-16,18	36,12	14,02	10	2	3,6	7,0
	7	0,62-36,92	0,40-18,26	34,50	16,73	10	2	3,5	8,4
	8	0,50-29,64	0,26-16,79	27,58	14,32	10	2	2,8	7,2
G-2	1	0,82-42,16	0,52-22,34	40,24	20,10	10	2	4,0	10,1
	2	0,78-41,36	0,50-21,73	39,75	19,34	10	2	4,0	9,7
	3	0,70-38,42	0,48-19,30	26,30	18,43	10	2	2,6	9,2
	4	0,65-34,50	0,42-17,40	32,48	16,28	10	2	3,2	8,1
	5	0,66-38,22	0,36-20,01	35,60	18,74	10	2	3,6	9,4
	8	0,63-36,28	0,36-19,49	33,19	17,32	10	2	3,3	8,7

Source: own study.

Circumstances of sampling during the 450-minute exposure included such activities performed by employees of mining divisions as:

- descent, exit by shaft to the mine, train ride to the longwall area, access and return from the workstation,
- preparatory work,
- operation of: shearer, conveyors, longwall equipment,
- combine mining, mining with explosives,
- mechanized housing control,

- drilling blasting holes and maintaining harvester cavities,
- transporting materials to the longwall, rebuilding longwall equipment behind the advance,
- robbing of roadway lining, reconstruction of intersections of roadway excavations with the coal wall,
- technology breaks.

Table 2.
The results of measurements of the chemical substance - crystalline silica at individual sites of mining divisions by the dosimetric method

Ward	Position	The concentration range of crystalline silica in the respirable fraction [mg/m³]	Indicator W_E [mg/m³]	NDS respirabled fraction	Indicator W_N (times of NDS)
G-1	1	0,032-0,411	0,402	0,1	4,0
	2	0,030-0,408	0,396	0,1	4,0
	3	0,032-0,356	0,332	0,1	3,3
	4	0,020-0,462	0,449	0,1	4,5
	5	0,028-0,374	0,353	0,1	3,5
	6	0,036-0,456	0,431	0,1	4,3
	7	0,036-0,440	0,432	0,1	4,3
	8	0,028-0,358	0,340	0,1	3,4
G-2	1	0,018-0,294	0,270	0,1	2,7
	2	0,018-0,280	0,262	0,1	2,6
	3	0,016-0,265	0,249	0,1	2,5
	4	0,012-0,214	0,196	0,1	2,0
	5	0,014-0,262	0,248	0,1	2,5
	8	0,017-0,202	0,186	0,1	1,9

Source: own study.

The study shows that all workplaces in the surveyed mining divisions are at risk of above-normal exposure to dust and harmful substances. The highest concentrations of dust are found at the position of the shearer and miners employed in the shearer's cavities, as well as at the position of the shearer's helper in non-cavity mining.

The decisive factor in the state of danger for working mining crews is undoubtedly the high fineness of the coal fraction and the presence of crystalline silica in the air inhaled by miners even in a longwall run in seam 507 where there is no trimming of the roof or bottom of the excavation, and there is little overgrowth of stone. As it turns out, the fresh air supplied to the coal faces already contains certain amounts of silica, which contribute to exceeding the currently applicable normative values for this chemical at the workplace. According to current regulations, the frequency of environmental measurements at the mine should therefore increase (Table 3). Following this, under Articles 101 and 222 of the Labor Code Act, the employer should take additional preventive measures to improve working conditions and monitor the health of those exposed to carcinogens.

To supplement the collected measurement results among 56 employees of the mining divisions (G-1, G-2) of the X mine, anonymous diagnostic tests of the respiratory system were also carried out to assess the prevalence of respiratory disorders among the surveyed miners.

Table 3.
Frequency of measurements depending on the concentrations of harmful factors found

Workplace number		Indicator W_N (times of NDS)	Research frequency
G-1	G-2		
Name of the harmful agent - coal (hard coal, lignite)			
		NDS < 0.1	*
		0.1 < W_N < 0.5 NDS	at least once every two years
1,2,3,4,5,6,7,8	1,2,3,4,5,8	IN_N > 0.5 NDS	at least once a year
Name of harmful substance - crystalline silica (quartz, cristobalite) - respirable fraction			
		0.1 < W_N < 0.5 NDS	At least once every 6 months (carcinogens or mutagens are present)
1,2,3,4,5,6,7,8	1,2,3,4,5,8	IN_N > 0.5 NDS	At least once every 3 months (carcinogens or mutagens are present)
*- in accordance with § 7. Ordinance of the Minister of Health dated 02.02.201 Ir. on tests and measurements of factors harmful to health in the work environment (Journal of Laws No. 33 of 201 Ir.), as amended.			

Source: own study.

The scope of diagnostic tests included:

a) Patient interview - the purpose of which was to learn about the employee's identification data; his personal characteristics such as age, height, weight; health complaints; past illnesses; family health burdens, lifestyle, addictions, working conditions. In this study, the CAT - COPD Assessment Test (Farnik et al., 2019) was used to assess the patient's current complaints, which identified the patient's presenting symptoms such as coughing, sputum retention, chest tightness, daily activities inside and outside the home, shortness of breath, anxiety and insecurity, sleep disturbances, and energy for activities (Table 4). The patient in the survey on a scale of 1-5 determined his attitude toward the ailment, where 1 meant no ailment and 5 meant great difficulty caused by the ailment.

b) A physical examination - whose purpose was to conduct a general assessment of the health and appearance of the worker under examination using the sensory organs of sight, hearing, touch. It included:
   - Viewing: the patient's skin and its discoloration; the shape and appearance of the chest in terms of its structure, the shape of the fingers of the hands.
   - Assessment of respiration: proportions of inhalations and exhalations, breathing tracks, chest mobility, number of breaths per minute, respiratory disorders.
   - Palpation examination: assessing the symmetry of respiratory movements of the chest, determining local rib soreness, evaluating vocal tremor and the presence of air in the subcutaneous tissue.
   - Chest auscultation: to determine the size and mobility of the lungs, identify pleural fluid or air in the pleural cavity or the airlessness of the lung parenchyma.

Table 4.
CAT test results of employees of X mine's mining divisions

Number of respondents	Age of respondents							
	≤ 20	21-25	26-30	31-35	36-40	41-45	46-50	> 50
respondents (smokers)	2 (0)	6 (2)	14 (5)	9 (6)	10 (5)	12 (6)	2 (2)	1 (0)
Occurring symptoms	number of subjects/(CAT score average)							
cough	-	1 (3,0)	4 (3,0)	2 (3,0)	5 (3,7)	5 (3,7)	1 (3,0)	-
lagging of sputum	2 (3,0)	2 (3,0)	10 (3,0)	6 (3,5)	9 (3,3)	10 (3,5)	2 (4,0)	1 (4,5)
chest tightness	-	-	-	-	2 (4,0)	4 (2,5)	1 (3,0)	-
shortness of breath and breathlessness	-	-	-	1 (3,0)	2 (3,5)	4 (3,5)	1 (4,0)	1 (3,5)
fatigue	-	-	2 (3,5)	4 (3,0)	4 (3,0)	8 (3,5)	1 (4,0)	1 (4,0)
fear and uncertainty	-	-	-	-	-	2 (3,5)	-	-
sleep disorders	-	-	-	-	1 (4,0)	2 (4,0)	-	-
lack of energy	-	-	1 (3,0)	-	6 (3,5)	3 (3,7)	1 (3,5)	-
CAT score	< 10	< 10	12,5	12,5	25	23,9	21,5	12,0
Interpretation of CAT scores: 1. 5 points - Upper limit of normal in healthy, non-smokers. 2. < 10 points - Little impact of illness on life. Most days good. Symptoms of fatigue 3. 10-20 points. - Medium impact of the disease on life. Appearing shortness of breath, cough, 1-2 exacerbations per year 4. 21-30 pts - Large impact on life. Illness prevents most activities. 5. > 30 points. Very high impact on life. Impaired performance of basic activities.								

Source: own study.

c) auscultation: enabling the detection of respiratory anomalies in the form of bronchial and pulmonary murmurs, crackles, wheezes and furls (Table 5).

Table 5.
CAT test results of employees of X mine's mining divisions

Recognized symptoms	Age and number of respondents							
	≤ 20	21-25	26-30	31-35	36-40	41-45	46-50	> 50
	2	6	14	9	10	12	2	1
	Number tested with symptoms							
skin lesions	-	-	-	-	-	-	-	-
chest deformity	-	-	-	-	-	2	-	-
clubbed fingers	-	-	-	-	1	4	-	-
shallowed breathing, breathlessness	-	-	4	-	2	4	1	1
extended exhalation	-	-	2	-	2	1	-	-
unilateral weakness of chest movements	-	-	-	-	2	3	1	-
reduction in the number of breaths	-	-	-	-	4	4	1	1
respiratory disorders	-	-	-	2	3	4	1	1
lowering of the lungs	-	-	-	-	1	2	-	-
muffled popping sound	-	-	-	-	2	2	-	-
drumming sound	-	-	-	-	-	1	-	-
voice tremor	-	-	-	-	1	2	-	1
bronchial or pulmonary murmurs	-	1	4	4	7	5	1	1
swish	-	-	1	1	3	4	1	-
furls	-	-	-	2	-	3	-	-
pleural friction	-	-	-	-	1	1	-	-

Source: own study.

- spirometry tests - whose purpose was to determine the lung capacity and volume of the studied workers and the airflow that occurs during the different phases of the respiratory cycle. The tests were performed with the Lungtest mobile spirometer from MES in accordance with the criteria for correctness and reproducibility of performing basic spirometry tests according to the recommendations of the ATS - American Thoracic Society (Boros, Mejza, Gomółka, 2020).

For the correctness of the tests, the instrument was calibrated before each measurement. Personal characteristics of the worker such as age, gender, height and weight were entered into the memory of the measuring device (spirometer). The test was performed in a sitting position with a nose clip in place. The test of taking air into the lungs and blowing air into the spirometer was repeated three times and was considered reliable if the results were similar. Airway obstruction was determined according to the recommendations of the GOLD report for COPD (López-Campos, Soler-Cataluña, Miravitlles, 2020) based on the finding of airflow limitation during expiration based on the obtained FEV1/FVC and FEV1 values (Table 6).

Table 6.
Degree of pulmonary impairment in spirometric study of workers in mining departments of X mine

Degree of obstruction	Eligibility criteria by FEV1	Age and number of respondents							
		≤ 20	21-25	26-30	31-35	36-40	41-45	46-50	> 50
		2	6	14	9	10	12	2	1
		Number tested with symptoms							
light	> 80%	-	1	1	1	1	1	-	-
moderate	50-80%	-	-	-	1	2	3	-	1
severe	30-50%	-	-	-	-	2	2	1	-
very difficult	< 30%	-	-	-	-	-	-	-	-

Source: own study.

A diagnostic study based on the interview and CAT Test showed that more than 11.7% of the miners of the X mine's mining divisions surveyed suffered from worrisome respiratory ailments, which worsened markedly after the age of 36 and after an average of 15 years of continuous exposure to dust. Increased symptoms were diagnosed in shearers, longwall cavity workers and longwall spoil haulage workers, despite the fact that 48.0% of workers with symptoms of respiratory disorders have never smoked cigarettes, and 96.3% are not exposed to industrial dust outside the mine. Minor discomfort manifested by lingering sputum and cough is experienced by the vast majority of respondents who try to get rid of contaminants entering the respiratory system on a daily basis during work. The result of the interview is also confirmed by the physical examination, especially auscultation, which in 32.1% of the subjects shows murmurs, wheezes and furls indicating narrowing of the airways lying inside or outside the chest and the presence of secretions in the airways. Interestingly, these conditions are observed not only in the elderly, but also in young workers between 20-30 years of age. Unfortunately, there may be cases of atelectasis, emphysema and decreased airflow of lung tissue among the workers surveyed, as can be evidenced by muffled and eardrum-like tapping noises (12.5% of those surveyed). The study also shows the possibility of neoplastic changes in 2.4% of the subjects as manifested by pleural friction and clubbed fingers, which may indicate neoplastic fibrous changes of the lung tissue. This observation was also confirmed by spirometry tests, which showed a severe degree of respiratory obstruction of less than 35% in 7.1% of the subjects (Figure 5).

In total, features of respiratory obstruction were diagnosed in 11 people, i.e. 19.4% of those surveyed, which is a significant result, especially in a situation where, among the 56 employees of the X mine's mining divisions surveyed, none of the workers were under the supervision of a pulmonologist. Miners are therefore unaware of the causes of their ailments and health conditions. Their preventive examinations for the diagnosis of respiratory diseases were overwhelmingly limited to chest X-rays every few years. All those who were diagnosed with features of respiratory obstruction as part of the research conducted by the Department of Safety Engineering at the X mine were referred for further diagnostic testing.

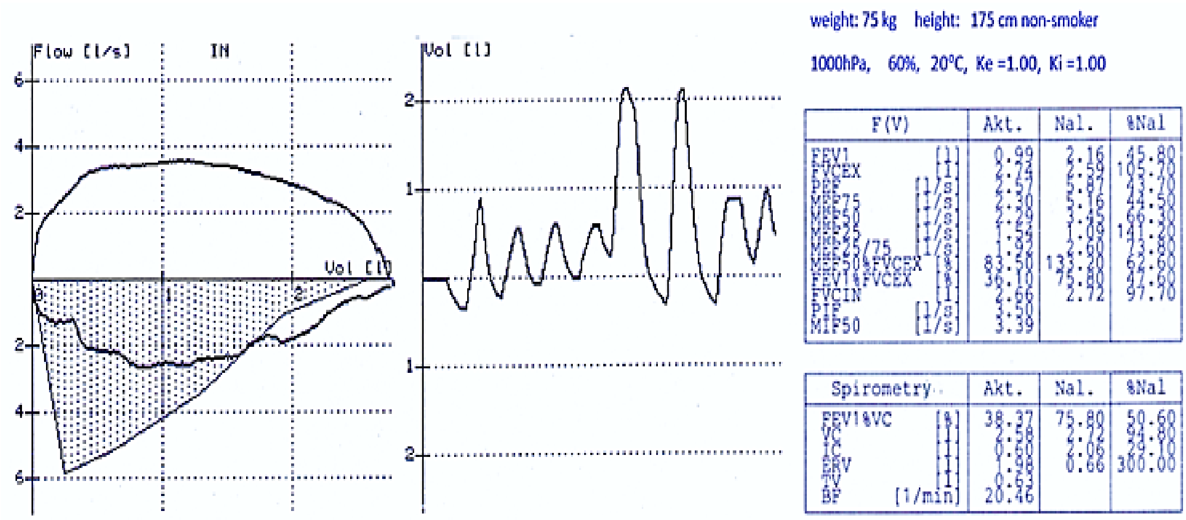

Figure 5. Spirometry results of the harvester of the G-1 division.

Source: own study.

The results of the study among employees of the mining divisions of the X mine are consistent with the presented results of the studies of the authors cited earlier, from the United States, China, Canada, and indicate similar reasons for the increase in the incidence of pneumoconiosis among miners of Polish coal mines. However, in Poland, in addition to exceeding several times the normative values of fibrosing dust in the air at individual workstations, the cause of the increase in occupational morbidity should be seen in the low awareness of miners about their health, fear of dismissal or the need to change jobs to less well-paid ones, and consequently delaying contact with a doctor.

5. Conclusions

The air measurements carried out in the mining divisions of the X mine show that mine dust (coal-dust) still poses a serious health risk to coal miners, especially in deep mines, so its constant monitoring should be a priority for every mine and mining plant. In succor of this recommendation is the amendment of the legislation of the European Union member states, which, following Directive of the European Parliament and of the Council (EU) 2017/2398 of December 12, 2017, mandates the inclusion of the respirable fraction of crystalline silica formed during work among carcinogenic substances. These measures have forced companies to increase the frequency of environmental measurements of mine dust and the recording of workers exposed to crystalline silica. However, this has not translated directly into increased occupational safety and lowered statistics on the occupational incidence of pneumoconiosis. As demonstrated by the staff of the Department of Safety Engineering at the Silesian University of Technology and *pulmonology* specialists, the study of working conditions and the health status of employees of the G-1 and G-2 mining divisions of the X mine, the measurement of dust concentrations in the air and the identification of its mineral composition alone will not contribute to reducing the morbidity of miners. Also, the use of even the best prophylactic measures to reduce dust in mine workings will not dramatically reduce morbidity statistics without covering miners with effective medical diagnostics to identify early symptoms of disease. Recognized lesions among miners of mining divisions are the result of many years of neglect of medical prophylaxis and proper cooperation between occupational physicians and the employer's occupational health and safety services, especially with regard to visits by medics to underground workplaces. The responsibility for this state of affairs, as the Labor Code's provisions show, rests with the employer, management and the employer's occupational health and safety services.

Therefore, along with increasing the frequency of measurements of air pollution in mining conditions, the occupational medical diagnostics of miners should also be expanded to include additional tests including spirometry, full-size chest X-ray, capillary blood gas test, peripheral blood count, or low-dose, high-resolution computed tomography allowing scrinig of lung cancer. It also seems expedient to increase the broadly defined safety culture and persuade employees to change their current habits and behaviors, as well as to shape them into desirable actions to protect their own health (White, 2012; Mocek, K., Mocek, P., 2023).

Only joint action in this regard by employers, doctors and the miners themselves can help reduce health risks and limit the drama of miners exposed for many years to above-normal exposure to mine (coal-dust) dust. However, if medics are not allowed into the process of hazard identification, risk assessment and environmental testing directly at workplaces, it is difficult to count on improvements in occupational safety.

The study further showed that: ensuring adequate working conditions is one of the elements that determine the effective use of human resources at a mine. This is best seen in the case of natural hazards, which, when well monitored, do not cause undue concern to coal mine miners. The identification of harmful factors at mines, the estimation of the risk of their impact on the human body, and ultimately the preventive measures taken to minimize them are not entirely effective. Errors and negligence in this regard by employers, services, OSH and management contribute to real financial losses for companies, increased morbidity statistics and new hidden illnesses among workers who should potentially be healthy.

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