https://doi.org/10.32056/KOMAG2023.2.2

Proper control of working conditions as a stimulator for reducing the incidence of pneumoconiosis in the coal mining industry

Received: 25.05.2023

Accepted: 13.07.2023

Published online: 31.07.2023

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Abstract:

Statistical data on occupational diseases recorded by the Institute of Occupational Medicine in Lodz, Poland, indicate a renewed increase in the number of cases of pneumoconiosis in Poland in recent years, especially in the PKD section of mining and quarrying industries. At the same time, in 2018 as a result of the implementation of directives of the European Parliament and the Council of the European Union, the changes were introduced to the Polish legislation in the area of protection of workers from the risk of exposure to carcinogenic or mutagenic agents related to the respirable fraction of crystalline silica found, among others, in mine dust. As a result of these solutions, since 2020 we have seen a spike in the number of miners employed in conditions of risk of carcinogenic dust. These facts indicate that despite the wide measurement of harmful factors in coal mines, the effectiveness of preventive measures taken does not bring tangible benefits, and OSH services have problems with the proper assessment of industrial dust hazards at workplaces. In the article, based on surveys, diagnostic (health) tests of workers and verification of the risk assessment methods used, the authors try to point out the most common mistakes made in estimating the level of risk associated with exposure to industrial dust.

Keywords: coal mine, hazards, mine dust, preparation departments, pneumoconiosis, preventive measures, surveys, occupational risk assessment

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1. Introduction

According to the Institute of Occupational Medicine in Łódź [1], industrial dust, including asbestos-containing dust and coal and lignite containing free silica, is mentioned most often (36.7% of cases of occupational diseases) as the reason of occupational diseases in Poland in 2021. In addition to various types of pneumoconiosis (N = 490 - 2020), industrial dusts have also been indicated as a factor contributing to the development of pleural diseases, asthma, allergic rhinitis and extrinsic allergic alveolitis.

Exposure to industrial dust is also the most common cause of malignant tumour recognized as an occupational disease. Among the 193 cancer cases diagnosed in 2018-2020, 164 (85.0%) were caused by asbestos dust, and 36 (18.7%) by dust containing free crystalline silica. These dusts are responsible for 106 confirmed cases of lung cancer and all cases of mesothelioma (67 cases). Although the overall number of occupational diseases in Poland has been decreasing in recent years, the incidence of pneumoconiosis is increasing. The leader in this respect is traditionally the Silesian Voivodship, where every year more than 50% of all diagnosed cases of pneumoconiosis in Poland are recorded. This regularity is related to the structure of the industry in the Silesian Voivodeship and the highest percentage of people employed in the mining industry in the Poland [2].

According to the Central Statistical Office [3], in the NACE – in section of mining and quarrying- in dusty conditions, in 2020 there were 38,823 employees (an increase of 39% compared to 2019), of which the largest number were employed in the hard coal mining section - 34,876 (89.8 %), i.e. more than every second case of a person exposed to dust in Poland. Hard coal mining industry has the highest rate of dust exposure per 1,000 employees in the plants covered by the research, which increased by 175.5% over the last 5 years from 263.6 in 2016 to 462.5 in 2020. Miners in hard coal mines are most often employed in conditions of exposure to fibrosing dusts 20,479 people - 70.2% exposed to fibrosing dusts in Poland and carcinogenic dusts 14,397 people - 69.4% exposed to carcinogenic dusts in Poland [4].

Considering the above facts, the constant increase in the number of cases of pneumoconiosis among miners of Polish mines and the fact that despite many actions taken by mining companies, the mines themselves and health and safety services, it should be worrying that we are still unable to effectively reduce this trend. To find out the reasons for this situation, the employees of the Department of Safety Engineering at the Silesian University of Technology, together with students of the Pomeranian Medical University in Szczecin and a specialist in the field of pulmonology, conducted a series of environmental, medical and surveys in one of the mines, trying to find the answer to the question: "How to limit unfavourable trends and reduce the incidence of for occupational diseases caused by industrial dust in the mining industry.

2. Materials and Methods – basis for the hazard assessment

The legal basis for recognizing and ascertaining occupational diseases in Poland is the Act of June 26, 1974 on the Labour Code and implementing regulations in this regard, which include, among others, Regulation of the Council of Ministers of 30 June 2009 on occupational diseases, as amended. Pursuant to Art. 235[1] of the Labour Code Act (Journal of Laws of 1974 No. 24 item 141), an occupational disease is considered to be a disease listed in the list of occupational diseases, if, as a result of the assessment of working conditions, it can be stated unquestionably or with high probability that it was caused by exposure to factors harmful to health in the working environment or in connection with the way work is performed, referred to as "occupational exposure". An integral part of the said regulation is the list of occupational diseases, in which pneumoconiosis was placed in item 3, including Item 3.2 pneumoconiosis of hard coal miners and the rules for documenting disease symptoms authorizing the diagnosis of an occupational disease. Another equally important regulation on exposure to industrial dust is the Regulation of the Minister of Health of February 2, 2011 on tests and measurements of factors harmful to health in the work environment, as amended, and the Regulation of the Minister of Health of January 24, 2020 amending the regulation in on chemical substances, their mixtures, factors or technological processes with a carcinogenic or mutagenic effect

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in the work environment [5,6]. Both cited regulations contain guidelines for the correct assessment of the harmfulness of dust to the human body. In the assessment of occupational exposure to dust, the concentration of dust contained in the air in a given work environment (quantitative analysis) and the assessment of the chemical composition of dust present in a given workplace (qualitative analysis) are taken into account. Qualitative analysis is of particular importance in testing the mixed dusts, such as mine dust, the chemical composition of which is uncertain.

Qualitative analysis of the collected sample is performed by X-ray diffraction or with the use of absorption spectrophotometry. Obtained measurement results and calculated exposure factors refer to arbitrarily determined maximum allowable concentrations (MAC) for identified hazard factors in occupational exposure conditions.

MAC is determined for the following dusts:

- total dust (applies to all types of dust),
- respirable dust (applies only to dusts containing less than 2% of crystalline silica, natural graphite, talc without asbestos fibres, Portland and metallurgical cement dusts, apatite and phosphorite dusts and amorphous silicas),
- respirable fibrous (applies only to dusts with a fibrous structure, e.g. asbestos, artificial mineral fibres, ceramic fibres).

Working conditions should be considered safe if the calculated exposure factor does not exceed the MAC value for a given dust, and dangerous when concentration exceeds them. These indicators are also the basis for the employer to fulfil another very important obligation contained in Article 226 of the Labour Code, according to which "the employer: assesses and documents the occupational risk related to the work performed and applies the necessary preventive measures to reduce the risk; informs employees about the occupational risk associated with the work performed, and about the rules of protection against hazards".

Risk assessment, also known as the process of analyzing and determining the acceptability of risk, consists of five basic stages:

- STAGE I - collecting information,
- STAGE II - identification of hazards,
- STAGE III - risk assessment and determination of its acceptability,
- STAGE IV - development of corrective and/or preventive measures,
- STAGE V - documenting the risk assessment.

Its proper procedure and the computational methods used may affect the accuracy of preventive measures taken by workplaces management and effectively counteract occupational morbidity, e.g. pneumoconiosis among hard coal miners, which the authors will try to prove in the presented publication.

3. Tests results and discussion

3.1. Characteristics of the tested object in the environmental tests

The subject of tests carried out as part of the cooperation of employees of the Department of Safety Engineering of the Silesian University of Technology, with employees from the Central Laboratory for Work Environment Research "Stanisław Bielaszka" from Jastrzębie Zdrój and representatives of the medical community of the Pomeranian Medical University in Szczecin were, among others, roadways of the GRP-2 preparatory work department of the X mine and its employees. During the measurements of air dust concentration at the workstations of the GRP-2 department, mining operations were related to the drilling of a coal-stone slope using the AM-75 roadheader (Fig. 1) between the 900 m and 850 m levels.

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Fig. 1. Face GRP-2 of X mine

Employees of the preparatory department were employed in a three-shift system according to the work schedule presented in Table 1, in six mine workings, to which the following letter designations were assigned: A – slope 3 (face); B – roadway 4, C – roadway 7, D – roadway 11 (working connected with transport of the run-of-mine from the face to the central main); E - slipway 12, F - loading ditch (transport working), and at six workstations: shearer operator - 1, shearer operator assistant - 2, miner - builder - 3, miner in transport - 4, conveyor operator - 5, miner in the face - 6, shot miner - 7, driller - 8.

Table 1. Work schedule of the GRP-2 department team

Activities	Duration [min]	Total duration of the shift
Going down and up	20	450 min
Transfer by passenger train	30	
Getting to and from the workplace	35	
Preparatory and transport work	60	
Mining with a shearer and operation of conveyors	200	
Construction of the frame of the roof support	105	

Results of measurements of airborne dust concentration at each working and at the workstations of the GRP 2 department of the X mine showed that the level of dust concentration and the content of carcinogenic crystal silica in many cases significantly exceed the new hygienic standards both in the mining face with a shearer and blasting work, as well as in transport workings (Table 2). The respirable dust is a greatest threat to employees, as its concentration exceeded the allowable value at each workstation by 3.7 to 5.1 times, and in the face and transport roadways by 4.6 to 6.0 times. In turn, in the case of free crystalline silica, hygienic standards are exceeded even 9.0 times (Table 3).

Table 2. The results of measurements of hard coal airborne dust concentration in each working and at the workstations of the GRP-2 department using the dosimetry method

Depart-ment	Position	Dust concentration in fractions [mg/m^3]		Indicator W_E [mg/m^3]		MAC		Indicator W_N (multiplicity of MAC)	
		inhalable	respirable	inh.	resp.	inh.	resp.	inh.	resp.
Workings									
GRP-2	A	0.94-39.40	0.43-12.36	38.32	11.95	10	2	3.8	6.0
	B	0.78-41.18	0.35-11.95	40.79	11.03	10	2	4.1	5.5
	C	0.58-42.60	0.28-10.50	41.55	9.70	10	2	4.2	4.9
	D	0.27-44.31	0.20-9.73	44.01	9.13	10	2	4.4	4.6
	E	0.46-32.64	0.26-7.20	31.95	6.75	10	2	3.2	3.4
	F	0.23-28.24	0.14-5.18	27.84	4.89	10	2	2.8	2.4

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Workstations									
GRP-2	1	0.51-35.10	0.26-9.11	33.82	10.20	10	2	3.4	5.1
	2	0.48-33.22	0.20-9.64	31.36	9.34	10	2	3.1	4.7
	3	0.28-26.46	0.11-7.30	24.29	7.28	10	2	2.4	3.6
	4	0.09-21.13	0.07-6.35	19.21	6.13	10	2	1.9	3.1
	5	0.23-31.77	0.15-8.38	31.20	8.96	10	2	3.1	4.5
	6	0.12-26.30	0.04-6.33	24.78	7.47	10	2	2.5	3.7

Table 3. Results of measurements of the chemical substance - crystalline silica in each working and at the stations of the GRP-2 department using the dosimetry method

Depart-ment	Position	Range of concentration of crystalline silica in the respirable fraction [mg/m^3]	Indicator W_E [mg/m^3]	MAC of the respirable fraction	Indicator W_N (multiplicity of MAC))
Workings					
GRP-2	A	0,066-0,945	0,912	0,1	9,1
	B	0,058-0,873	0,826	0,1	8,3
	C	0,056-0,764	0,703	0,1	7,0
	D	0,049-0,614	0,596	0,1	6,0
	E	0,028-0,582	0,527	0,1	5,3
	F	0,025-0,430	0,392	0,1	3,9
Workstations					
GRP-2	1	0,046-0,621	0,600	0,1	6,0
	2	0,038-0,610	0,592	0,1	5,9
	3	0,026-0,555	0,514	0,1	5,1
	4	0,009-0,214	0,196	0,1	2,0
	5	0,028-0,582	0,563	0,1	5,6
	6	0,025-0,430	0,403	0,1	4,0

Medical examinations among employees of the GRP-2 department exposed to mine dust showed a many functional and health disorders in 18% of active employees of the GRP-2 department [2,4], and in the last 5 years, five cases of pneumoconiosis recognized on the basis of decision about the occupational diseases.

3.2. Occupational risk assessment in a selected tested object

To estimate the occupational risk, various assessment methods are used in the world depending on the prevailing hazards and the workplace specificity. They can be divided into qualitative and quantitative methods.

Qualitative risk assessment methods are very often used for immeasurable factors for which no limit values have been set. The magnitude of the risk is a combination of the hazard itself and the severity of the hazard consequences.

Quantitative risk assessment methods are used for measurable factors for which limit values have been set. They consist in comparing the value of the quantity characterizing the exposure P with the limit value $P_{max.}$ These methods are used to calculate the concentration or intensity of harmful factors [7,8]

In Polish hard coal mines, the method of the Polish Standard PN-N-18002:2011 [9] is most often used to assess harmful factors, in which the risk (R) is defined as a function of the probability of an event (P) and its potential consequences (S) referred to the value of exceeding the limit of a given harmful factor (formula 1):

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

and the Risk Score method [10], in which the risk (R) is defined as the product of the probability of the hazard (P), exposure to the hazard (E) and the probable effects of the hazard (S), which can be written as formula 2:

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

The Silesian University of Technology in its research projects, proposed an assessment of the risk of harmful factors based on a number of mathematical indicators taking into account, in addition to the value of exceeding the hygienic standards, also the number of employees exposed and morbidity [11], so the health risk (R_{ZW}) was defined as the product of exposure probability indicators (W_P), exposure factor (W_E), number of persons exposed (W_L), and probability factor of loss resulting from exposure (W_S) according to formula 3.

$$R_{ZW} = W_p \times W_E \times W_L \times W_S \tag{3}$$

The assumptions of the above-mentioned methods were used in the research part to estimate the health risk for employees of the GRP-2 department of the X mine, based on the measurement data of airborne dust concentration given in Table 2, taking into account the nominal work time of the miners of this department according to the time schedule presented in Table 1. Going down to the mine and up the crew is practically not exposed to harmful dusts. During the arrival and departure from the workplace, preparatory and transport work and other elements of the production process, the measurement of the content of harmful dust was taken using individual dust meters of the CIP-10 and AP-2000Ex type. The measurements covered workstations in all workings in the GRP-2 department.

Health risk for the GRP-2 department was assessed at the workings level using all three risk assessment methods mentioned earlier. A full health risk assessment for each method is presented in Table 4 (PN-N-18002 method), Table 5 (Risk Score method) and Table 6 (Silesian University of Technology method.

The measurements confirm the theses of other researchers [12,13] that the determination of occupational (health) risk by the method of the Polish Standard PN-N-18002:2011, depending on the considered event, has a relative error ranging from a dozen to even 60%, because this method omits many important environmental parameters depending, among others, on the time of exposure and the competence of the team assessing a given hazard. On the other hand, in the Risk Score method, the most common method used by mines, the relative statistical error exceeds 15%. The Risk Score method takes into account exposure to risk, which significantly improves its credibility, but does not take into account the human factor and pathological changes. In the teams assessing the risk using the Risk Score method, there is also no occupational medicine specialist who could assess the potential impact of a harmful factor on the actual health condition of the employee. As a consequence, the inability to take into account in both methods even small uncertainties in the calculation of the original values of losses, the probability of events and the frequency of exposure results in a small differentiation of the assessed objects in terms of the existing threat (Table 7). An underestimation of the risk may result in unnecessary human losses such as an increase in the dynamics of pneumoconiosis, while an overestimation of the risk may result in material losses for mining plants due to too costly overestimation of the necessary preventive measures aimed at reducing the risk. The method of the Silesian University of Technology, although laborious and complicated due to the multitude of variable parameters, seems to be the most desirable in the assessment of health risk. Its relative statistical error due to the use of actual variables is also the smallest due to the elimination of the free assessment of facts by the members of the assessment team, which in turn affects the final result of the occupational risk assessment and the possibility of indicating the effective preventive measures.

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Table 4. Health risk assessment for workings of the GRP-2 department for mine X due to airborne dust using the PN-N-18002 method

	Name of the parameter	Workings of the department					
		Dip road 3 (face)	Roadway 4	Roadway 7	Roadway 11	Inclined drift 12	Loading ditch 850 m
	Symbol	A	B	C	D	E	F
1.	Average concentration of free crystalline silica SiO_2 [mg/m^3]	0.912	0.826	0.703	0.596	0.527	27.84
2.	Average total dust concentration in the working, C_{Wc} [mg/m^3]	38.32	40.79	41.55	44.01	31.95	30.09
3.	MAC for total dust [mg/m^3]	10	10.0	10.0	10.0	10.0	10.0
4.	Average concentration of respirable dust in the working, C_{Wc} [mg/m^3]	11.95	11.03	9.70	9.13	6.75	4.89
5.	MAC for respirable dust [mg/m3]	2.0	2.0	2.0	2.0	2.0	2.0
6.	Multiplicity indicator of exceeding the K_{MAC} normative	5.6	5.2	4.6	4.3	3.2	2.3
7.	Hazard probability	high	high	high	high	high	high
8.	Severity of the harmful consequences	high	high	high	high	high	high
9.	Health risk assessment	high	high	high	high	high	high
10.	Admissibility of health risk	unacceptable					

Table 5. Health risk assessment for workings of the GRP-2 department for mine X due to airborne dust using the Risk Score method

	Name of the parameter	Workings of the department					
		Dip road 3 (face)	Roadway 4	Roadway 7	Roadway 11	Inclined drift 12	Loading ditch 850 m
	Symbol	A	B	C	D	E	F
1.	Average concentration of free crystalline silica SiO_2 [mg/m^3]	0.912	0.826	0.703	0.596	0.527	27.84
2.	Average total dust concentration in the working, C_{Wc} [mg/m^3]	38.32	40.79	41.55	44.01	31.95	30.09
3.	MAC for total dust [mg/m^3]	10.0	10.0	10.0	10.0	10.0	10.0
4.	Average concentration of respirable dust in the working, C_{Wc} [mg/m^3]	11.95	11.03	9.70	9.13	6.75	4.89
5.	MAC for respirable dust [mg/m3]	2.0	2.0	2.0	2.0	2.0	2.0
6.	Multiplicity indicator of exceeding the K_{MAC} normative	5.6	5.2	4.6	4.3	3.2	2.3
7.	Hazard probability P	10	10	10	10	3	3
8.	Exposure to the hazard E	10	6	6	6	6	6
9.	Potential effects of the hazard - S	7	7	7	7	7	7
10.	Risk factor	700	420	420	420	126	126
11.	Category of risk	Very high				significant	
12.	Risk zone	Critical				dangerous	

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Table 6. Health risk assessment for workings of the GRP-2 department for mine X due to airborne dust

	Name of the parameter	Workings of the department					
		Dip road 3 (face)	Roadway 4	Roadway 7	Roadway 11	Inclined drift 12	Loading ditch 850 m
	Symbol	**A**	**B**	**C**	**D**	**E**	**F**
1.	Average concentration of free crystalline silica SiO_2 [mg/m^3]	0.912	0.826	0.703	0.596	0.527	27.84
2.	Average total dust concentration in the working, CWc [mg/m^3]	38.32	40.79	41.55	44.01	31.95	30.09
3.	MAC for total dust [mg/m^3]	10	10.0	10.0	10.0	10.0	10.0
4.	Average concentration of respirable dust in the working C_{Wr} [mg/m^3]	11.95	11.03	9.70	9.13	6.75	4.89
5.	TLV for respirable dust [mg/m^3]	2.0	2.0	2.0	2.0	2.0	2.0
6.	Daily exposure for one worker [hours]	7.5	7.5	7.5	7.5	7.5	7.5
7.	Multiplicity indicator of exceeding the K_{MAC} normative	5.6	5.2	4.6	4.3	3.2	2.3
8.	Hazard risk indicator P	**10**	**10**	**10**	**10**	**10**	**10**
9.	Average number of hours worked in exposure by a worker in a given working per one year L_{gw}	1738	1738	1738	1680	1680	1680
10.	Number of working hours in a year L_{gr}	1950	1950	1950	1950	1950	1950
11.	Indicator of the risk of absorption of a given harmful factor by an employee, E_C	5.0	4.6	4.1	3.7	2.8	2.0
12.	Hazard Exposure Risk Index, E	**10**	**10**	**10**	**10**	**10**	**10**
13.	The average number of employees exposed daily to the harmful factor L_{NW}	15	12	9	6	12	12
14.	Total number of employees of the department, L_{AZ}	66	66	66	66	66	66
15.	Risk indicator of exposure of a given number of people employed in the W_L excavation	0.23	0.18	0.14	0.09	0.18	0.18
16.	Risk indicator of the number of people at risk, W_L	**4**	**2**	**2**	**1**	**2**	**2**
17.	Number of cases of pneumoconiosis in the last 5 years	5	5	5	5	5	5
18.	Average number of diagnosed cases of pneumoconiosis among the department employees in the last 5 years, L_{CH}	1	1	1	1	1	1
19.	Average number of employees employed in the department in the last 5 years L_{ZAT}	63	63	63	63	63	63

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20.	Occupational morbidity rate of employees, W_Z	0.00137	0.00137	0.00137	0.00137	0.00137	0.00137
21.	Loss risk indicator due to the hazard, W_S	**10**	**6**	**3**	**3**	**0.5**	**0.5**
22.	Health risk index, W_{RZ}	4000	1200	600	300	100	100
23.	Risk category	Not acceptable	undesired	significant	acceptable	acceptable	acceptable
24.	Risk zone	critical	Specially dangerous	dangerous	almost safe	almost safe	almost safe

The tests enabled developing the final ranking of the workings of the GRP-2 department of the X mine in terms of the risk category and the sequence of preventive actions according each method of occupational risk assessment (Table 7).

Table 7. Ranking of the workings of the GRP-2 department regarding the risk of harmful exposure to coal dust

Method of Polish PN-N-18002 Standard							
Acceptance of risk in the working							
Unacceptable				**Acceptable**		**Acceptable**	
Dip road 3 (face)							
roadway 4							
roadway 7							
roadway 11							
Inclined drift 12							
Loading ditch 850m							
Risk Score Method							
Critical workings		**Specially dangerous workings**		**Dangerous workings**		**Almost safe workings**	
Risk factor	Workings name	Risk factor	Workings name	Risk factor	Workings name	Risk factor	Workings name
700	dip road 3			126	inclined drift 12		
420	roadway 4			126	loading ditch		
420	roadway 7						
420	roadway 11						
Method of Silesian University of Technology (Poland)							
Critical workings		**Specially dangerous workings**		**Dangerous workings**		**Almost safe workings**	
Risk factor	Workings name	Risk factor	Workings name	Risk factor	Workings name	Risk factor	Workings name
4000	dip road 3	1200	roadway 4	600	roadway 7	300	roadway 11
						300	inclined drift 12
						100	loading ditch

3.3. Questionnaire inquiry among GRP-2 department employees

68 employees of the GRP-2 preparatory department of the X mine took part in the inquiry. The vast majority of the respondents were still active employees of the mine - 92.1%.

In addition to answers to basic questions related to age, seniority, professional status, the respondents were also asked to indicate the department of the mine in which they worked for the longest time and to answer the following 25 more detailed questions:

a) exposure to industrial dust at work,

b) the type of sources of industrial dust that accompanies them at work,

c) changes that have recently taken place in the method of assessing the dust hazard at the workplace,

d) health effects that may appear in connection with long-term exposure to industrial dust,

e) preventive measures taken by the employer to reduce the dust hazard.

The answer to the above issues gave an image of an average employee of the GRP- 2 preparation department who:

1) Is in an average age of around 43 years old and has been working in a mine for 17 years, with an average of 16.5 in preparation departments.
2) Is aware of the health issues, which might be caused by long-term exposure to mine dust.
3) Is exposed to dust, whose main source is the process of excavating and hauling, for about 5 hours per day in their workplace.
4) Mining and rock dust influences their wellbeing and they feel its influence on the respiratory system.
5) Is informed by their employer of the dusting level at the workplace and is equipped with personal protective equipment (Graph No. 1).
6) Knows about collective dust protection methods, although associates them mostly with reducing dust's explosive properties, rather than its harmful effect.
7) Isn't aware of any additional obligations the employer has in view of the change in regulations, which count crystalline silica as a carcinogen.
8) Performs a chest X-ray once every few years, sometimes a spirometry test, during the periodic examinations, but is unlikely to have heard of any other diagnostic lung tests.
9) Shows interest in their actual health condition only when retired or when experiencing severe respiratory ailments (Graph No. 2).

Doesn't pay much attention to the occupational risk assessment, because usually doesn't understand the meaning of it.

4. Conclusions

Despite the international efforts and actions taken in order to reduce the exposure of coal mine workers to harmful dust from mining process, there are still tens of thousands of miners exposed to its harmful effects. One of the results of this exposure is pneumoconiosis, an illness commonly occurring amongst miners, which has been the subject of research and scientific publications for many researchers over the years. Apart from personal protective equipment provided for workers exposed to dust-forming processes, other technical solutions such as sprinklers or dust control systems installed on mining machines and in mine workings of hard coal mines are used in order to reduce the risk. Those installations are designed to reduce the amount of dust in the workplace.

The results of the questionnaires are presented below in the form of graphs 1 and 2.

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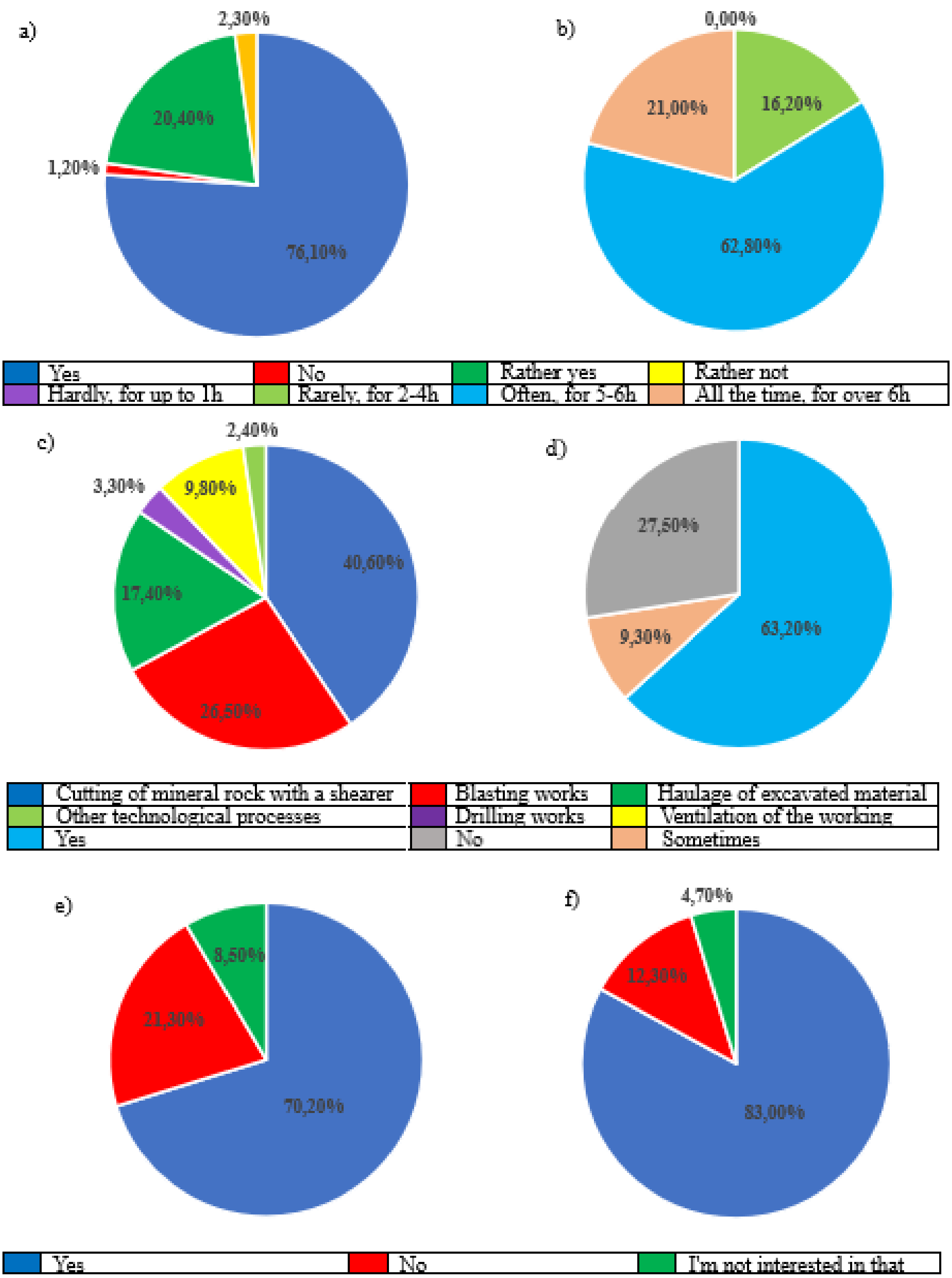

Graph No.1. Answers to the questionnaire questions: a) Is there a high level of dust in your workplace?, b) How often during the day are you exposed to dusty air at work?, c) What is the main source of dust at your workplace?, d) Does the dusty air at your workplace adversely affect your wellbeing?, e) Are you sufficiently informed about the dust levels at your workplace (you know the results of dust measurements)? f) Do you know how long-term exposure to coal dust and dust containing crystalline silica can influence your health?

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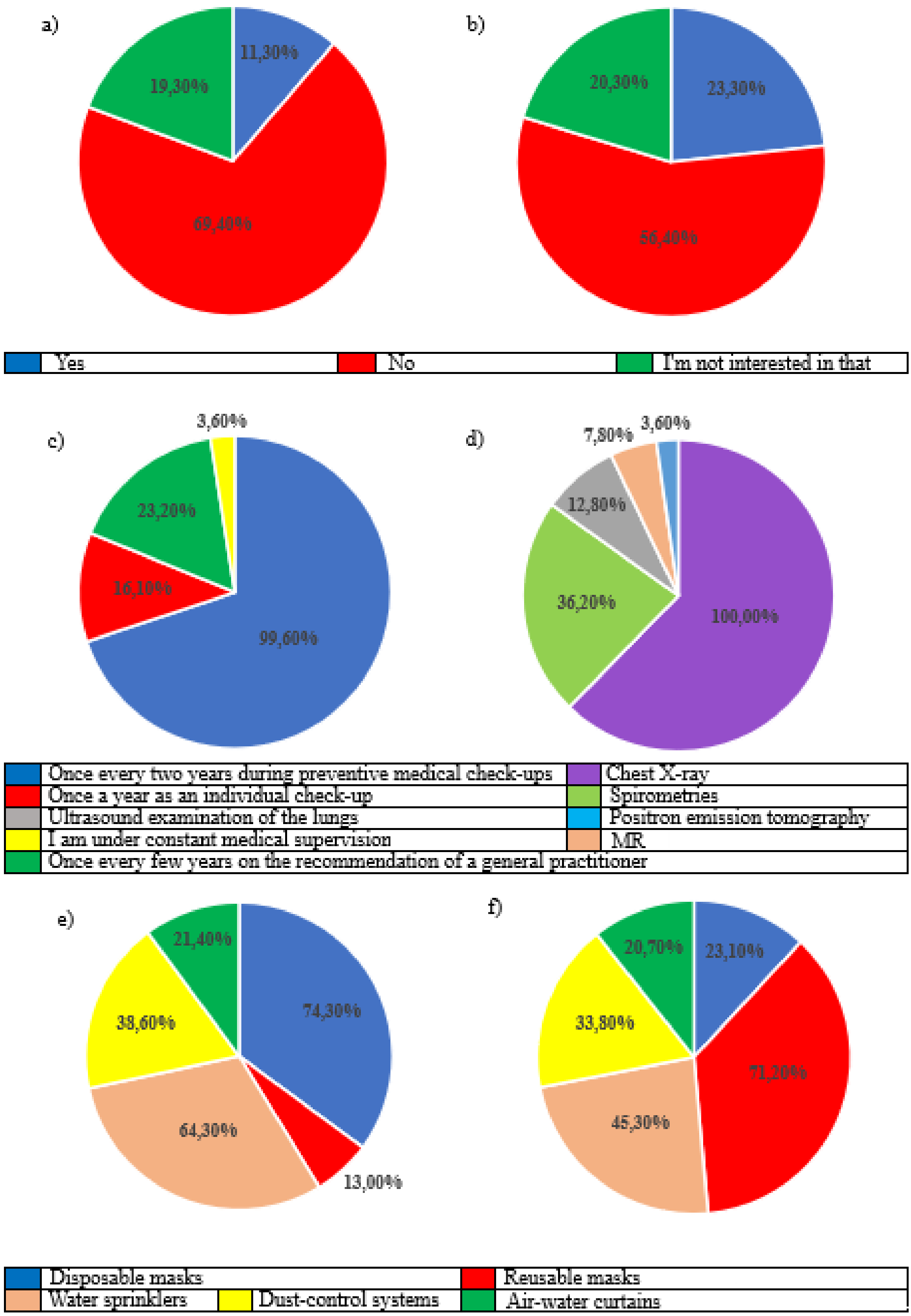

Graph No. 2. Answers to the questionnaire questions: a) Do you know the employer's obligations in relation to the change in the maximum concentration limits for dust and chemicals?, b) Is the crystalline silica contained in mine dust classed as a carcinogen?, c) How often do you perform

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respiratory health checks? d) What type of respiratory tests were performed on you? e) What type of dust protection equipment is most commonly used at your workplace? f) How would you rate the effectiveness of the dust control measures in place at your workplace?

As shown by environmental studies carried out by employees of the Department of Safety Engineering at the Silesian University of Technology and medical examinations of miners of the GRP-2 division of mine X, the individual and collective protection measures currently used in mining, despite advances in knowledge and new technical solutions, are not able to completely eliminate the risk of illness among workers. This problem is particularly apparent for dusts containing free crystalline silica, which is why most European countries have reduced the limit values for respirable silica to no more than 0.1 mg/m^3. These changes were introduced in Poland as a result of the Directive (EU) 2017/2398 of the European Parliament and of the Council of 12 December 2017, amending Directive 2004/37/EC on the protection of workers from the risks related to exposure to carcinogens or mutagens at work (OJ EU L 345, 27.12.2017) [29] and extending the record of the Regulation of the Minister of Health on chemicals, their mixtures, agents or technological processes with a carcinogenic or mutagenic effect in the working environment to include "work involving exposure to crystalline silica - respirable fraction generated at work." The clause introduced imposes additional obligations on employers and physicians providing preventive health care to employees working in conditions of exposure to harmful dusts, involving not only an increase in environmental measurements of air dust, but also an extension of preventive medical care.

A well-conducted occupational risk assessment is also an important element in combating existing health risks in the production process. The research presented in this publication has shown that the use of simplified expert occupational risk assessment methods that omit some of the important measurable parameters of the working environment can adversely affect the valuation of existing risks and be subject to significant statistical errors, resulting in underestimation or overestimation. Therefore, occupational health physicians should be included in the health risk assessment teams, who will be able to estimate the health effects and implement appropriate medical prevention, which should, in the long term, reduce the incidence of pneumoconiosis and other occupational diseases not only in the mining industry.

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