Journal of Geomine (2024), 2(1), 13-20
DOI: 10.22077/jgm.2024.7989.1031

Analysis of methane emissions sources into the environment of longwall mining during coal extraction (A case Study)

Ali Hosseini[1], Mehdi Najafi[2]

Recived: 2024 Aug. 01, Revised: 2024 Nov. 03, Online Published: 2024 Nov. 22

ABSTRACT

The release of methane into the working area of coal mines can affect safety and production. The methane naturally produced and stored in coal and surrounding strata can be released from different sources in longwall mining. The rate and amount of gas released depends on the initial amount of gas in the coal (gas content), the strength of the coal-bearing strata, the geometry of the mine workings, the rate of coal production, and coal seam permeability. This paper reviews analysis and assessment of methane emission sources into the longwall environment. For this issue, experts' ideas in the field of ventilation and methane drainage operation were collected and the opinions of these experts were analyzed. The results showed that methane emission from the overlaying strata and methane emission from the underlaying strata are respectively the most methane emission sources to the Goaf area and then to the longwall environment.

KEYWORDS

Longwall, Methane emission, Methane sources, gas content

I. INTRODUCTION

Methane hazard is one of the gravest natural hazards in underground coal mine. Gas emission from the seam being worked mainly occurs at the exposed faces. Methane emissions into the environment of the longwall during coal exploitation come from: (1) active longwall working face; (2) coal mass on the conveyer belts; (3) from the ribs, which are exposed to the ventilation air; (4) goaf after coal exploitation, which is connected with the exploited longwall environment (From overlying and underlying coal seams) (Lama and Nguyen, 1987; Szlazak et al., 2014). Methane emission from goaf, adjacent strata and seams accounts for the highest proportion in a district. In some Australian mines, this cause accounts for more than 75% of the total emission, and in mines using free drainage of the mined seam more than 90% gas content in the ventilation comes from this source. Krause et al. (2014), has been investigation an analysis of the parameters and factors, which have critical influence on the formation of methane hazard in longwall areas with high production capacity (Krause and Skiba, 2014). Determining the sources of methane emission in underground coal mines and determining the capacity of methane emitted from each source can significantly help the design of methane ventilation and methane drainage. Accurate estimation of methane hazard level, at the designing stage of exploitation, should be based upon the results of forecast with assuming different variants of longwall parameters (length and exploitation advance rate). Values of forecasted methane emissions for designed longwall constitute basis for selecting a ventilation system, ventilation parameters and methane drainage methods, and when specifying acceptable and safe production capacity (Cybulski et al., 1999; Krause and Łukowicz, 1999; Krause, 2005). This study presents an analysis and an assessment of the sources influencing methane emission in longwall mining areas. The research was based on a survey conducted among experts (with practical experience form Poland, England and Iran. The purpose of this paper is determination of methane emission from different sources into E4 longwall panel in Tabas mechanized coal mine No1.

II. CASE STUDY

Tabas coal mine is located 75 km of the Tabas city (Fig. 1). Five main coal seams have been explored (B1, B2, C1, C2 and D) at the coal deposit and currently C1 is being worked. Side view of typical face line was shown in Fig. 2. Tabas C1 coal seam gas average content is around 16 m^3/ton. The methane content of coal seams is shown in Fig. 3 for increasing depth. As can be seen, in layers B1, B2, C1, C2 and D, with increasing depth, the content of methane gas inside the layer increases. This information was obtained from exploratory boreholes in Tabas Parvadeh No1 coal mine (Hosseini et al., 2022). So far, 9 panels have been mined in the No. 1 Tabas Parvadeh coal mine. W0, W1, W2, W3, E0, E1, E2, E3 and E4 panels. Methane drainage started from E3 panel and until now panels E3, E4 and W3 have be gas drained.

[1]Tabas Parvadeh Coal Company, Tabas, Iran, [2]Department of Mining and Metallurgical Eng., Yazd University, Yazd, Iran.
✉ A. Hosseini: ali.hosseini4126@gmail.com

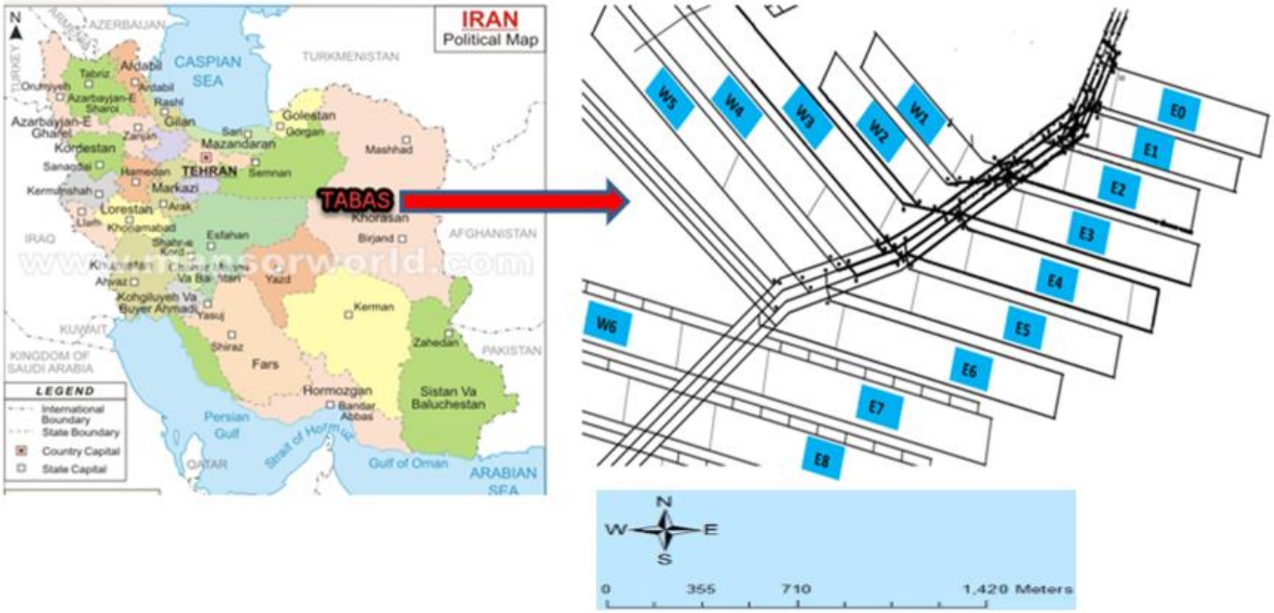

Fig.1. Tabas Parvadeh No1 coal mine map and coal seams ((Hosseini et al., 2021; Hosseini et al., 2022)

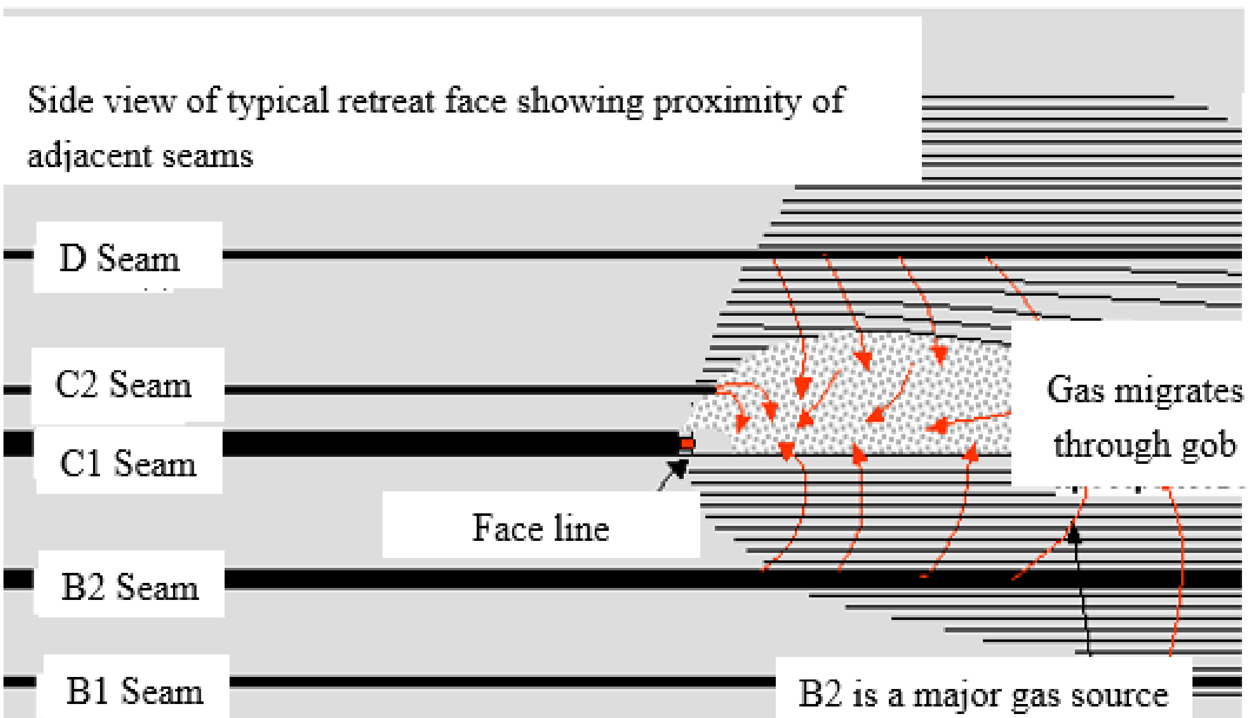

Fig. 2. Tabas Parvadeh No1 coal seams (Hosseini et al., 2021; Hosseini et al., 2022)

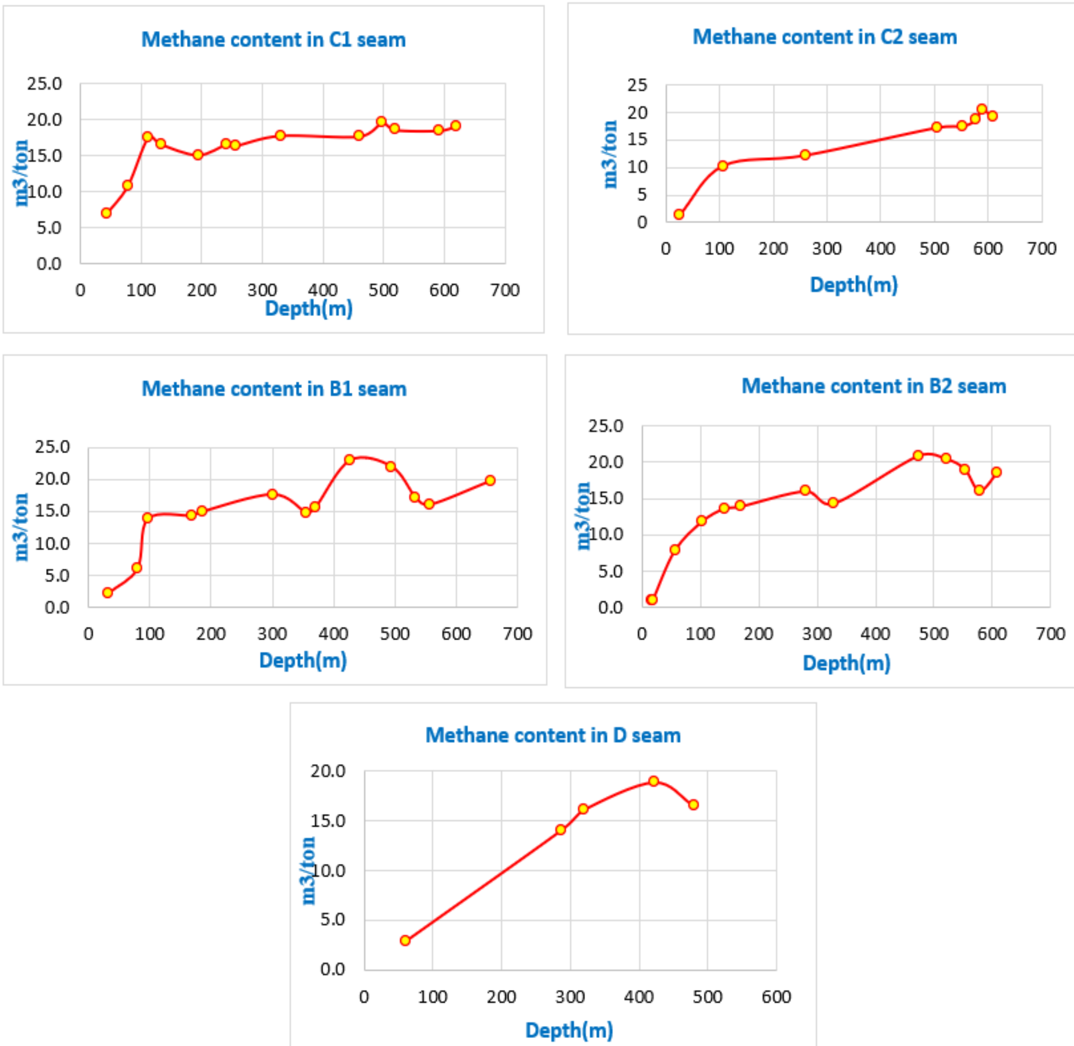

Fig. 3. Methane content changes in the Tabas coal mine seams relative to depth (m^3/ton) (Hosseini et al., 2021; Hosseini et al., 2022)

III. Methods

As mentioned above, the sources of methane emissions to the Longwall environment are different. In this research, to investigate the effect of each of these sources on the release of methane to the Longwall environment, we created a questionnaire from experts in this field and analyzed their opinions. Table 1 shows a set of five sources of methane emission into the environment of the longwall panel. The weight of influence of a particular source on the emission, given by the respondents a group of 20 experts dealing with the subject of ventilation and methane drainage 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 examined parameter. 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 greatest extent of influence on methane emission in a longwall environment (Table 2). The respondents were mainly ventilation and methane drainage engineers, whose responsibilities involve methane control in the Tabas coal mine No. 1 (Methane drainage and ventilation engineers form Poland, England and Iran). Limiting the number of respondents only to the experts, with practical experience in ventilation and methane drainage, increased the credibility of the survey. The results of the questionnaire are shown in Table 2. The results are collected in a matrix (20, 5), where the rows represent given respondents, and the columns contain numerical values ranging between 1 and 10, attributed to methane emission sources in a longwall area.

Table 1. Sources of methane emission into the Longwall

Methane emission sources into the Longwall panel		Point (0-10)
A	Methane emission from mining coal seam (during mining with a shearer)	
B	Methane emission from overlaying strata (Over exploited seam)	
C	Methane emission from underlaying strata (Under exploited seam)	
D	Methane emission from ribs	
E	Methane emission from coal being transported on the conveyor belts and AFC	

In Table 3, the values of the weight attributed to the given parameters by the 20 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 methane emission sources, have the following parameters:

Methane emission from overlaying strata (174 points)

Methane emission from mining coal seam (162 points)

Methane emission from underlying strata (102 points)

Methane emission from ribs (50 points)

Methane emission from coal being transported on the conveyor belts and AFC (49 points)

Maximum value points for each of the five parameters was 200 points.

Arranging the results of a survey and collecting them in the form of a matrix X (20, 5) is the initial stage of a statistical analysis. The next step is recognizing the structure of the data, i.e., the structure of a given group regarding their collective attitude towards a particular parameter. To evaluate the percentage share of the respondents who consider a particular parameter to be of signigicant influence on methane hazard in longwalls, the five 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 regarding their collective attitude towards a particular parameter.

Numerical values concerning the influence of particular parameters on methane emission sources in a longwall environment are showed in Fig. 4. 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 4 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 (Krause and Swolkień, 2013):

Table 2. Sources of methane emission into the Longwall

Respondents	A	B	C	D	E
1	8	9	5	2	2
2	10	8	7	5	3
3	7	7	7	3	2
4	8	8	7	2	2
5	9	9	7	3	4
6	8	10	4	1	2
7	7	8	3	4	3
8	9	7	4	1	4
9	8	9	5	3	2
10	6	10	4	2	1
11	7	7	6	2	2
12	10	10	5	4	1
13	7	8	5	1	2
14	8	9	5	3	4
15	9	9	4	1	3
16	9	10	6	2	2
17	7	9	4	2	4
18	9	10	4	4	3
19	8	8	5	3	1
20	8	9	5	2	2
Total	162	174	102	50	49
Rank	1	2	3	4	5

$$P_i = \frac{n_i}{N} 100\% \quad (1)$$

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 equal the size of the examined group:

$$n_1 + n_2 + \dots + n_k = N \quad (2)$$

Following equation, stratum weights satisfy:

$$P_1 + P_2 + \dots + P_k = 100\% \quad (3)$$

Three ranges of numerical values regarding the weight of the parameters influencing methane emission sources in longwalls were assumed (Table 3):

0–3 – weak influence on methane emission sources

4–7 – moderate influence on methane emission sources

8–10 – strong influence on methane emission sources.

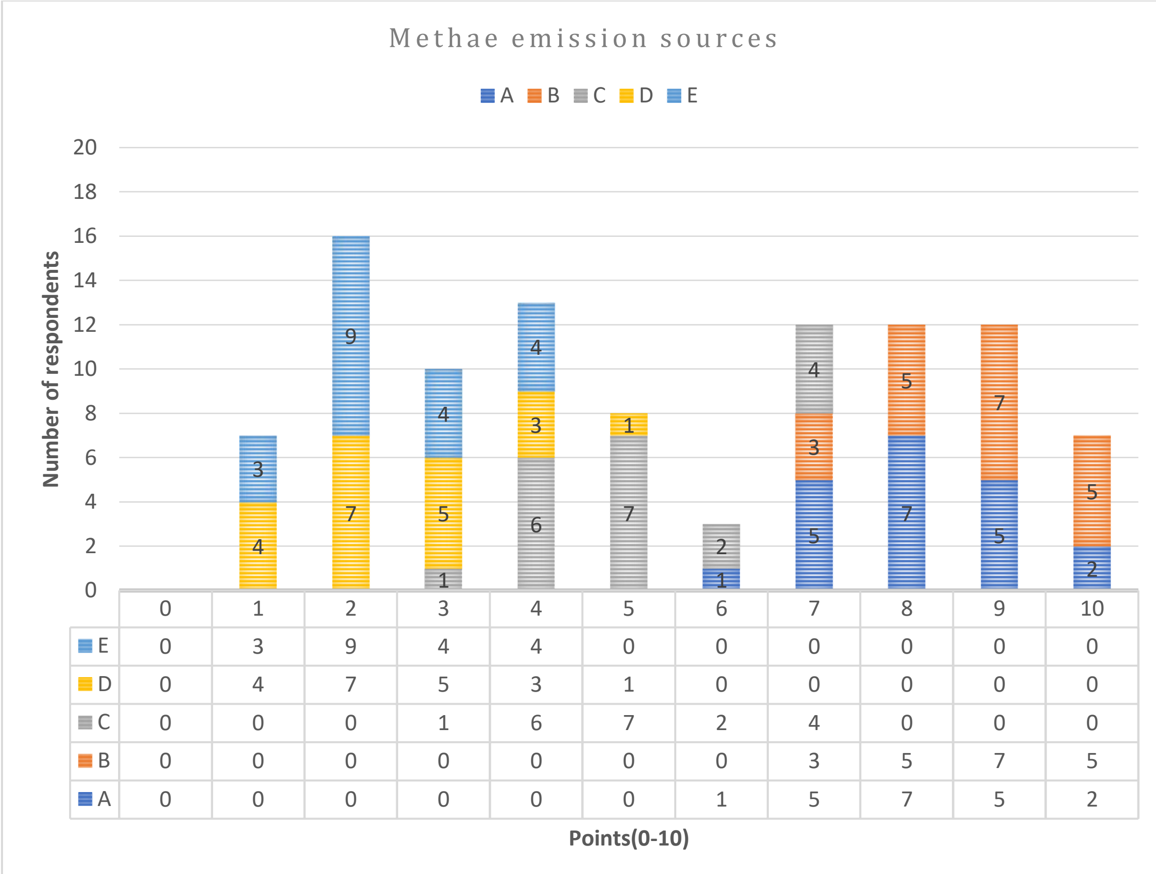

Fig. 4. Numerical values representing the effect of particular parameters on methane emission in a longwall environment

Table 3. Three ranges of numerical values regarding the weight of the parameters influencing methane emission sources in longwalls

For numerical values of weight 0–3	For numerical values of weight 4–7	For numerical values of weight 8–10
Weak effect of a parameter on the methane emission sources	Moderate effect of a parameter on the methane emission sources	Strong effect of a parameter on methane emission sources
Blue	Yellow	Red

Analysis of the survey dedicated to assessing the parameters that effect methane emission sources in longwall environments is shown in Table 4 and 5 and presents the following conclusions:

Strong effect on methane emission sources:

– Methane emission from overlaying strata (Over exploited seam) = 85%

– Methane emission from mining coal seam (during mining with a shearer) = 70%

– Methane emission from underlaying strata (Under exploited seam) = 0%

– Methane emission from ribs = 0%

– Methane emission from coal being transported on the conveyor belts and AFC = 0%

Moderate effect on methane emission sources:

– Methane emission from underlying strata (Under-exploited seam) = 95%

– Methane emission from mining coal seam (during mining with a shearer) = 30%

– Methane emission from overlaying strata (Over exploited seam) = 15%

– Methane emission from ribs = 20%

– Methane emission from coal being transported on the conveyor belts and AFC = 20%

Weak effect on methane emission sources:

– Methane emission from ribs = 80%

– Methane emission from coal being transported on the conveyor belts and AFC = 80%

– Methane emission from underlying strata (Under-exploited seam) = 5%

– Methane emission from overlaying strata (Over exploited seam) = 0%

– Methane emission from mining coal seam (during mining with a shearer) = 0%

Table 4. Values of stratum weight

Numerical Value		A	B	C	D	E
	0	0	0	0	0	0
	1	0	0	0	20	15
	2	0	0	0	35	45
	3	0	0	5	25	20
4-7	4	0	0	30	15	20
	5	0	0	35	5	0
	6	5	0	10	0	0
	7	25	15	20	0	0
8-10	8	35	25	0	0	0
	9	25	35	0	0	0
	10	10	25	0	0	0

Table 5. Percentage distribution of the parameters according to the ranges of influence on methane emission sources

Numerical Value	A	B	C	D	E
Weak (0-3)	0	0	5	80	80
Moderate (4-7)	30	15	95	20	20
Strong (8-10)	70	85	0	0	0
Total	100	100	100	100	100

Fig. 5 shows the percentage effect every parameter on methane emission sources: (in three different colors).

IV. METHANE EMISSION RESOURCES IN LONGWALL MINING

Methane emissions to the long-range environment come from the following sources:

A. Methane emission from mining coal seam (during mining with a shearer)

One source of methane emission to the environment of longwall is extraction of coal seams with shearer. The volume of methane emissions into the environment of longwall during coal shearer extraction can be calculated based on the following formula (Krause and Skiba, 2014):

$$V_{CH4} = \frac{L_s \times m_e \times \gamma \times z \times M_o \times \eta_s}{100t} \quad (6)$$

where:

L_s: Length of the longwall panel, m

V_{CH4}: The flow of emitted methane into a longwall, m^3/min

m_e: Heigh of coal seam, m

γ: Density of coal, t/m^3

z: Shearer cut depth, m

M_o: Methane content of exploited seam, m^3/ton

t: Duration of coal extraction cycle, min

η_s: Degree of exploited coal seam degasification – according to Eq. (2):

$$\eta_s = 8.534 \times M_o^{-0.67} \quad (7)$$

Table 6 presents calculated values of methane emissions into the environment of the longwall during the coal extraction cycle. Following longwall's parameters were assumed:

L_s = 250 m

m_e = 3 m

z = 0.8 m

Primary methane content in the coal seam M_o = 8 m^3/min

The calculations were conducted for three durations of shearer's extraction cycle, i.e.: 80 min, 100 min and 120 min. Value η_s was calculated based on Eq. (2), Methane emissions forecasting into longwall environment during coal extraction was calculated based on Eq. (1).

Table 6. Forecasts of methane emissions to longwall environment during shearer operation

Predicted methane emissions into the environment of longwall during coal extraction (Duration of shearer's mining cycle)	CH4 (m^3/min)
80 min	26
100 min	21
120 min	17

B. Methane emission from overlying and underlying coal seam

The underlying and overlying seams under exploitation released to the longwall, their methane content and distance from the exploited seam impact the volume of released methane resources migrating into the environment of the longwall goaf (Fig. 6). The volume of the underlying and overlying seams released by conducted exploitation depends on the length and inclination of the longwall and its exploitation progress. Wide of the longwall and its dip of coal seam directly impact the range and size of methane desorption zone cross-section.

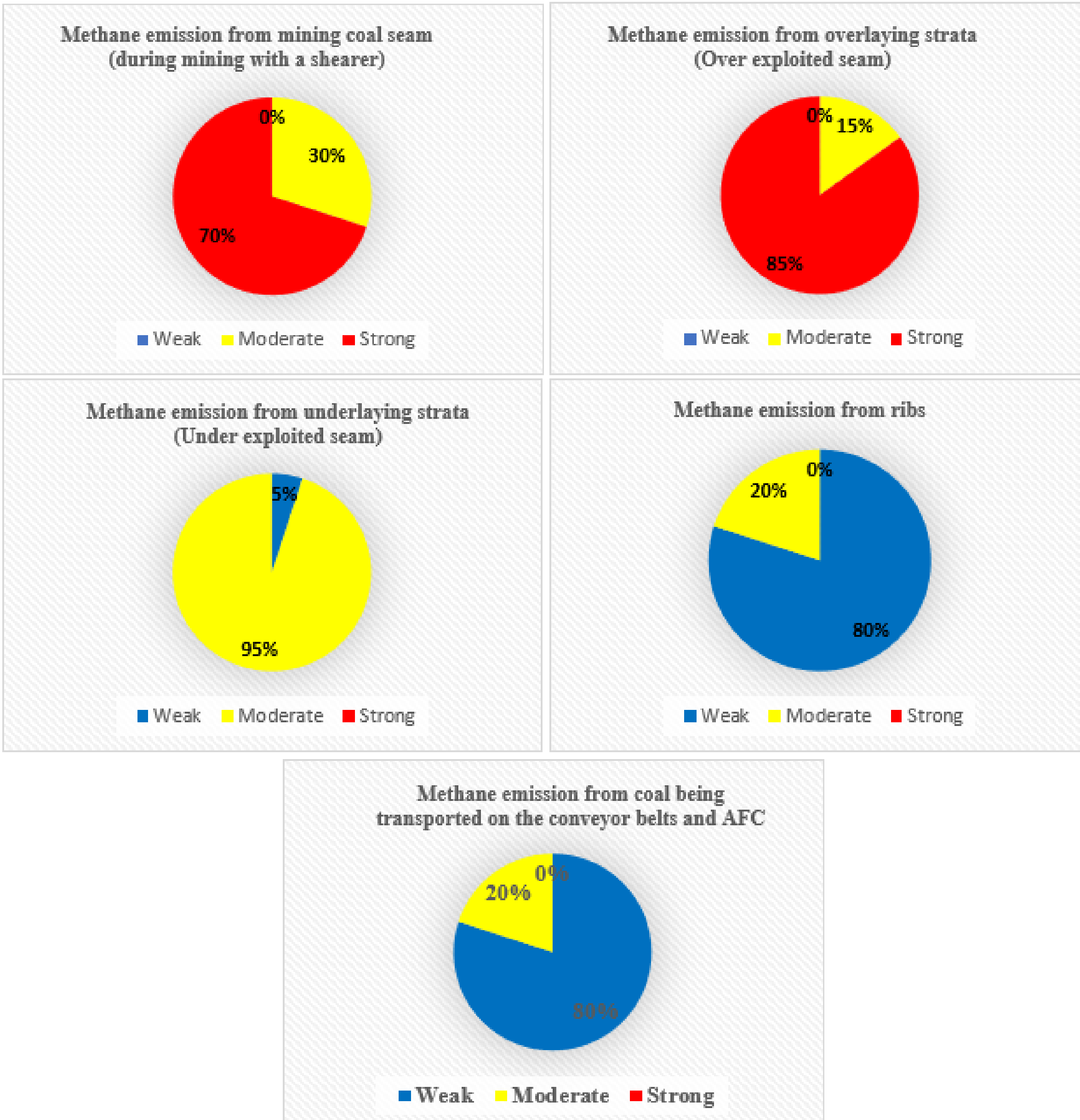

Fig. 5. Percentage distribution of particular parameters according to their ranges of effect on methane emission sources

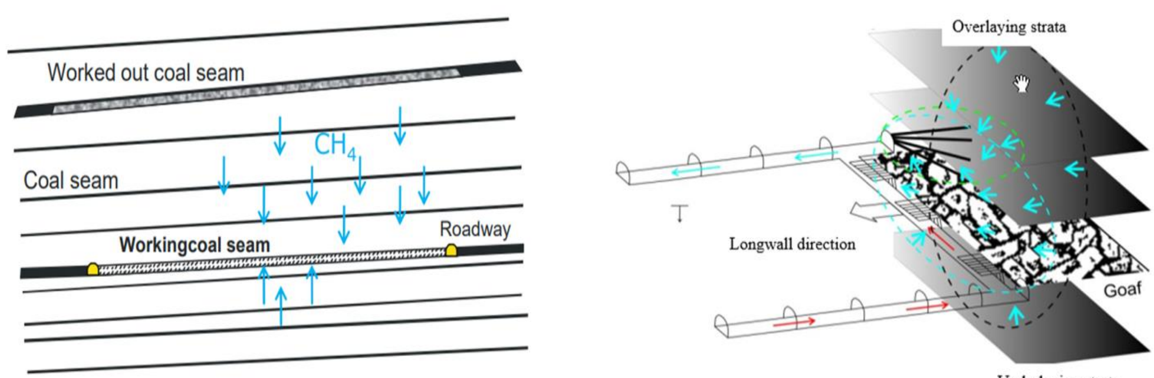

Fig. 6. Methane emission from overlaying and underlaying in longwall (Obracaj and Swolkien, 2016)

The floor rock strata experience stress relief and damage during longwall mining, even though the damage degree is less than that experienced by the overburden strata. Then, gas previously in the floor rock strata inevitably is released to the working face. Additionally, gas in the surrounding rock layers above the subsided overburden strata or under the damaged floor strata could flow through the mining-induced permeability increase area. Ultimately, this gas could reach the goaf area and working face (Szlazak et al., 2014; Szlazak et al., 2014; Szlazak and Swolkien, 2016).

C. Methane emission from ribs

Part of the methane that emitted in to the environment of the working face is caused by the methane released from the walls of the tunnels dug in the coal seam, which enters the longwall environment through ventilation.

D. Methane emission from coal being transported on the conveyor belts and AFC

A part of the gas released in the panel from the coal transported on the conveyor belt and chain conveyor is released into the ventilation air of the mine and then into the environment of the longwall.

V. Conclusion

Methane emission into the environment of exploited coal panels constitutes serious problems which affects safety and economy of complex coal production. Sources of methane emissions to the longwall working face environment are different. In order to investigate the effect of each of these sources on the release of methane to the longwall environment, we created a questionnaire from experts in this field and analyzed their opinions. The survey conducted among experts (practitioners) who deal with ventilation and methane hazard fighting showed that the methane emission from overlaying strata (Over exploited seam), methane emission from mining coal seam (during mining with a shearer) and methane emission from underlying strata (Under exploited seam) is the most methane emission sources in longwall mining method respectively.

References

Cybulski K, Krause E, Łukowicz. (1999). Influence of production capacity on shaping methane hazard in workings of longwall area. Krakow: GH University of Science and Technology.

Hosseini , A., Najafi , M., & Morshedy , A. H. (2021). Determination of Methane Desorption Zone for the design of a drainage borehole Pattern (Case Study: E4 Panel of the Tabas Mechanized Coal Mine, Iran). Rudarsko-geološko-Naftni Zbornik, 36(1), 61-75. doi:10.17794/rgn.2021.1.6

Hosseini , A., Najafi , M., & Morshedy , A. H. (2022). Determination of suitable distance between methane drainage stations in Tabas mechanized coal mine (Iran) based on theoretical calculations and field investigation. Journal of Mining Institute, 258, 1050-1060. doi:10.31897/PMI.2022.106

Hosseini, A., Najafi, M., Hossein morshedy., A. (2022). The effect of technical parameters of cross-measure boreholes methane drainage method on the amount of exhaust gas (Case study: Tabas Parvadeh coal mine No.1). Journal of Analytical and Numerical Methods in Mining Engineering, 12(30), 79-89. doi:10.29252/ANM.2021.17356.1522

Krause, E. (2005). Factors influencing increase in methane hazard in longwalls of high production capacity. Mining Survey, 19-25.

Krause, E., Skiba, J. (2014). Formation of methane hazard in longwall coal mines with increasingly higher production capacity. International Journal of Mining Science and Technology, 24, 403-407.

Krause, E., Swolkień, J. (2013). An analysis and assessment of parameters shaping methane hazard in longwall areas. Journal of Sustainable Mining, 12.

Lama, R.D., Nguyen, V. u. (1987). A model for determination of methane flow parameters in coal from desorption tests. Proceedings of the Twentieth International Symposium on the Application of Computers and Mathematics in the Mineral Industries.

Obracaj, D., Swolkien, J. (2016). Method of methane drainage with using the cased long boreholes. Cracow: AGH University of Science and Technology.

Szlazak, N., Borowski, M., Obracaj, D., Swolkien, J., Korzec, M. (2014). Selected issues related to methane hazard in hard coal mines. AGH university of science and technology press. Krakow. Krakow.

Szlazak, N., Borowski, M., Obracaj, D., Swolkien, J., Korzec, M. (2014). Comparison ofmethane drainage methods use in polish coal mines. Arch. Min. Sci, 59(3), 655–675.

Szlazak, N., Swolkien, J. (2016). The effectiveness of the methane drainage of rock mass with a U ventilation system. (3), 617-634. doi: 10.1515/amsc-2016-0044