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ANALYSIS AND ASSESSMENT OF PARAMETERS SHAPING METHANE HAZARD IN LONGWALL AREAS

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Abstract

Increasing coal production concentration and mining in coal seams of high methane content contribute to its growing emission to longwall areas. In this paper, analysis of survey data concerning the assessment of parameters that influence the level of methane hazard in mining areas is presented. The survey was conducted with experts on ventilation and methane hazard in coal mines. The parameters which influence methane hazard in longwall areas were assigned specific weights (numerical values). The summary will show which of the assessed parameters have a strong, or weak, influence on methane hazard in longwall areas close to coal seams of high methane content.

Keywords

safety, mining industry, longwall, methane, assessment

1. INTRODUCTION

While reaching new depths in hard coal production, and, at the same time, limiting the scope of necessary rebuilding works (deepening shafts, constructing new mining levels), problems arise that concern the stability of ventilating mining areas, which, in the future, will more and more often require the undercut technique. With the increasing depth of mining, the initial temperature of rock mass increases too, contributing to lowering ventilation efficiency. Contemporary ventilation networks in coal mines are highly complex, which, with increasing concentration of production and methane content saturation, can lead to an increase in methane hazard.

A properly prepared ventilation network consists of pipes that deliver fresh air to the lowest levels of a coal mine, then ventilate headings, development workings and roadways take the used air along the inclination of the seams to the upper ventilation levels and to the upcast shaft. Networks that provide high stability of ventilation in mining areas are networks with normal air currents. The use of fans with low accumulation parameters in upcast shafts limits methane hazard caused by the lower migration of methane from gobs to active workings. Low accumulation of fans reduces the self-heating of coal in gobs and, in turn, the risk of an endogenic fire. A steady increase in the parameters and the efficiency of the accumulation of the main fans at the upcast shafts causes an increase in the migration of air with gob methane to active workings, and, in turn, the risk of endogenic fire. At present, ventilation headings in coal mines

are based on two types of networks: normal ones and diagonal ones. The diagonal orientation of mining areas, and their gobs, in a ventilation network of a coal mine can cause difficulties in air distribution, air delivery and the stability of ventilating them (Krause, Łukowicz 2012).

Airflow along headings and airflow migration from gobs is the result of the influence of certain values of aerodynamic potentials in the nodes of ventilation networks. In the case of longwalls that are surrounded by a relaxed seam, saturated with methane, the migration of methane, from degassing undermined and overmined seams into gobs, causes methane to migrate from gobs into mining areas.

The choice of ventilation method matters too, it also influences methane hazard in a longwall. Intensive migration of air through gobs, occurring due to certain methods of ventilating longwalls limits the possibilities of demethanating them effectively. This leads to an increase in methane hazard migrating from gobs into headings. Limiting the effectiveness of demethanation may lead to reducing the advance of the longwall, and, in turn, coal production. In light of the findings, the rules for designing the exploitation of methane seams should take into consideration the weight of the parameters and factors that affect methane hazard.

The following paper presents an analysis and an assessment of the parameters which influence methane hazard in mining areas. The research was based on a survey conducted among experts (with practical experience) dealing with the problems of ventilating and fighting methane hazard in coal mines.

2. FACTORS INFLUENCING METHANE HAZARD IN LONGWALL AREAS

Coal production in seams of increasing methane content saturation and increasing concentration of production have contributed, in the last several years, to constant growth in methane emission in longwall areas. The growth is caused mainly by an increasing amount of methane migrating to gobs because of degasifying relaxed ‘undercut’ and ‘overcut’ seams. The factors influencing methane hazard in longwall areas have been the subject of numerous researches, analyses and studies conducted, among others, by specialists from the Central Mining Institute – Barbara Experimental Mine.

Several publications (Krause 2005, 2009; Krause, Wierzbinski 2009) addressed the issue of the source of methane hazard in exploited longwalls of Polish coal mines. Operational experiments and the results obtained during longwall advance in methane seams facilitated identifying elements that influence methane hazard. Identifying them led to preparing a set of parameters and factors that could enable conducting an analysis and assessment of methane hazard.

Table 1 shows a set of 11 parameters and factors influencing methane hazard in exploited longwalls of coal mines. The weight of influence of a particular parameter on the hazard, given by the respondents, was noted in column 3.

Table 1. Factors and parameters influencing methane hazard in the exploited longwalls (questionnaire)

No.	Parameter/Factor	Points 0–10
1	2	3
1	Absolute methane-bearing capacity in longwall environment, m ³ CH ₄ /min	
2	Absolute ventilation methane-bearing capacity of longwall environment, m ³ CH ₄ /min	
3	Absolute methane-bearing capacity of longwall gobs, m ³ CH ₄ /min	
4	Air delivery in longwall, m ³ /min	
5	Longwall ventilation network (U, Y, other)	
6	Exploitation system (longitudinal, transverse, diagonal)	
7	Cross-section of longwall entries along its length, m ²	
8	Cross-section of longwall entries at junctions, m ²	
9	Undercut mining of longwall	
10	Methane emission from roof and floor into longwall area	
11	Direct presence of sandstones in roof or floor of seams	

The absolute methane-bearing capacity of a longwall is a factor that characterises the amount of methane released in a mining area from the exploited seam as well as the undercut and/or overcut seams, degasifying in a longwall environment. The amount of methane released in the gobs of a longwall as a result of degasifying seams, i.e. absolute methane-bearing capacity of longwall gobs may influence the value of the efficiency of their demethanation and, in consequence, the value of the absolute ventilation methane-bearing capacity of a longwall environment. Values concerning the absolute ventilation methane-bearing capacity and the methane-bearing capacity of gobs are parameters that directly influence the methane balance in a mining area. Air delivery in the area, the applied method of ventilating a wall and the absolute ventilation methane-bearing capacity have an influence on the ventilation-methane balance and the content of methane in the air in headings in the mining area. The system of mining and the location of a longwall in the ventilation subnetwork are factors which influence the direction of gas migration, together with methane in gobs of a longwall and in the operating headings of a mining area. Undercut mining areas and cross-sections of longwall entries

in unfavourable conditions of developing values of aerodynamic potential may influence the migration of methane from the longwall gobs and neighbouring ones. The direct emission of methane from the floor or the roof into a longwall poses a combustion threat and, in consequence, the threat of explosion in the gobs of a longwall. The presence of cohesive rocks (e.g. sandstone prone to sparking and igniting methane when mined) is yet another additional factor which can influence methane hazard in a longwall.

A group of 42 experts dealing with the subject of ventilation and fighting methane hazard in coal mines were asked to fill in a questionnaire designed by the authors. They were to attribute the appropriate weight (ranging from 1 to 10) to each of the examined parameters. An expert could attribute one given weight to one parameter only. The weight of ‘0’ means the lowest influence, whilst the weight of ‘10’ shows the highest extent of influence on methane hazard in a longwall environment.

The respondents were mainly ventilation engineers, their deputies, and ventilation chief foremen whose scope of responsibilities involve fighting methane hazard. Specialists dealing with ventilating and methane hazard fighting in non-gassy mines and low-methane mines were not asked to fill in the questionnaire. Limiting the number of respondents only to the experts, with practical experience in ventilation and methane hazard fighting, increased the credibility of the survey. The results of the survey are collected in Table 2.

The results are collected in the form of a matrix **X** (42, 11), where the rows represent given respondents, and the columns contain numerical values ranging between 1 and 10, attributed to particular parameters and factors influencing methane hazard in a longwall environment.

Table 2. Weight attributed to the particular parameters shaping methane hazard by the 42 specialists

No.	Parameters										
	1	2	3	4	5	6	7	8	9	10	11
1	5	10	4	7	9	1	6	8	0	3	2
2	10	9	7	4	6	5	1	3	0	8	2
3	8	9	7	10	6	3	4	5	0	1	2
4	9	10	5	6	8	1	4	7	0	3	2
5	8	10	7	6	9	1	4	5	0	3	2
6	10	5	6	7	9	4	3	8	1	2	0
7	10	9	2	3	6	7	4	5	8	0	1
8	10	9	2	3	6	7	4	5	8	0	1
9	5	6	4	8	9	7	1	10	0	3	2
10	4	5	7	8	10	6	1	9	0	2	3
11	6	5	4	10	7	3	9	8	0	2	1
12	5	10	8	7	9	4	3	6	0	1	2
13	2	3	4	9	10	6	8	7	0	5	1
14	4	3	2	7	10	6	8	9	0	5	1
15	6	10	8	7	9	2	5	4	0	1	3
16	6	10	9	7	8	3	5	4	0	1	2
17	5	9	10	8	7	6	4	3	1	2	0
18	6	9	10	8	7	5	3	4	2	1	0
19	7	6	5	10	4	0	9	8	2	1	3
20	7	6	5	10	4	0	9	8	2	1	3
21	4	10	5	8	9	3	7	6	0	2	1
22	10	9	8	5	4	3	7	6	0	1	2
23	10	9	8	6	2	1	3	7	0	5	4
24	10	8	9	7	4	3	5	6	0	2	1
25	9	10	4	7	8	0	5	6	1	3	2
26	10	9	4	8	7	1	6	5	0	3	2
27	5	6	4	9	10	2	8	7	0	3	1
28	7	8	6	10	9	3	4	5	0	2	1
29	7	10	9	5	8	3	6	4	0	2	1
30	9	10	4	6	8	1	5	7	0	3	2
31	8	10	4	7	9	2	5	6	0	3	1

32	8	9	10	7	6	3	4	5	1	2	0
33	0	10	7	8	4	2	6	9	5	3	1
34	0	10	9	4	8	7	5	6	1	2	3
35	2	1	5	9	7	6	8	10	0	3	4
36	8	10	7	9	6	3	4	5	2	1	0
37	8	10	7	9	6	5	4	3	1	2	0
38	9	10	6	8	7	2	4	5	1	3	0
39	10	9	7	8	6	3	1	4	2	5	0
40	9	10	6	7	8	5	3	4	0	2	1
41	6	10	7	2	8	5	0	3	4	9	1
42	7	10	6	8	9	2	0	5	4	3	1
Total	289	351	258	302	306	142	195	250	46	109	62
Rank	4	1	5	3	2	8	7	6	11	9	10

In Table 2, the values of the weight attributed to the given parameters by the 42 respondents were summed up and the obtained results were ranked according to their influence on methane hazard. In the specialists' opinions, the biggest influences on shaping methane hazard, have the following parameters:

- absolute ventilation methane-bearing capacity of a longwall environment – 351 points,
- longwall ventilation network (U, Y, other) – 306 points,
- air delivery in longwall – 302 points.

The smallest influence on methane hazard are as follows:

- undercut mining of a longwall – 46 points,
- direct presence of sandstone in the floor or the roof of a longwall – 62 points.

For each of the 11 parameters the maximum available value was 420 points.

3. DATA STRUCTURE ANALYSIS

Arranging the results of a survey and collecting them in the form of a matrix X (42, 11) is the initial stage of a statistical analysis. The next step is recognising the structure of the data, i.e. the structure of a given group with reference to their collective attitude towards a particular parameters.

To evaluate the percentage share of the respondents who consider a particular parameter to be of great influence on methane hazard in longwalls, the 11 parameters were presented according to the weight they were given by

the experts. The presented distribution is an empirical one, i.e. it shows the structure of a given group with reference to their collective attitude towards a particular parameter.

Numerical values concerning the influence of particular parameters on methane hazard in a longwall environment are presented below (Fig. 1). An X-axis shows numerical values from 0 to 10, the Y-axis shows the number of respondents who gave the parameter the same weight.

Table 3 shows the values of stratum weights, i.e. the relative amount which informs what share of the group has the value of the variable, for which the weight was calculated:

$$p_i = \frac{n_i}{N} 100\%$$

where:

- p_i – stratum weight of group i
- N – size of the group
- n_i – sizes of distinguished groups

The total sizes of the distinguished groups equals the size of the examined group:

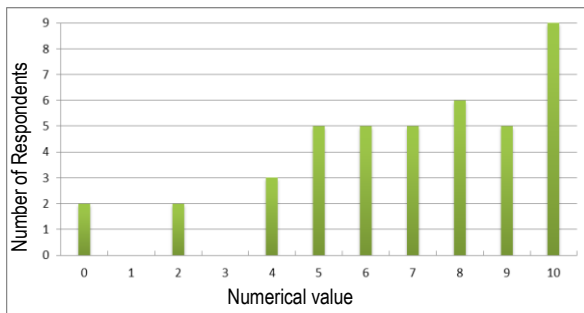
$$n_1 + n_2 + \dots + n_k = N$$

Moreover, stratum weights satisfy the equation:

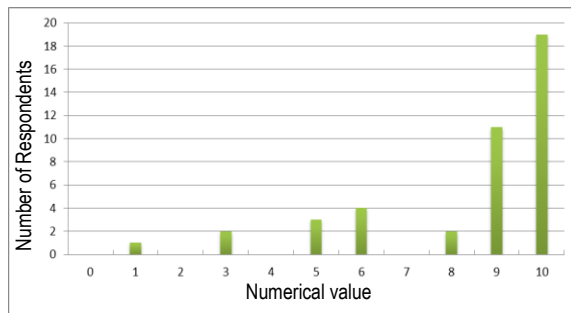
$$p_1 + p_2 + \dots + p_k = 100\%$$

Three ranges of numerical values regarding the weight of the parameters influencing methane hazard in longwalls were assumed:

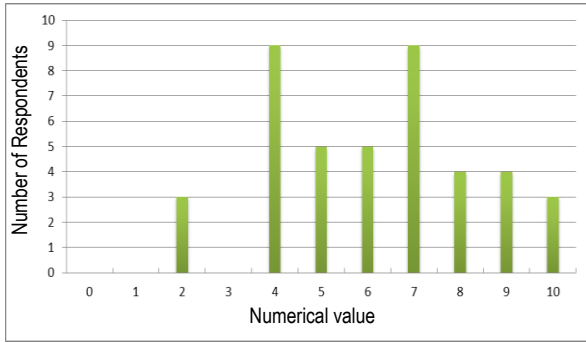
- 0–3 – weak influence on methane hazard
- 4–7 – moderate influence on methane hazard
- 8–10 – strong influence on methane hazard



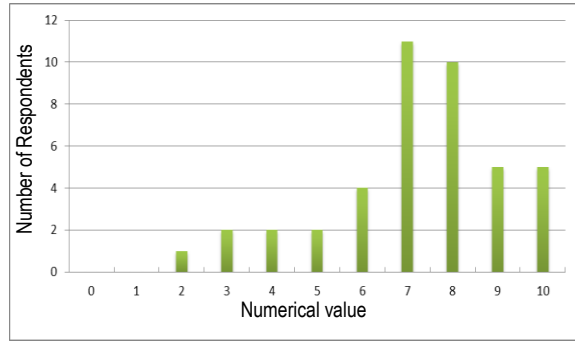
a) Numerical values representing the influence of absolute methane-bearing capacity in a longwall environment by the number of respondents giving the parameter the same weight



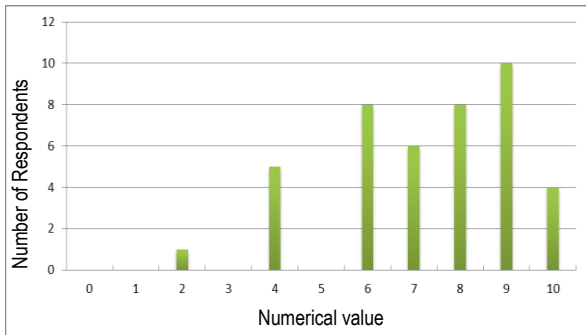
b) Numerical values representing the influence of absolute ventilation methane-bearing capacity of a longwall environment by the number of respondents giving the parameter the same weight



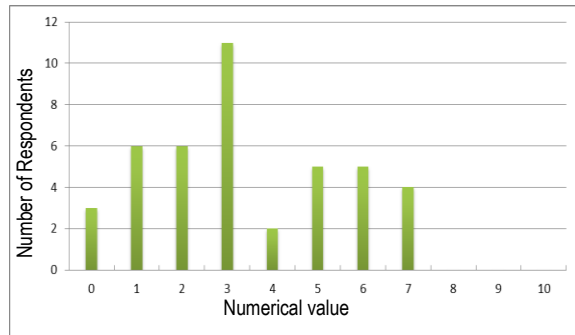
c) Numerical values representing the influence of absolute methane-bearing capacity of longwall gobs by the number of respondents giving the parameter the same weight



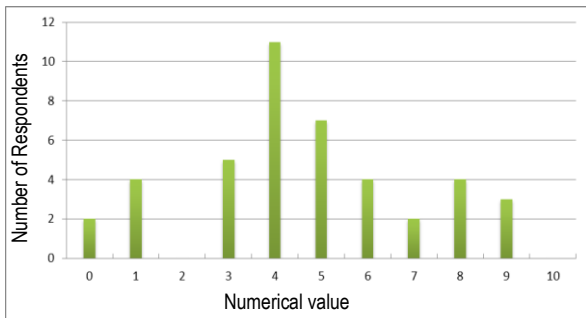
d) Numerical values representing the influence of air delivery in a longwall environment by the number of respondents giving the parameter the same weight



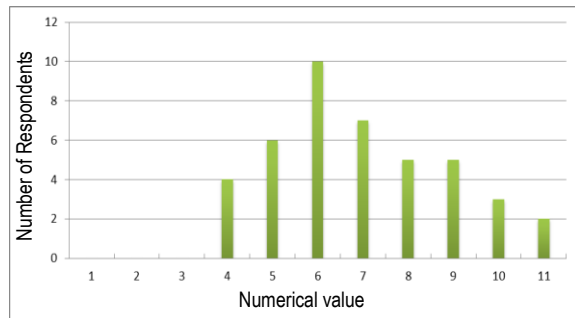
e) Numerical values representing the influence of longwall ventilation networks by the number of respondents giving the parameter the same weight



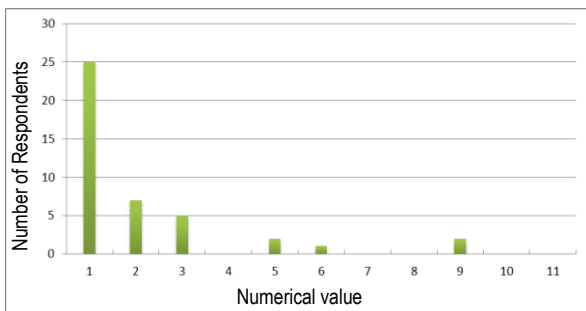
f) Numerical values representing the influence of an exploitation system by the number of respondents giving the parameter the same weight



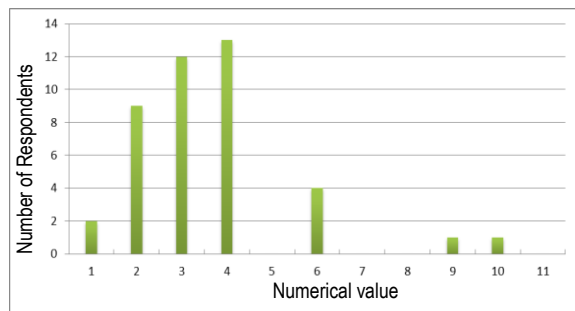
g) Numerical values representing the influence of cross-section longwall entries along its length by the number of respondents giving the parameter the same weight



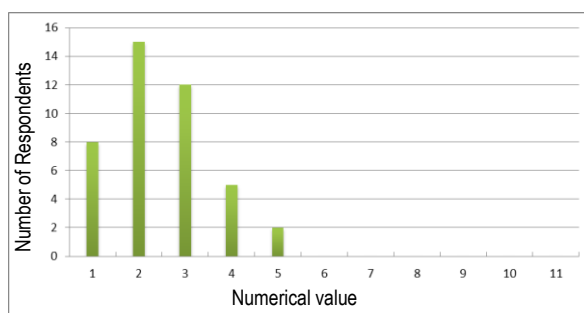
h) Numerical values representing the influence of cross-section longwall entries at junctions by the number of respondents giving the parameter the same weight



i) Numerical values representing the influence of undercut mining of longwalls by the number of respondents giving the parameter the same weight



j) Numerical values representing the influence of methane emission from roofs and floors into longwall areas by the number of respondents giving the parameter the same weight



k) Numerical values representing the influence of the direct presence of sandstone in roofs or floors of seams by the number of respondents giving the parameter the same weight

Fig. 1. Numerical values representing the influence of particular parameters on methane hazard in a longwall environment

Table 3. Values of stratum weight

Numerical Value	No. of parameter										
	1	2	3	4	5	6	7	8	9	10	11
0	4,76	0,00	0,00	0,00	0,00	7,14	4,76	0,00	59,52	4,76	19,05
1	0,00	2,38	0,00	0,00	0,00	14,29	9,52	0,00	16,67	21,43	35,71
2	4,76	0,00	7,14	2,38	2,38	14,29	0,00	0,00	11,90	28,57	28,57
3	0,00	4,76	0,00	4,76	0,00	26,19	11,90	9,52	0,00	30,95	11,90
4	7,14	0,00	21,43	4,76	11,90	4,76	26,19	14,29	4,76	0,00	4,76
5	11,90	7,14	11,90	4,76	0,00	11,90	16,67	23,81	2,38	9,52	0,00
6	11,90	9,52	11,90	9,52	19,05	11,90	9,52	16,67	0,00	0,00	0,00
7	11,90	0,00	21,43	26,19	14,29	9,52	4,76	11,90	0,00	0,00	0,00
8	14,29	4,76	9,52	23,81	19,05	0,00	9,52	11,90	4,76	2,38	0,00
9	11,90	26,19	9,52	11,90	23,81	0,00	7,14	7,14	0,00	2,38	0,00
10	21,43	45,24	7,14	11,90	9,52	0,00	0,00	4,76	0,00	0,00	0,00

Table 4. Percentage distribution of the parameters according to the ranges of influence on methane hazard

Numerical Value	No. of parameter										
	1	2	3	4	5	6	7	8	9	10	11
0–3	9,52	7,14	7,14	7,14	2,38	61,90	26,19	9,52	88,10	85,71	95,24
4–7	42,86	16,67	66,67	45,24	45,24	38,10	57,14	66,67	7,14	9,52	4,76
8–10	47,62	76,19	26,19	47,62	52,38	0,00	16,67	23,81	4,76	4,76	0,00

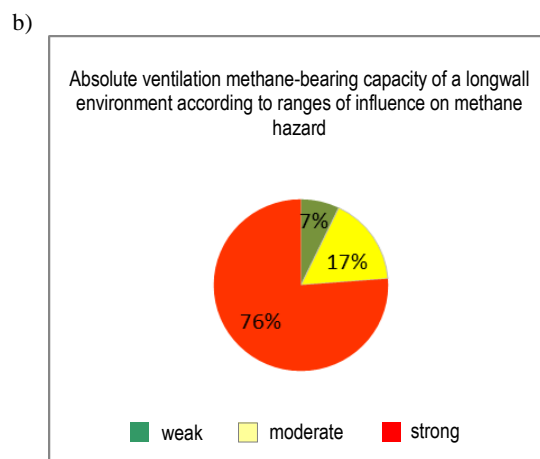
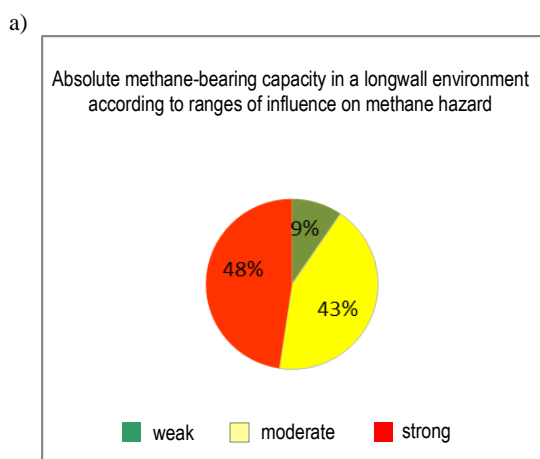
Figure 2 shows (in three different colours) the percentage distribution of parameters according to the ranges of influence on methane hazard:

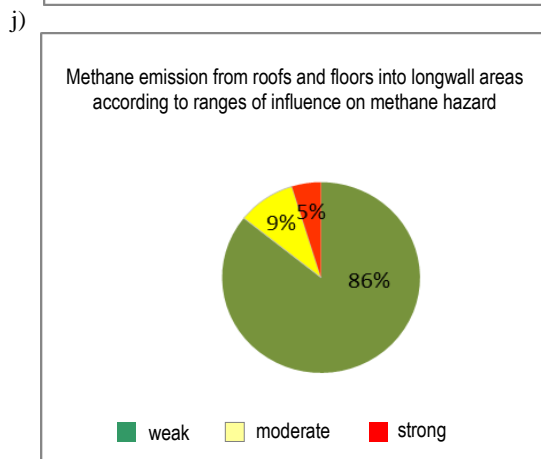
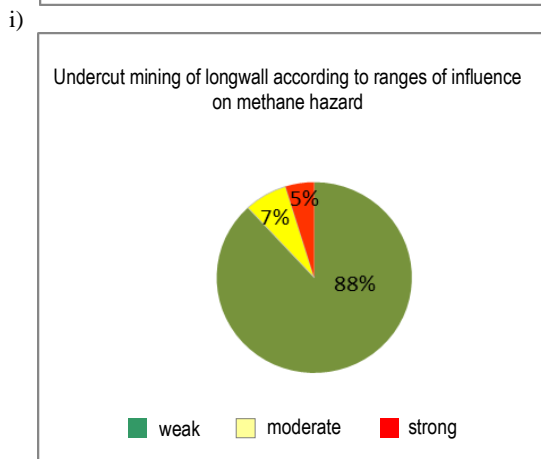
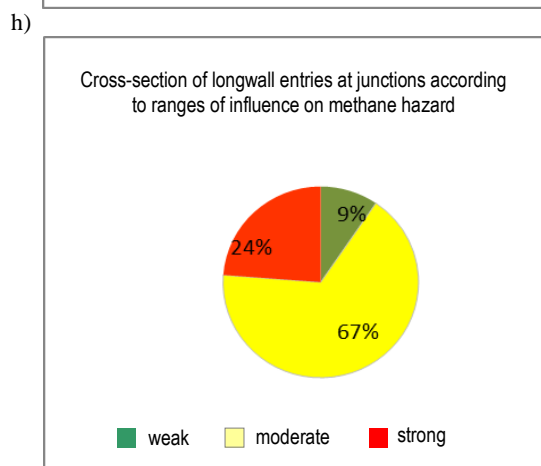
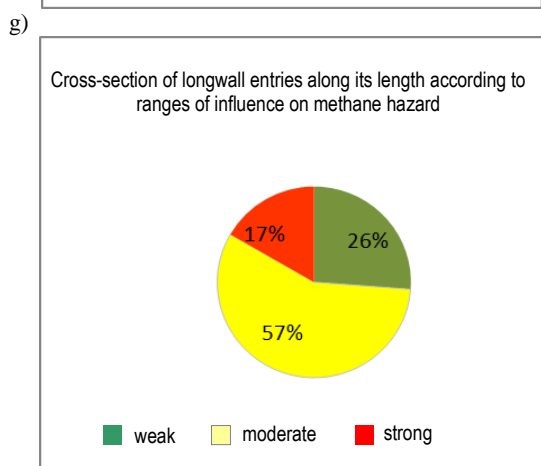
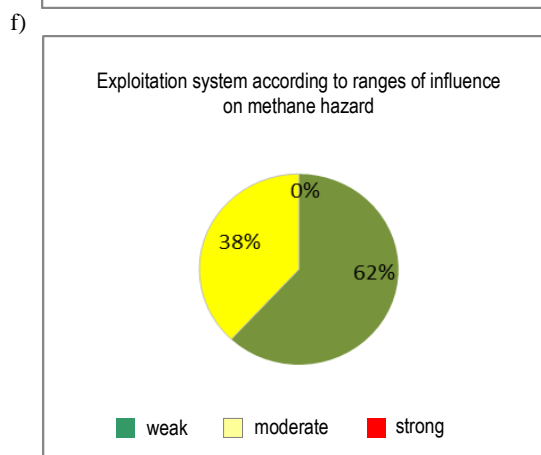
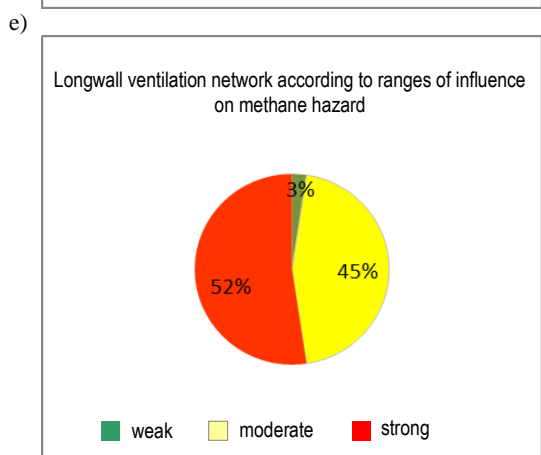
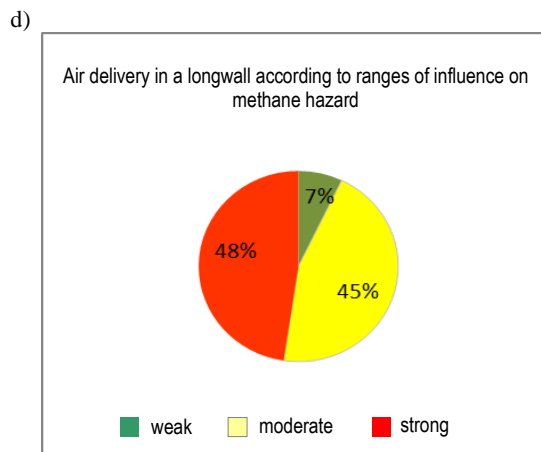
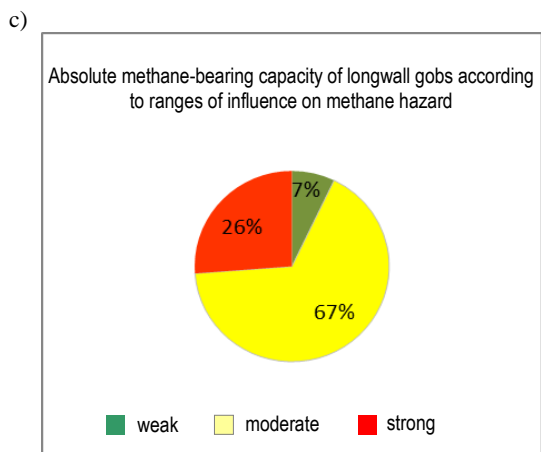
- for numerical values of weight 0–3 – weak influence of a parameter on the hazard (green)
- for numerical values of weight 4–7 – moderate influence of a parameter on the hazard (yellow)

- for numerical values of weight 8–10 – strong influence of a parameter on methane hazard (red)

Analysis of the survey dedicated to assessing the parameters which influence methane hazard in longwall environments of exploited methane seams (Table 4) presented the following conclusions:

- strong influence on methane hazard:
 - absolute ventilation methane-bearing capacity of longwall environments – 76%
 - longwall ventilation network – 53%
 - air delivery in longwall environments – 48%
 - absolute methane-bearing capacity in longwall environments – 48%
- moderate influence on methane hazard:
 - cross-section of longwall entries at junctions – 67%
 - absolute methane-bearing capacity of longwall gobs – 67%
 - cross-section of longwall entries along its length – 57%
- weak influence on methane hazard:
 - direct presence of sandstone in the roofs or floors of the exploited seam – 95%
 - undercut mining of longwalls – 88%
 - methane emission from roofs and floors into longwall areas – 86%
 - exploitation system – 62%





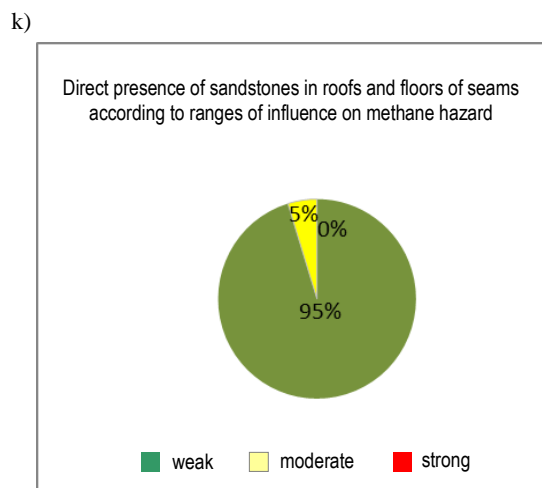


Fig. 2. Percentage distribution of particular parameters according to their ranges of influence on methane hazard

4. SUMMARY

The survey conducted among experts (practitioners) who deal with ventilation and methane hazard fighting showed that the level of the hazard is influenced mostly by the absolute ventilation methane-bearing capacity of longwall environments. Among the 42 respondents, 19 of them gave the factor the highest weight – 10 points, 11 of them gave it 9 points, and 2 respondents – 8 points, i.e. indicating its strong influence on methane hazard in longwall environments. According to 53% of the respondents, the second strongest parameter influencing methane hazard in longwall environments is the ventilation network (U, Y, other).

According to 95% of respondents, the direct presence of sandstone in the roofs or the floors of the exploited seams, had a very weak influence on methane hazard in longwall environments. The reason for such a low result of this parameter may be the fact that nowadays high-pressure spraying systems are mounted on shearers. The survey also showed the weak influence of the undercut orientation of a longwall on methane hazard. 88% of respondents claimed that the influence of the parameter is weak, 7% – that it is moderate, and only 5% said that its influence on methane hazard in a longwall is strong. The reason for the opinions may be the fact that most of the longwalls exploited nowadays in methane coal mines are exploited with the undercut technique. To ensure intensive ventilation of undercut areas, the main fans in upcast shafts work with high parameters of accumulation and air rates, producing a strong airflow, often of low stability.

The above analysis of parameters and factors influencing methane hazard in longwall environments, based on the results of a survey conducted among experts familiar with the problems of ventilation and fighting methane hazard in coal mines, confirmed the influence of the discussed parameters and factors on methane hazard in longwall environments. An analysis of the survey results shows which steps should be taken in the future while designing longwall methane seams as it will have a positive effect on the future concentration of production.

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