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INTRODUCTION

All mines owned by Jastrzębska Spółka Węglowa S.A. are methane mines. This means that the air flowing out of mine shafts contains a certain concentration of methane, depending on the amount of air and the amount of methane flowing into them, which is emitted into the excavations. Methane concentration in ventilation shafts, in accordance with current regulations, may not exceed 0.75%. The part of methane present in the rock mass, thanks to the use of demethylation system, is captured in ducts of demethylation system and discharged to the surface (Berger J., Nawrat S. 2011; Jakubów A. 2017; Kozłowski B., Grębski Z., 1982; Markiewicz J., Badyłak A. 2011), which limits the amount of methane flowing into the ventilation air. This methane is utilized to some extent.

Methane from coal deposits is also emitted after decommissioning of the mines and can be used economically (Łukaszczyk Z. 2019, Nawrat S. et al. 2011).

The total amount of methane that is emitted per minute into the mine's excavations and into the demethanation system is called absolute or total methane (Kozłowski B, Grębski Z. 1982). The amount of methane released in a certain period of time in the mine (e.g. during one month) converted into a tone of extraction in that period is called relative methane. The amount of methane released into the ventilation air converted into unit time is called ventilation methane. The amount of methane contained in demethanation system converted into unit time is called methane content of demethanation system.

The methane content of mines is variable in time, which is caused by the uneven methane content of coal seams and surrounding rocks in the space of deposit, as well as the intensity of mining (Badura H. 2003; Roszkowski J., Szlązak N. 1999; Stasińska et al. 2014).

ANALYSIS OF METHANE EMISSIONS TO AIR IN 2017

The mines owned by JSW S.A. differ significantly in terms of methane, including ventilation methane. Figure 1 shows the amount of methane that was released in individual mines in 2017.

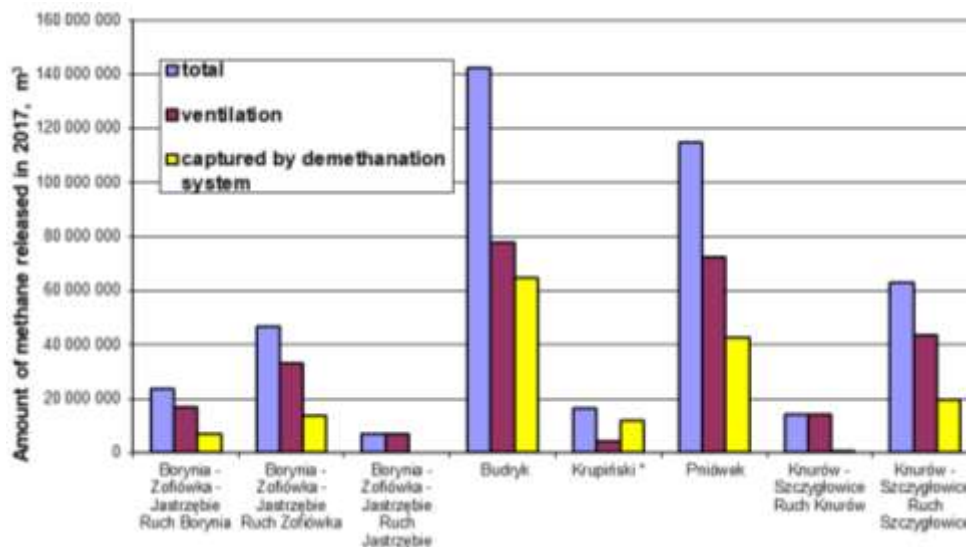


Fig. 1 Amount of methane released in JSW S.A. mines in 2017 calculated based on ventilation data

These data are based on measurements of methane concentration and air volume in ventilation shafts (ventilation and total methane) and measurements of the amount of methane captured by demethanation system. Detailed values are presented in Table 1.

In 2017, about 428.6 million m³ of methane was released in all JSW S.A. mines. Figure 2 presents the amounts of methane released in the mines calculated on the basis of relative methane. These amounts are slightly smaller as they only apply on days when mining was carried out.

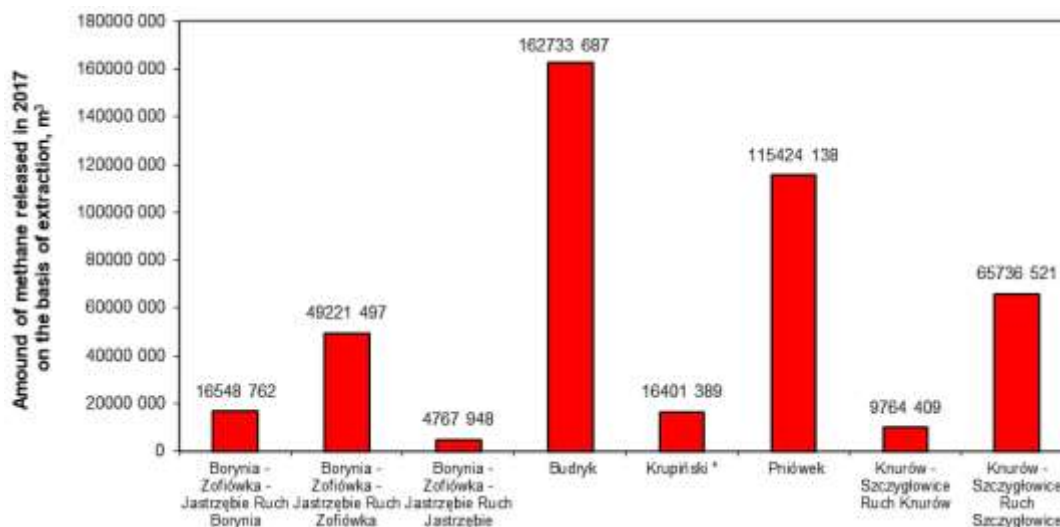


Fig. 2 Amount of methane released in 2017 in JSW S.A. mines calculated on the basis of extraction

As shown in Figure 1 and Table 1, the largest amount of methane was released in 2017 in “Budryk” mine (about 142.3 million m³), followed by “Pniówek” (about 114.8 million m³) and “Szczygłowice” (about 63.1 million m³). The main part of the total amount of methane, about 268.3 million m³, was released into the mine air and discharged into the atmosphere.

The greatest amount of methane was released into the mine atmosphere in “Budryk” mine – about 77.6 million m³, followed by “Pniówek” – about 72.4 million m³ and “Szczygłowice” – about 43.4 million m³. Also a significant amount of methane was released into the ventilation air in “Zofiówka” mine – about 33 million m³.

The total amount of methane that was released into the atmosphere of JSW S.A. mines was approximately 268.3 million m³.

The most advantageous way to combat the methane hazard, for the sake of work safety, is demethanation. However, this is a costly method and currently used only when sufficiently high work safety cannot be ensured.

In some mines, the amount of air supplied to the longwall areas currently depends mainly on the degree of climatic risk. In many cases, the amount of air supplied to the longwall area for this reason is sufficient so that the concentration of methane does not exceed the permissible methane concentrations. The demethanation efficiency achieved in JSW S.A. mines in 2017 is shown in Figure 3.

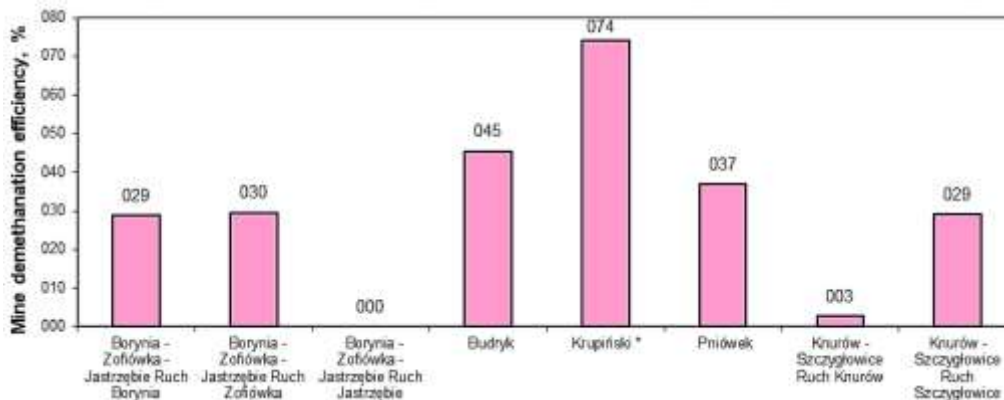


Fig. 3 Mine demethanation efficiency in 2017

The highest demethanation efficiency was achieved in “Krupiński” mine. It was 74.12%. The second in this respect, “Budryk” mine reached 45.48% and the third one, “Pniówek” mine, reached 36.94% methane demethanation efficiency. The “Jastrzębie” mine did not use demethylation. The demethanation efficiency in “Knurów” mine was 2.80%.

Figure 4 shows the utilization level of methane captured by demethanation system.

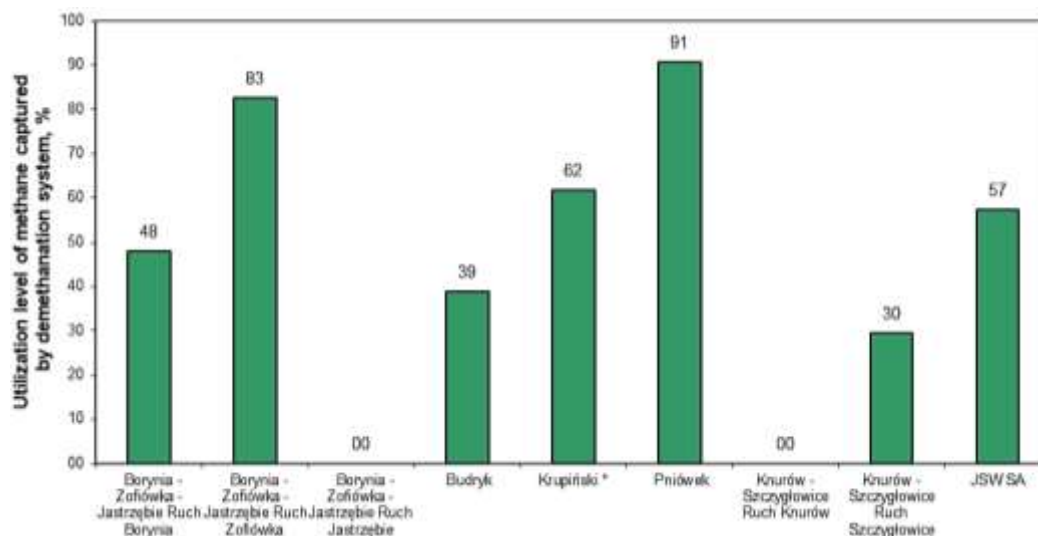


Fig. 4 Percentage use of methane captured by demethanation system in 2017

The capture of methane by demethylation system, as well as the demand for methane disposal products were not stable. Moreover, not all mines, to a large extent independent of the mine management or JSW S.A., are not adequately equipped with methane disposal products. For these reasons only part of the methane captured by demethylation system was used productively. As shown in the graph in Figure 4, the best use was made of methane captured in “Pniówek” mine, i.e. 90.6%. A high utilization level, above 50%, also occurred in “Zofiówka” mines – 82.6% and “Krupiński” – 61.6%. However, the “Knurów” mine did not have the possibility to use the captured methane.

Unused methane in all mines was emitted to the atmosphere.

Figure 5 shows the amounts of methane, which was captured by demethylation system, discharged into the atmosphere.

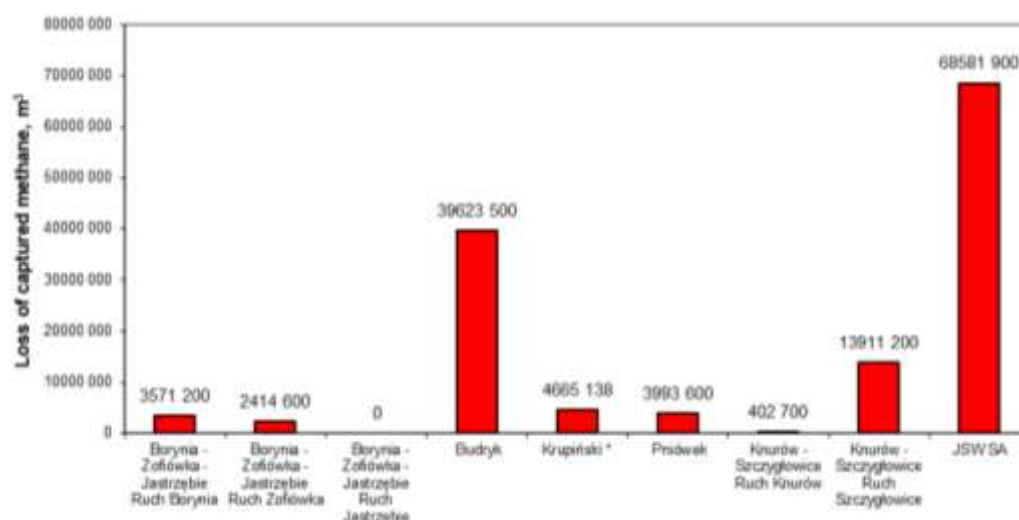


Fig. 5 Loss of methane captured by the demethanation system in 2017

The largest amount – about 64.8 million m³ was discharged by “Budryk” mine. The “Pniówek” mine, despite the high level of methane use, discharged about

42.4 million m³ into the atmosphere, and “Szczygłowice” mine about 19.7 million m³. In total, in 2017, 160.2 million m³ of methane, previously treated with the demethylation system, was discharged into the atmosphere.

Table 1 Basic parameters concerning the methane content of mines and the use of methane captured by demethanation system in 2017

Mine	Amount of methane released, m ³			Demethanation efficiency	Efficiency of the use of captured methane
	total	into the ventilation air	captured by demethanation system		
Borynia - Zofiówka - Jastrzębie Ruch Borynia	23804424	16961112	6843312	28.7	47.8
Borynia - Zofiówka - Jastrzębie Ruch Zofiówka	46878264	32981400	13896864	29.6	82.6
Borynia - Zofiówka - Jastrzębie Ruch Jastrzębie	6769728	6769728	0	0.0	0.0
Budryk	142364016	77610096	64753920	45.5	38.8
Krupiński	16403976	4246848	12157128	74.1	61.6
Pniówek	114822576	72401400	42421176	36.9	90.6
Knurów - Szczygłowice Ruch Knurów	14401440	13996728	404712	2.8	0.0
Knurów - Szczygłowice Ruch Szczygłowice	63108792	43372512	19736280	31.3	29.5
JSW S.A.	428553216	268339824	160213392	37.4	57.2

Table 2 Amount of methane discharged into the atmosphere

Mine	Amount of methane discharged into the atmosphere in 2017, m ³		
	ventilation	from demethanation system	Total
Borynia - Zofiówka - Jastrzębie Ruch Borynia	16961112	3571200	20532312
Borynia - Zofiówka - Jastrzębie Ruch Zofiówka	32981400	2414600	35396000
Borynia - Zofiówka - Jastrzębie Ruch Jastrzębie	6769728	0	6769728
Budryk	77610096	39623500	117233596
Krupiński	4246848	4665138	8911986
Pniówek	72401400	3993600	76395000
Knurów - Szczygłowice Ruch Knurów	13996728	402700	14399428
Knurów - Szczygłowice Ruch Szczygłowice	43372512	13911200	57283712
JSW S.A.	268339824	68581900	336921724

Basic data on the amount of methane released in 2017 and its use are presented in Table 1, while the amount of methane discharged into the atmosphere is presented in Table 2.

In 2017, the highest demethanation efficiency was recorded in “Krupiński” mine – 74.1%. In “Budryk” mine the demethanation efficiency was 45.5% and in “Pniówek” mine – 36.9%. Whereas the highest efficiency of use of the captured methane was recorded in “Pniówek” mine (90.6%), “Zofiówka” mine came second in this respect (82.6%), while the third is “Krupiński” mine.

In terms of total methane emissions to the atmosphere, the first place was taken by “Budryk” mine (117.2 million m³ including ventilation 77.6 million m³ and 39.6 million m³ from the demethanation system), followed by “Pniówek” mine (76.4 million m³ including ventilation and 72.4 million m³ and 4.0 million m³ from the demethanation system) and “Szczygłowice” mine (57.3 million m³ including ventilation 43.4 million m³ and 13.9 million m³ from the demethanation system).

ANALYSIS OF METHANE EMISSIONS TO AIR IN 2018

Below are presented the parameters characterizing the methane emission and capture in JSW S.A. mines in 2018.

In total, by the end of 2018, about 406.4 million m³ of methane had been released in all JSW S.A. mines. The figures presented in Figure 6 are shown in Table 3.

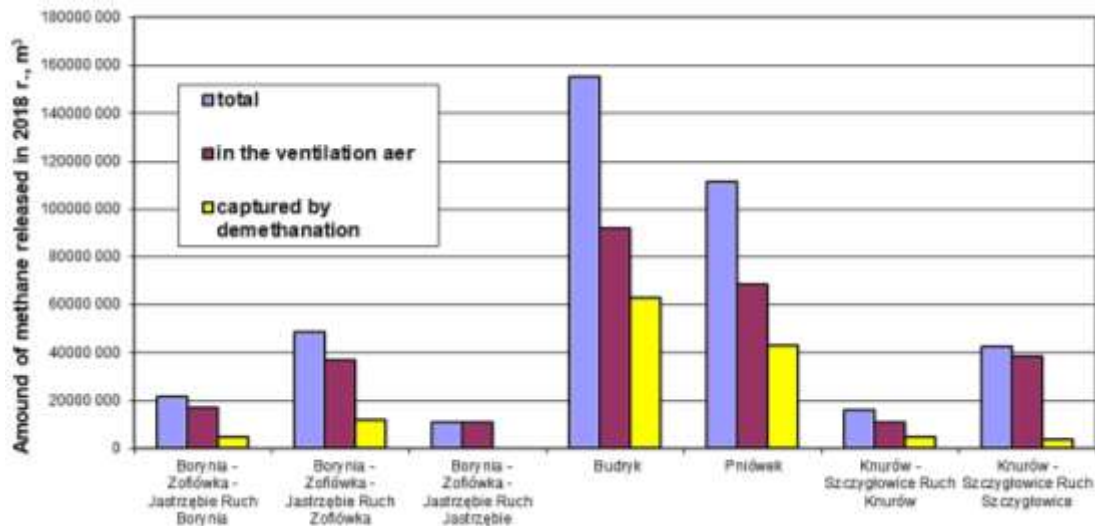


Fig. 6 Amount of methane released in JSW S.A. mines in 2018, calculated based on ventilation data

As in 2017, in 2018 the amount of methane calculated on the basis of extraction is less than that calculated on the basis of ventilation data.

The highest demethanation efficiency was reported in 2018 by the “Budryk” mine (40.6%), followed by “Pniówek” (38.4%) and “Knurów” (31.3%). The average methane demethanation efficiency in all JSW SA mines in 2018 was 32.3%.

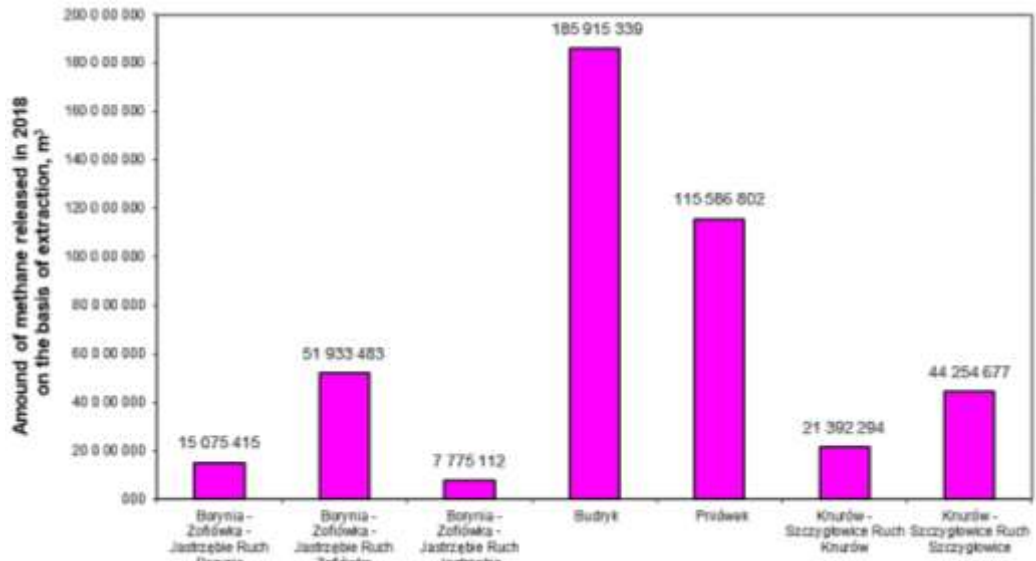


Fig. 7 Amount of methane released in JSW S.A. mines in 2018 calculated based on extraction

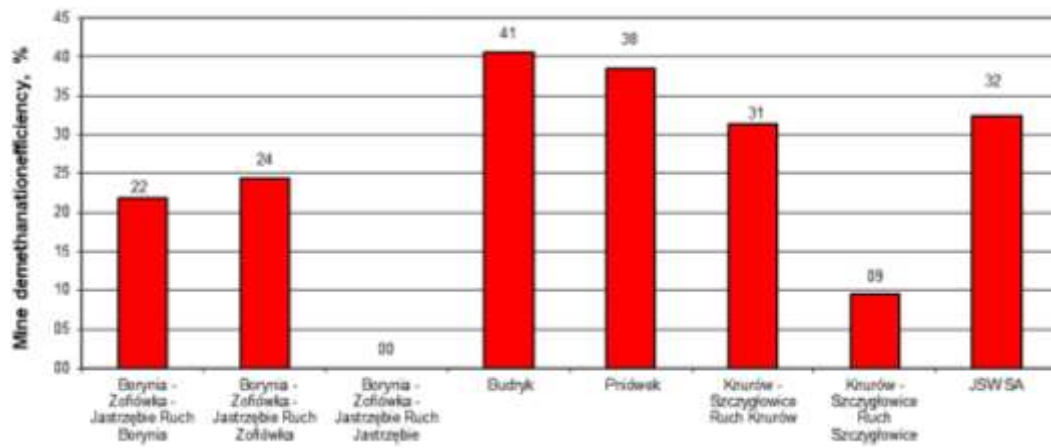


Fig. 8 Demethanation efficiency in JSW S.A. mines in 2018

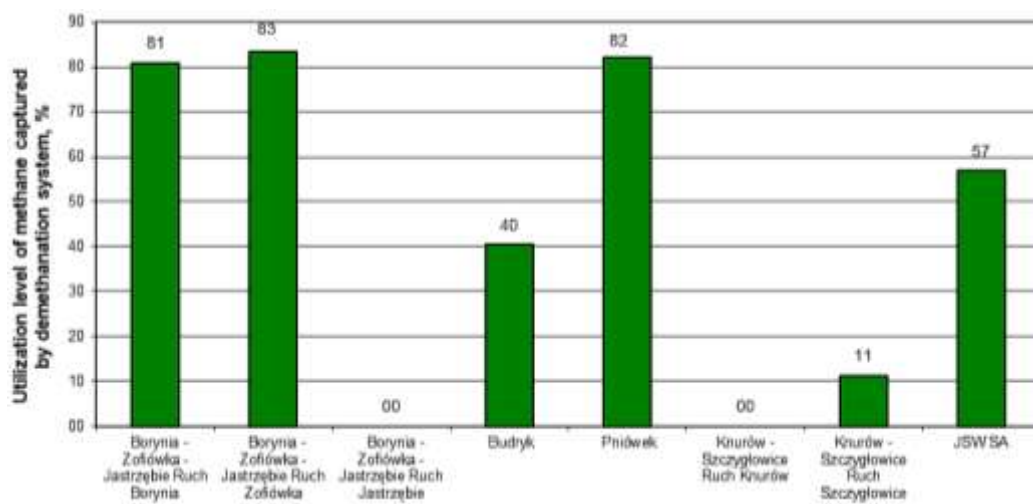


Fig. 9 Efficiency of use of captured methane in JSW S.A. mines in 2018

The most effective use of the captured methane in 2018 was in “Zofiówka”, “Pniówek” and “Borynia” mines (over 80%). The average value of the efficiency of using the captured methane in JSW S.A. mines was 56.8%.

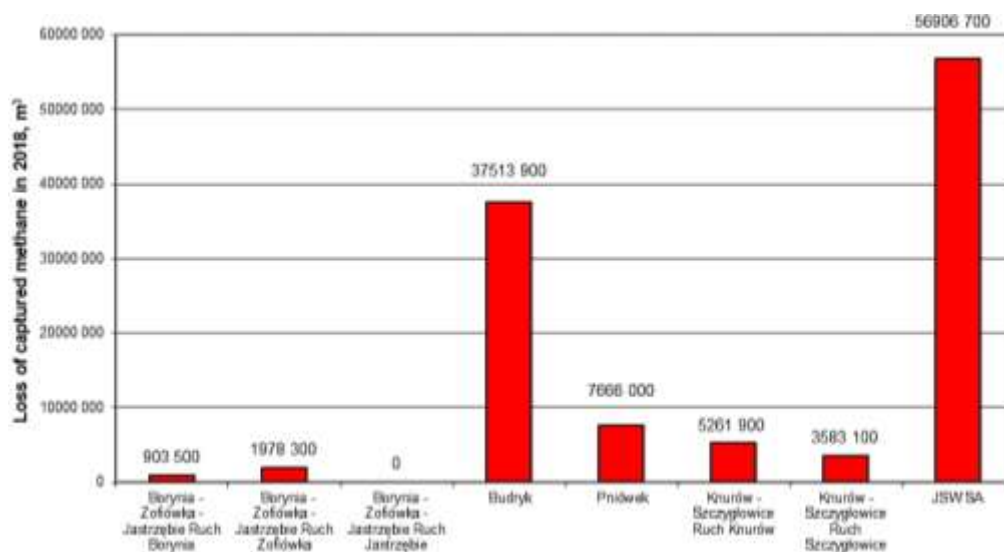


Fig. 10 Loss of methane captured by demethanation system in 2018

The largest losses of captured methane occurred in “Budryk” mine – about 37.5 million m³. The largest losses of methane captured in “Budryk” mine – about 37.5 million m³. Total losses amounted to about 56.9 million m³ of methane.

Table 3 Basic parameters concerning the methane content of mines and the use of methane captured by demethanation system in 2018

Mine	Amount of methane released, m ³			Demethanation efficiency	Efficiency of the use of captured methane
	total	into the ventilation air	captured by demethanation system		
Borynia - Zofiówka - Jastrzębie Ruch Borynia	21633696	16913808	4719888	21.8	80.8
Borynia - Zofiówka - Jastrzębie Ruch Zofiówka	48639024	36797256	11841768	24.3	83.3
Borynia - Zofiówka - Jastrzębie Ruch Jastrzębie	11037600	11037600	0	0.0	0.0
Budryk	155230704	92248056	62982648	40.6	40.4
Pniówek	111427200	68606568	42820632	38.4	82.1
Knurów - Szczygłowice Ruch Knurów	15857352	10890432	4966920	31.3	0.0
Knurów - Szczygłowice Ruch Szczygłowice	42536808	38500200	4036608	9.5	11.3
JSW S.A.	406362384	274993920	131368464	32.3	56.8

Table 4 Amount of methane discharged into the atmosphere in 2018

Mine	Amount of methane discharged into the atmosphere in 2017, m ³		
	ventilation	from demethanation system	Total
Borynia - Zofiówka - Jastrzębie Ruch Borynia	16913808	903500	17817308
Borynia - Zofiówka - Jastrzębie Ruch Zofiówka	36797256	1978300	38775556
Borynia - Zofiówka - Jastrzębie Ruch Jastrzębie	11037600	0	11037600
Budryk	92248056	37513900	129761956
Pniówek	68606568	7666000	76272568
Knurów - Szczygłowice Ruch Knurów	10890432	5261900	16152332
Knurów - Szczygłowice Ruch Szczygłowice	38500200	3583100	42083300
JSW S.A.	274993920	56906700	331900620

In 2018, the highest methane demethanation efficiency was recorded in “Budryk” mine – 40.6%. The second in this respect was “Pniówek” mine, where the demethanation efficiency was 38.4%, while the third was “Knurów” mine with the demethanation efficiency of 32.1%. Whereas the highest efficiency of use of the captured methane was in “Zofiówka” mine (83.3%), followed by “Pniówek” mine (82.1%), and “Borynia” mine came third in this respect (80.8%). Zero use of the captured methane was recorded in “Knurów-Szczygłowice” Ruch “Knurów”. The efficiency of use of the captured methane in the entire JSW S.A. was 56.8%. Methane emission to the atmosphere was caused by the release of methane into the ventilation air and incomplete use of methane captured by demethanation system.

In terms of total methane emissions to atmosphere, “Budryk” mine was ranked first (129.7 million m³ including ventilation 92.2 million m³ and 37.5 million m³ from the demethanation system), followed by “Pniówek” mine (76.3 million m³ including ventilation 68.6 million m³ and 7.7 million m³ from the demethanation system) and “Szczygłowice” mine (42.1 million m³ including ventilation 38.5 million m³ and 3.6 million m³ from the demethanation system).

By the end of 2018, 331.9 million m³ of all JSW S.A. mines were discharged into the atmosphere, with 275.0 million m³ of ventilation air and 56.9 million m³ of demethanation systems.

Comparison of the demethanation and utilization efficiency of methane captured by demethanation systems shows that in JSW S.A. mines the demethanation efficiency decreased from 37.4% in 2017 to 32.3% in 2018 and the utilization efficiency of captured methane decreased from 57.2% to 56.8%.

Relatively low utilization of methane included in demethanation system results in the need to seek additional methods of methane utilization.

ANALYSIS OF METHANE EMISSIONS TO AIR IN 2019

Below are presented the parameters characterizing the release and capture of methane in JSW S.A. mines in 2019. In 2019, the KWK “Borynia-Zofiówka-Jastrzebie” Ruch Jastrzebie mine ceased to exist and the new “Jastrzebie-Bzie” mine was established.

Figure 11 shows the amount of methane released in all mines of Jastrzębska Spółka Węglowa S.A.

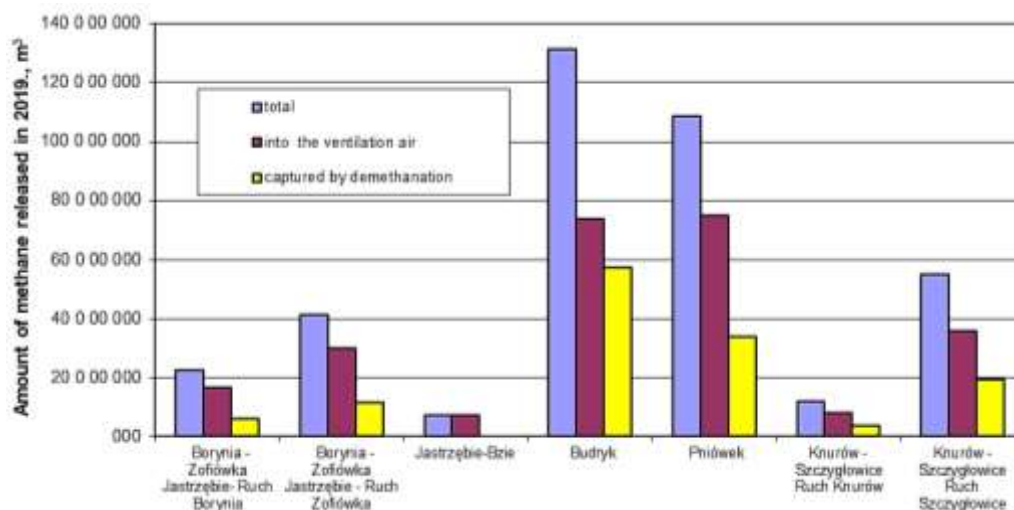


Fig. 11 Amount of methane released in JSW S.A. mines in 2019, calculated based on ventilation data

In total, by the end of 2018, about 406.4 million m³ of methane had been released in all JSW S.A. mines. The figures presented in Figure 12 are shown in Table 5.

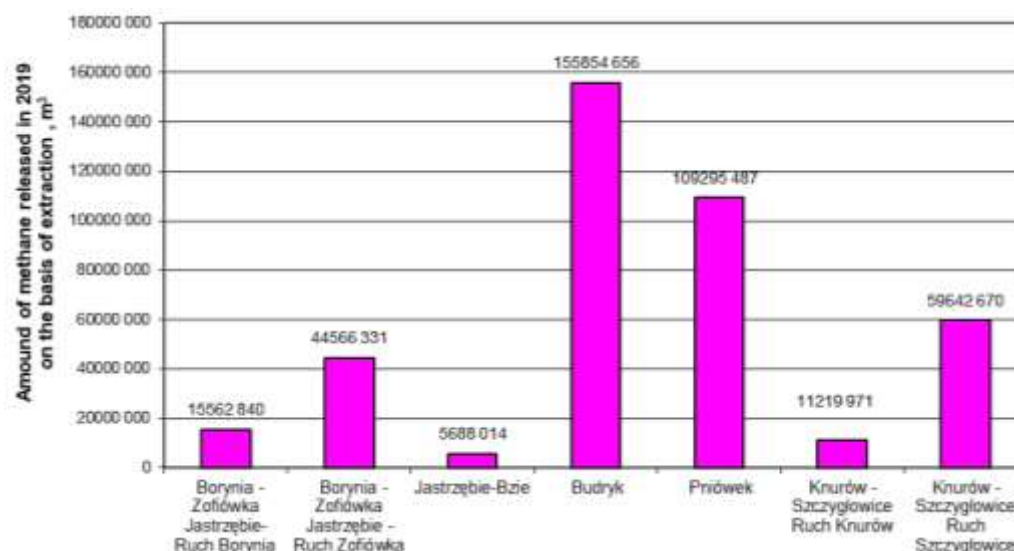


Fig. 12 Amount of methane released in JSW S.A. mines in 2019 calculated based on extraction

As in 2017, in 2018 the amount of methane calculated on the basis of extraction is less than that calculated on the basis of ventilation data.

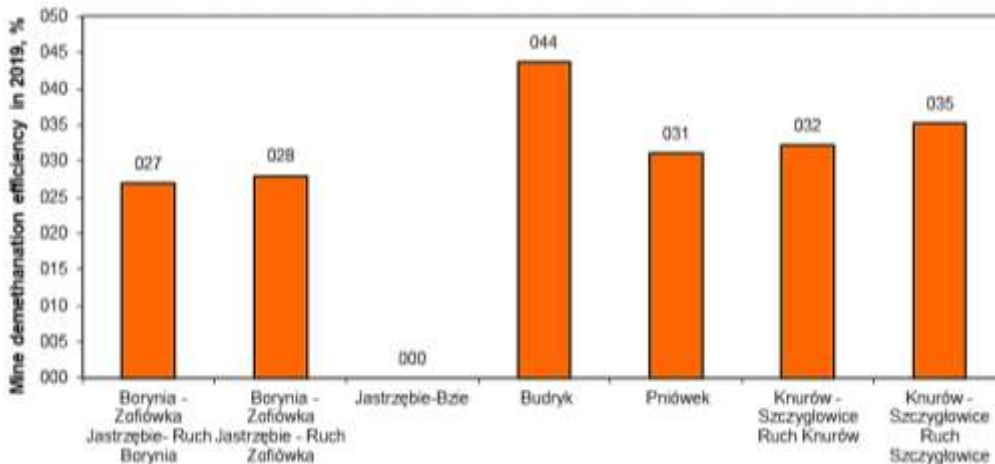


Fig. 13 Demethanation efficiency in JSW S.A. mines in 2019

The highest demethanation efficiency was reported by “Budryk” mine in 2019 (43.73%), followed by “Szczygłowie” (35.18%) and “Knurów” (32.20%). The average demethanation efficiency in all JSW S.A. mines was 37.63%.

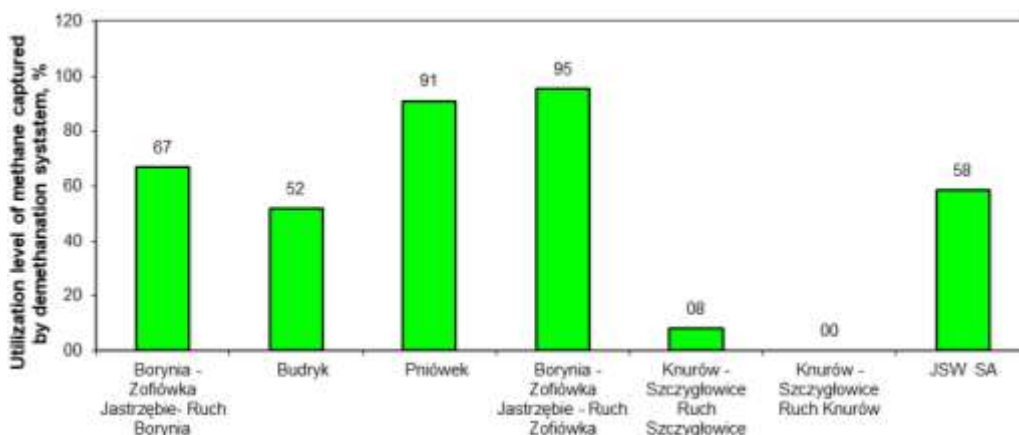


Fig. 14 Efficiency of use of captured methane in JSW S.A. mines in 2019

The most effective use of captured methane in 2019 was in “Zofiówka” (95.4%), “Pniówek” (91.0%) and “Borynia” (66.9%) mines. The average efficiency of using the captured methane in JSW S.A. mines was 58.4%. The KWK “Knurów-Szczygłowie” KWK Ruch Knurów, the total amount of methane captured discharged into the air.

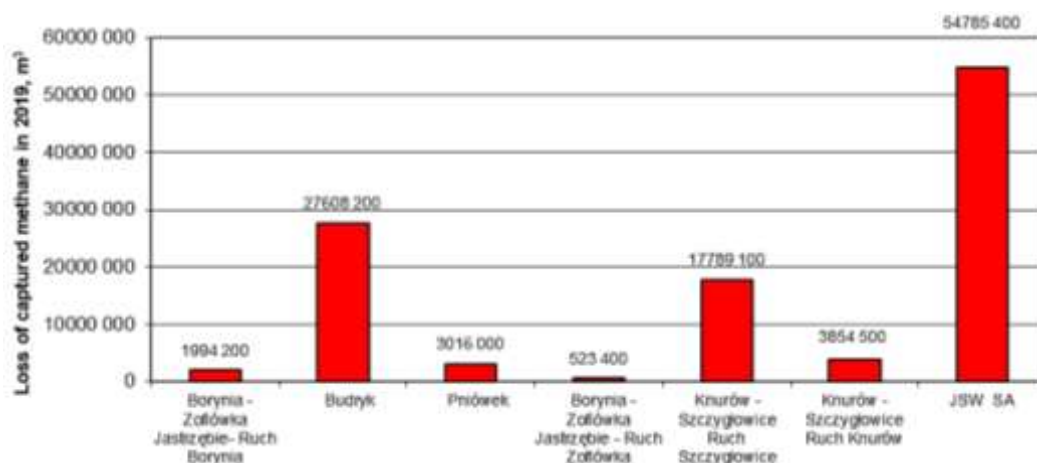


Fig. 15 Loss of methane captured by demethanation system in 2019

The largest losses of captured methane occurred in “Budryk” mine – about 27.6 million m³, in other mines they were much lower. Total losses of captured methane amounted to about 54.8 million m³.

Table 5 Basic parameters concerning the methane content of mines and the use of methane captured by demethanation system in 2019

Mine	Amount of methane released, m ³			Demethanation efficiency	Efficiency of the use of captured methane
	total	into the ventilation air	captured by demethanation system		
Borynia - Zofiówka - Jastrzębie Ruch Borynia	22527216	16477560	6049656	26.85	66.9
Borynia - Zofiówka - Jastrzębie Ruch Zofiówka	41159736	29775240	11384496	27.95	95.4
Borynia - Zofiówka - Jastrzębie Ruch Jastrzębie	7074576	7074576	0	-----	0.00
Budryk	131173992	73810008	57363984	43.73	51.9
Pniówek	108452304	74787624	33664680	31.04	91.0
Knurów - Szczygłowie Ruch Knurów	11967912	8115264	3852648	32.20	0
Knurów - Szczygłowie Ruch Szczygłowie	55035576	35672472	19363104	35.18	8.1
JSW S.A.	377391312	245712744	131678568	34.89	58.4

In 2019 the highest methane demethanation efficiency was recorded in “Budryk” mine – 43.73%. The second in this respect was “Szczygłowie” mine. where methane demethanation efficiency was 35.18% while the third was “Knurów” mine with methane demethanation efficiency of 32.20%.

In turn the highest utilization efficiency of captured methane was in “Zofiówka” mine (95.4%) followed by “Pniówek” mine (91.0%) and “Borynia” mine came

third in this respect (66.9%). Zero use of the captured methane was recorded in KWK “Knurów-Szczygłowiec” Ruch “Knurów”.

Table 6 Amount of methane discharged into the atmosphere in 2019

Mine	Amount of methane discharged into the atmosphere in 2017. m ³		
	ventilation	from demethanation system	Total
Borynia - Zofiówka - Jastrzębie Ruch Borynia	16477560	1994200	18471760
Borynia - Zofiówka - Jastrzębie Ruch Zofiówka	29775240	523400	30298640
Borynia - Zofiówka - Jastrzębie Ruch Jastrzębie	7074576	-----	7074576
Budryk	73810008	27608200	101418208
Pniówek	74787624	3016000	78642124
Knurów - Szczygłowiec Ruch Knurów	8115264	3854500	11969764
Knurów - Szczygłowiec Ruch Szczygłowiec	35672472	17789100	53461572
JSW S.A.	245712744	54785400	300498144

The efficiency of using the captured methane in the entire JSW S.A. was 58.4%. Methane emission to the atmosphere was caused by the release of methane into the ventilation air and incomplete use of methane captured by demethanation system.

In terms of total methane emissions to atmosphere. the first place was taken by “Budryk” mine (101.4 million m³ including ventilation 73.8 million m³ and 27.6 million m³ from the demethanation system). followed by “Pniówek” mine (78.6 million m³ including ventilation 74.8 million m³ and 3.9 million m³ from the demethanation system) and “Szczygłowiec” mine (53.5 million m³ including ventilation 35.7 million m³ and 17.8 million m³ from the demethanation system). By the end of 2019, 300.5 million m³ of all JSW S.A. mines were discharged into the atmosphere. including 245.7 million m³ of ventilation air and 54.8 million m³ of demethylation systems.

CONCLUSION

Comparison of the demethanation and utilization efficiency of methane captured by demethanation systems shows that in JSW S.A. mines the demethanation efficiency decreased from 37.4% in 2017 to 32.3% in 2018 and the utilization efficiency of captured methane decreased from 57.2% to 56.8%. On the other hand, in 2019 the demethanation efficiency increased in relation to 2018 and amounted to 34.8%, and the efficiency of use of the captured methane increased to 58.4%, i.e. it is the highest of three analysed years. However, it is a relatively low use of the captured methane. Therefore, it is necessary to seek methods of economic use of the captured methane and implement them in mines, especially in high methane mines.

The second, very important issue (especially in the case of introducing high charges for methane emission into the atmosphere by the European Union authorities) is the reduction of methane discharged into the atmosphere along with the ventilation air of mines. In 2019, this amount accounted for approximately 82% of the total methane emission by JSW S.A. mines. One of the methods to reduce this amount of methane is catalytic combustion. The current technique allows for economically justified combustion of methane with a concentration exceeding 0.5% in air. On the other hand, combustion with the supply of energy necessary to sustain combustion is possible at a methane concentration of not less than 0.3%.

Since a large part of the captured methane by demethanation systems is not utilized, mainly due to the high variability of the amount of captured methane, it is advisable to develop a technology for the storage of this methane and use it to increase the concentration in the ventilation air intended for combustion and electricity generation. The note concerns mainly the air-methane mixture with methane concentration less than 0.5%.

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Abstract: The paper presents formation of the amount of methane released from a coal deposit during coal mining. The total amount of released methane is composed of the amount separated directly into the ventilation air in mines (ventilation methane) and included in the demethanation system, isolated from the ventilation air. Methane from the demethanation system is only partially utilized. The unused part of methane is discharged into the atmosphere. The paper presents how the amount of methane released in individual mines of Jastrzębska Spółka Węglowa S.A. was shaped, with a division into methane released to the ventilation system and included in the demethanation system, taking into account the part used for economic purposes and the part discharged to atmosphere. The research material covers the years 2017-2019.

Keywords: ventilation methane, total methane, demethanation, methane disposal, JSW S.A. mines