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Emission and commercial utilization of coal mine methane in the Upper Silesian Coal Basin illustrated by the example of Katowice Coal Holding Company

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ABSTRACT

The article deals with the issue of the release of methane from coal seams and its emission to the atmosphere from the mines of Katowice Coal Holding Company in the years of 1997-2011. This period is characterized by organizational changes in Polish mining industry involving liquidation or a merger of mines, an increase in both the concentration of coal mining activity, and the depth of the exploitation at which the amount of methane in coal seams grows ever larger. The analysis of the variation in the methane emission from the coal mines in that period points out a decline in the intensity of the emission until 2005, probably owing to the liquidation of some mines, later, but in the years of 2006-2010 – a considerable increase in both the absolute methane emission of the mines and the methane emission to the atmosphere despite a dropping coal extraction. This signifies that mining activity takes place in increasingly difficult gas conditions prevailing at great depths. Despite a slight decrease in both the absolute methane emission and methane emission to the atmosphere in 2011, a continuously growing trend of this phenomenon should be expected in the future. A similar tendency is also visible in the whole Upper Silesian Coal Basin, however the methane emission peak falls in 2008. In order to curb the growth of the amount of the emitted methane, it should be commercially utilized. Particularly vital is considering methane as an unconventional resource, following the example of other countries.

KEY WORDS: greenhouse effect, coal, gas hazard, underground mining, Upper Silesian Coal Basin, Poland

1. Introduction

Methane present in coal basins is genetically linked to coal. Its origin is connected with the formation of the deposits of bituminous coal or less often – lignite. Methane is produced by the processes both biochemical (microbial methane) and geochemical (thermogenic methane generated due to the thermal transformation of the coal substance) (e.g. KOTARBA, 2001; MOORE, 2012; SCOTT, 2002). Coal itself has a very complicated inner structure, which allows adsorption of a certain amount of produced gases inside the coal substance. Due to the complex system of coal porosity and a significant specific (inner) surface of the coal substance, estimated at 2-300 m^3/g (KOZŁOWSKI & GRĘBSKI, 1982), the gas sorption capacity of coal may be very large, therefore enormous amounts of methane may be adsorbed in the coal structure. Sorbed methane, which in terms of physics and chemistry is related to the coal substance and located in coal micropores, is the basic form of the occurrence of methane in coal seams, whereas free methane filling coal macropores and fissures and present in porous waste rocks is secondary in coal seams. Both types of gases, at the given formation temperature, are in mutual equilibrium determined by gas pressure. An increase in the pressure leads to gas sorption in the coal seam, a reduction, in turn, results in desorption and migration into the surrounding rocks (PĘKAŁA, 1992).

In coal mines methane poses a serious risk of explosion and fire during mining activity. In order to combat this hazard, methane is removed from mine workings by ventilation of mine openings or degasification of the rock mass. The methane thus driven out of the mine most often gets into the atmosphere causing the greenhouse effect, since it is the second only to carbon dioxide most important greenhouse gas. Approximately 16% of the total amount of the methane released from coal seams is commercially utilized (KARACAN ET AL., 2011).

There are used two measures of methane emission into mine workings. The first of them, defined as the amount of methane liberated from coal seams per time unit, 'absolute methane emission' is, while the second, called 'relative methane emission', shows the amount recalculated for tonne of extracted coal. This paper presents figures concerning mostly to the first of them, values of which depend largely on the amount of the methane accumulated in coal seams, i.e. the methane content, represented by the volume of methane per unit of dry ash free coal (coal daf).

For the last several years, Polish coal mining industry has been undergoing major organizational changes. These changes primarily consist in liquidation or a merger of mines, concentration of coal extraction and exploitation carrying out at ever-greater depths. All this affect the amount of methane emitted from the coal mines.

Over the past years, the mines belonging to Katowice Coal Holding Company (KCHC), and the mines owned by other companies similarly, have undergone a thorough reorganization of the administration, and because of their significant share in coal extraction in the Upper Silesian Coal Basin (USCB) (about 20%), special attention is required to the issue of their methane emission. Thus, the objective of this work is to follow the changes in the intensity of this mine gas release from the mines of KCHC over time and compare it to the methane release from the other mines of the USCB. This issue is extremely important also because of EU legislation requiring the measurements and inventory of the greenhouse gases emission owing to the calculation of emission charges and emission trading (PATYŃSKA, 2013). The objective of the article has been presented on the background of brief description of methane conditions in the KCHC mines as well the role of coal-mine methane in greenhouse gases emission.

The mining areas of KCHC mines are located within the Katowice Upland, which is part of the Silesian-Cracow Upland (KONDRACKI, 1994). The study area is determined by the town of Ruda Śląska in the west, Katowice in the center, and Sosnowiec and Mysłowice in the east (Fig. 1) and covers the area of 190 km^2. The region is characterized by a high degree of the transformation of the natural environment caused by many years of mineral resources exploitation and the consequent development of the industry, resulting in, among others, air pollution due to anthropogenic emission of industrial dusts and gases (including mine methane).

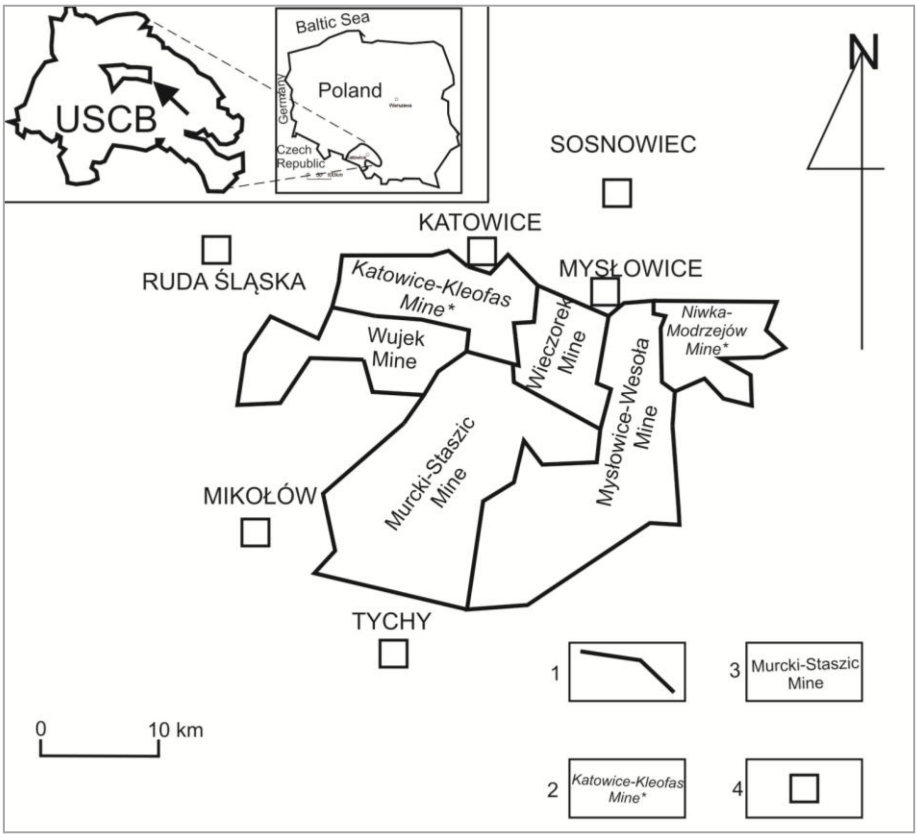

Fig. 1. Location of KCHC mines
1 – borderlines of mining areas, 2 – abandoned mines, 3 – working mines, 4 – important cities

2. Methane as greenhouse gas

Methane is a gas of a high absorption of infrared radiation. Its so-called radiative forcing power is from 21 to 25 times greater than of carbon dioxide. It has been calculated that in the eighties the radiative forcing induced by methane corresponded to about 15% of the total of greenhouse gases (EPA REPORT, vide: KOTARBA & NEY, 1995). It has been also found out that the amount of methane present in the atmosphere is about two hundred times smaller than CO_2, while the residence time of CH_4 is twenty times shorter than that of CO_2 (op. cit.). However, taking into account the radiative forcing power of methane, it can be concluded that methane and carbon dioxide are comparably harmful greenhouse gases.

Over the past 200 years the amount of methane in the atmosphere has been doubled as a result of human industrial activity. According to the estimates (SMITH & SLOSS, 1992), coal mining provides 25-47 Tg of methane per year, what constitutes about 10-20% of the total emission of this gas caused by human activity (KRUGER, vide: KOTARBA & NEY, 1995). The largest emitter of methane from coal mines are: China (34%), the USA (18%), Russia and Ukraine (6% each). Polish participation in the global emission of mine methane reaches 3% (KARACAN ET AL., 2011), almost exclusively on the part of the USCB.

The combustion of methane released by mines, which results in carbon dioxide emission, is beneficial to the environment – one metric tonne of combusted methane provides 2.75 tons of carbon dioxide, however, due to the 21 times stronger radiative forcing power of methane, a substantial reduction of emission by 18.25 tons of CO_2 per 1 tonne of combusted methane is obtained (SKOREK ET AL., 2004). Unfortunately, the efficiency of profitable utilization of captured methane is still low, what is a consequence of many barriers of an economic and legislative nature (see ch. 5).

3. Methane conditions in the mines of KCHC

Methane conditions of coal mines are shaped by numerous natural factors such as the geological structure of coal deposits (including lithological variability of the rocks surrounding coal seams), the nature of the cover of the deposit, the tectonic character of the area of coal extraction, and the petrographic structure of the coal substance and coal rank (e.g. KĘDZIOR, 2009a, 2012; MOORE, 2012; TARNOWSKI, 1989). Hydrogeological and hydrodynamic conditions prevailing in the coal seam, which affect the processes of sorption and desorption of gases from coal seams as well as gas migration of desorbing gases, are also the vital factor (e.g. KĘDZIOR, 2009a; SCOTT, 2002), still extensively tested.

Generally, there is observed trend towards the increasing methane content in coal seams along with the increase of the depth. It is the result of, on the one hand, the increase in the deposits' coal rank, which facilitates adsorption of methane, but on the other – the growing lithostatic pressure, which could retain methane in the coal seam. Nevertheless it should be borne in mind that at a substantial depth (> 1500 m) a decline in methane content is observed due to the increasing temperature of the rock mass, significantly reducing the coal capability to accumulate methane (e.g. BOROWSKI & SOSNOWSKI, 1977; KHAVARI-KHORASANI & MICHELSEN, 1999; NIEĆ, 1993).

The presence of methane in coal mines has always been posing an explosive and fire hazard. Methane together with air forms an explosive mixture if its content in the atmosphere is in the range of 5-15%. The mixture ignites when the ambient temperature exceeds 650°C, while at the temperature above 1500°C an explosion occurs. The gas explosion is the strongest when the methane content in the air reaches 9.5% (KOZŁOWSKI, 1982; KOZŁOWSKI & GRĘBSKI, 1982). There are categories of methane hazard in coal mines determined basing on the methane content in coal seams (Table 1). Coal seams classified into the III and IV categories of methane hazard constitute a high-methane zone, which imposes the introduction of degasification as the most effective measure to combat methane hazard. Another issue is the impact of mining activity on the amount and distribution of methane in the coal formation.

The mines of KCHC belong to the northern region of the USCB, which is characterized by the presence of two zones of the depth of the methane occurrence in the rock mass in the vertical profile (e.g. KOTAS, 1994, Fig. 2):

1) The upper zone (to the depth of about 700 m), in which the coal seams contain almost no methane, since in the geological past they were naturally degassed during taking place for millions of years the uplift of the basin, accompanying it erosion of the Carboniferous rock mass and natural ventilation of the upper part of the rock mass (e.g. PĘKAŁA, 1992), while the thin and permeable cover of coal-bearing Carboniferous formation prevented the retention of migrating gases in the coal seams.

2) The lower, high-methane zone (below the depth of 700 m) in which the methane content in coal seams rapidly increases with depth until it

reaches a maximum at the depth of about 1000 to 1100 m, where the coal seams belong to III and IV category of methane hazard.

As it can be seen from the above, the coal extraction at the depth below 700 m in the mines of KCHC (and in most of the mines in the Upper Silesian Coal Basin similarly) will be exposed to a significant amount of methane in the coal seams (> 4.5 m³/t coal daf) and the associated hazard. However, in the area of KCHC mines, coal extraction over more than 200 years caused a change in the pressure in the rock mass, which in turn contributed to the secondary displacement of methane and exploitation degassing of large parts of the deposit (e.g, GRZYBEK, 2000, LUNARZEWSKI, 1998). This phenomenon was intensified by the process of methane drainage of the mines. As the consequence of these processes, there can be observed methane distribution in the mines different from the primary distribution in coal deposits, which consists mainly in the increase in the range of degassed zones and in the depth of the occurrence of high-methane zone.

Table 1. Categories of methane hazard in hard coal mines in Poland

Category of methane hazard	Methane content in coal seams [m³/t coal daf*]
non-methane coal seam	>0.1
I	0.1-2.5
II	2.5-4.5
III	4.5-8.0
IV	<8.0

*daf - dry ash free coal substance

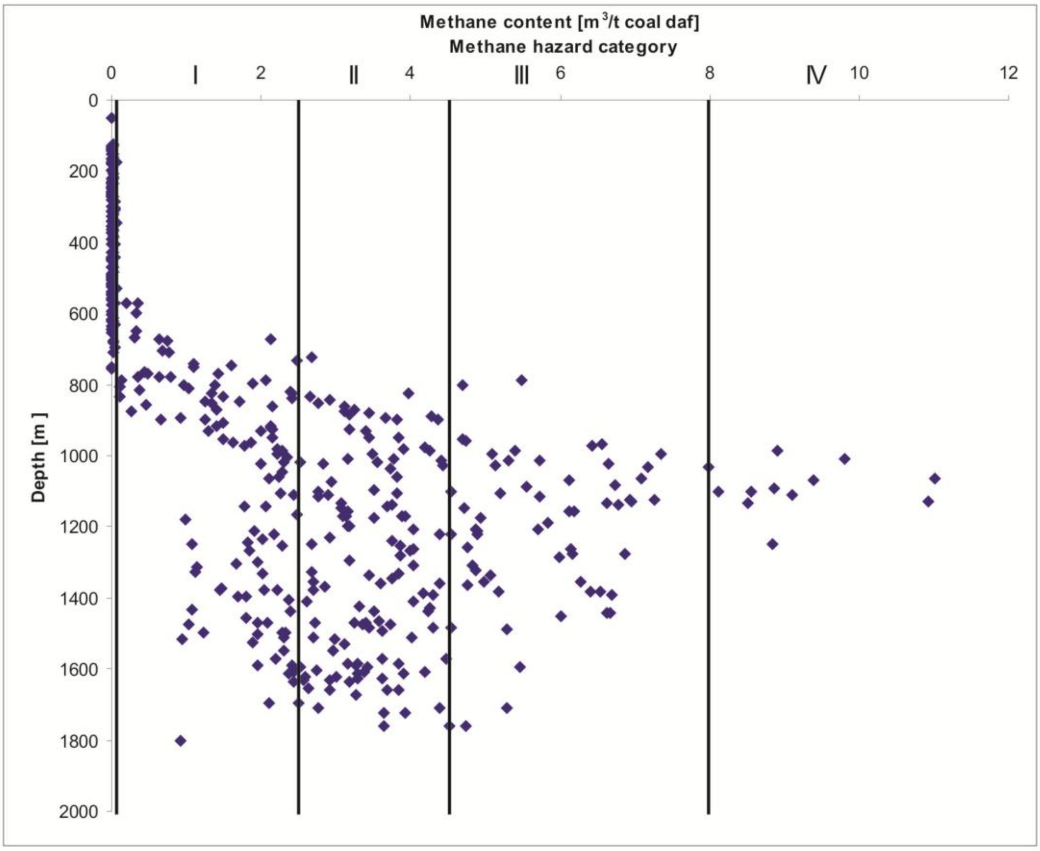

Fig. 2. Depth distribution of methane content and methane hazard categories in the coal mines of Katowice Coal Company (based on the data from bore-holes, the archive of Polish Geological Institute, Warsaw)

All the mines of KCHC are gassy and the coal extraction there is carried out in the conditions of every methane hazard category, at ever-deeper levels, where the hazard of methane explosion increases. The mines of the highest relative methane emission are, Mysłowice-Wesoła (about 15 m³/ t) and Murcki-Staszic (about 10 m³/t). These figures are the average values from the years 1997 to 2011. In these mines coal extraction takes place at the depth below 700 m, where methane content in coal seams varies significantly (> 2.5 m³/t coal daf) and often exceeds 8 m³/t coal daf, which corresponds to II-IV category of methane hazard. In the conditions of variable but high methane-bearing capacity of coal (II-IV category), the listed coal mines carried out their activity also in the seventies of the twentieth century (Kozłowski, 1982). It means that already then the activity descended onto the deposits levels of a significant methane content (>2.5 m^3/t coal daf) being a result of natural lithological and tectonic conditions. The lithological conditions manifest themselves in the presence of sealed packages of mudstone and sandstone rocks, retaining methane in the seams, while the tectonic ones, due to the presence of intersecting fault systems, conducting or retaining methane in the rock mass (e.g. Kędzior & Kulawik, 2005; Tarnowski, 1989).

4. Experimental

The object of this work is to present in a measurable way the total amount of methane emitted into the atmosphere by the mines owned by KCHC (Fig. 1), i.e.: Wujek Coal Mine, Murcki-Staszic Coal Mine, Mysłowice-Wesoła Coal Mine, Wieczorek Coal Mine, Katowice-Kleofas Coal Mine – abandoned, Niwka-Modrzejów Coal Mine – abandoned.

The studied period covered the years from 1997 to 2011. The reason for this time selection was the transformations undergone by individual mines, and in particular, the closure of two mines (Niwka-Modrzejów and Katowice-Kleofas) and a merger of the mines: Wujek and Śląsk, Mysłowice and Wesoła, as well as Murcki and Staszic. Moreover, during this time there was an increase in coal extraction of individual walls (the so-called 'extraction concentration') and coal extraction from ever greater depths in conditions of methane content of coal seams greater than previously.

The main source of methane emission in mines are methane bearing coal seams, but this gas is also liberated from waste rocks – sometimes, from the both of mentioned sources, through abandoned workings. The release of methane occurs in conditions of varying stress in the rock caused by mining activity. As it has been mentioned, the paper focuses on absolute methane emission. Below, the following constituent parts of this parameter are presented:

1) Ventilation methane emission, i.e. the amount of methane liberated into mining workings and then emitted by the mine through the ventilation shafts, together with ventilation air.

2) Methane emission from degasification systems, i.e. part of the methane released from coal seams which passes through a system of underground degassing but is not commercially utilized (it's released into the atmosphere by the degassing stations).

3) The amount of methane commercially utilized (not emitted into the atmosphere).

Absolute methane emission represents the sum of the values of the above three constituents.

Table 2. The volume of absolute methane emission, degasification and coal-mine methane utilization from the mines of the Katowice Coal Company (KHW) in the period of 1997-2011, after Krause & Sebastian (1998-2012)

Year	Coal output [mln t]	Absolute methane emission [mln m^3/y]	Ventilation methane emission [mln m^3/y]	Degasification [mln m^3/y]	Methane utilization [mln m^3/y]	Methane emission from degasification systems [mln m^3/y]	Methane emission into the atmosphere [mln m^3/y]	Utilization effectiveness [%]
1997	24.4	131.24	118.03	13.21	6.80	6.41	124.44	51.47
1998	20.9	133.73	116.43	17.30	9.16	8.14	124.57	52.93
1999	18.9	122.68	102.65	20.03	7.62	12.41	115.06	38.06
2000	18.8	117.75	91.87	25.88	5.97	19.91	111.78	23.05
2001	19.2	123.17	96.82	26.36	9.99	16.37	113.19	37.89
2002	19.0	124.86	97.58	27.27	11.08	16.19	113.77	40.64
2003	18.6	114.64	91.90	22.74	9.61	13.13	105.03	42.24
2004	18.5	114.35	91.73	22.62	9.04	13.58	105.31	39.95
2005	17.7	90.35	73.97	16.38	7.24	9.14	83.11	44.21
2006	15.2	95.66	79.28	16.38	7.24	9.14	88.42	44.21
2007	15.4	116.92	99.64	17.28	8.44	8.84	108.48	48.83
2008	14.0	125.46	105.11	20.35	7.38	12.97	118.08	36.30
2009	12.9	127.17	107.17	20.00	7.60	12.40	119.57	38.00
2010	12.3	136.49	114.39	22.10	9.80	12.30	126.69	44.34
2011	12.7	129.26	107.63	21.63	8.80	12.83	120.46	40.68
total	258.5	1803.74	1494.19	309.55	125.77	183.78	1677.97	41.52*

* average value from years 1997-2011

The above figures were expressed in millions of cubic meters over each year, and afterwards they were skimmed off (Table 2). The estimated amount of the methane emitted into the atmosphere was compared to the volume of the gas commercially used, what allows to discuss briefly the problems connected with utilizing the captured gas in the next chapters of the paper.

5. Results and discussion

Variations in absolute methane emission from the mines of KCHC as well as in the amount of methane emitted into the atmosphere and commercially utilized in the years 1997-2011 are illustrated in Fig. 3a and b. In the case of the first of the above values, a downward trend is visible until 2005, then there is a growth trend up to 2010 and a slight decrease in 2011. The situation is different in the case of the variability of the methane commercially utilized – it indicates a quite stable trend (6-10 millions m^3/year) (Fig. 3b) with a slight increase in 2002.

The changes in the volume of coal output in KCHC in this period are shown in Fig. 3c, which shows a steady decline from 24 million tons in 1997 to 12 million tons in 2010 and 2011. The aforementioned decrease in the intensity of methane emission from KCHC mines up to 2005 can be explained by the decline in coal extraction and closure of the Katowice-Kleofas and Niwka-Modrzejów mines. In 2005, there were noted both the lowest annual absolute methane emission and the amount of methane emitted into the atmosphere equal to 116.92 million m^3 and 83.11 million m^3 respectively.

Since 2006 there has been observed an increase in the quoted volumes – up to 125.46 million m^3 (absolute methane emission) and 118 million m^3 (methane emitted into the atmosphere) in 2010. The growth may be related to the development and exploitation of coal seams of a high methane content (III and IV categories of methane hazard), occurring at a greater depth, and to the growing concentration of coal extraction. The increase in absolute methane emission in KCHC mines after 2005 has been occurring despite the apparent decline in coal extraction. The slight decrease in absolute methane emission in 2011 did not significantly affect the growth trend observed since 2006.

The amounts of the methane emitted and coal extracted from the coal mines are listed in Table 2. It turns out that during the presented fifteen years KCHC mines released 1803.74 million m^3 of methane, about 1678 million m^3 of which were emitted into the atmosphere, while the remainder of the approximately 126 million m^3 were used for economic purposes. The methane emission to the atmosphere include methane released through ventilation shafts together with ventilation air (1494 million m^3) and emitted by degasification stations (so-called methane exhaust – 183,7 million m^3). This points out that the vast majority of methane emitted into the atmosphere comes from the ventilation shafts (82.8% of absolute methane emission). Unfortunately, at the moment we are not able to use it commercially, due to, among others, excessively rarefied methane (only 1%) in mine air. Despite intensive work on this issue (e.g. NAWRAT, 2011), technologies for the utilization of ventilation air methane (VAM) are still very expensive.

The continuous degassing of workings is carried out by the Mysłowice-Wesoła, Murcki-Staszic and Wujek mines. Among the listed mines, merely Mysłowice-Wesoła and Murcki-Staszic utilize the captured methane for themselves and sell it to external customers. The efficiency ratio of utilizing the methane transferred to the degassing station, in the case of Myslowice-Wesoła mine amounted to almost 81% in 2011, while in the Murcki-Staszic mine (Staszic mining area) was slightly more than 23% (KRAUSE & SEBASTIAN, 1998-2012). The methane obtained from degassing Mysłowice-Wesoła mine (Wesoła mining area) is used, among others, to produce thermal energy by Heat and Power Station, plc in Katowice (ZEC). The share of methane in the production of thermal energy by ZEC Katowice, in the heating season 2009/10 amounted to about 6.5%. The rest fell on hard coal (www.zec.katowice.pl). Apart from this, in 2012 two gas engines were installed at Wieczorek mine for combustion of methane transported through a gas pipeline from Staszic mining area and generation of thermal energy. Other mines of KCHC have not undertaken such an enterprise, mainly for economic reasons, as the expenditure on the development of methane station is far greater than the income generated from the sale of methane (KĘDZIOR & KULAWIK, 2005). Since Wujek mine has not been utilized the captured methane, it can be assumed that on average almost 60% of the methane collected by KHW mines is released into the atmosphere. Attempts to increase the efficiency of utilization of the captured methane encounter various problems, which include (KĘDZIOR, 2009b, NAWRAT ET AL., 2008):

1) a lack of gas storage in the mines which would allow its retention during the periods of lower demand for methane fuel from wiring systems,

2) a low methane content in the mine gas and an unstable gas molecular composition (it is a

methane-air mixture of an average methane content of 40-60%),

3) a lack of the correlation between the processes of coal seams degasification and energy processes due to the fact that methane drainage of coal seams is treated as a technology ensuring mining safety,

4) economic difficulties of the coal mines in the past and underestimating the potential income from this kind of activity.

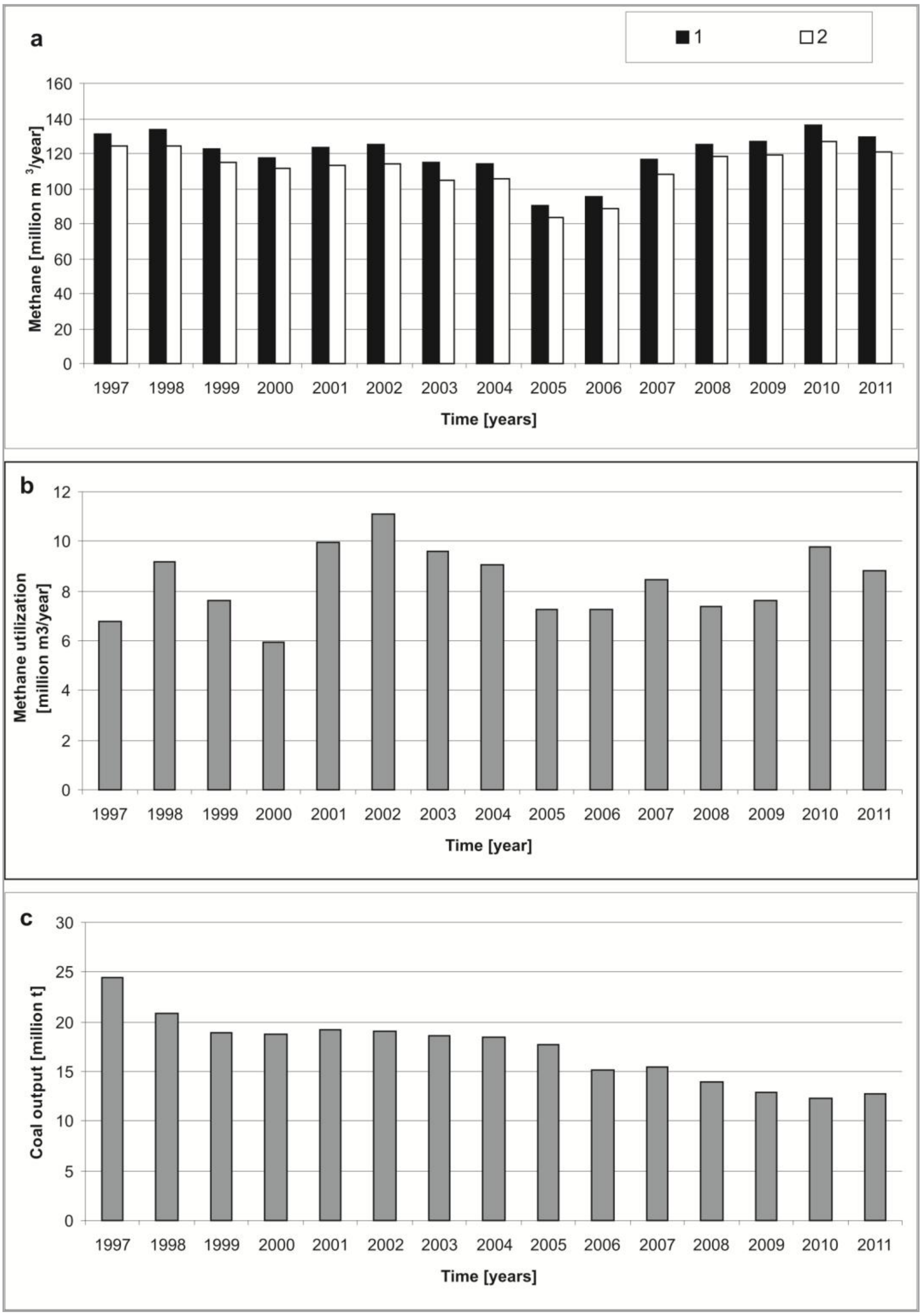

Fig. 3. Methane emission (a), utilization (b) from the mines of Katowice Coal Company compared to coal output (c), after Krause & Sebastian (1998-2012)
1 – absolute methane emission, 2 – methane emission into the atmosphere

A certain improvement to the situation may be brought by the amendments to the energy law providing for classifying methane as an unconventional resource, which, in turn, will oblige electricity retailers to have in their offer also electricity obtained from this gas or in the absence thereof, to pay a substitution fee. This pro-environmental action, following the example of Western European countries (especially Germany), should contribute to a significant improvement in the efficiency of the production and utilization of methane by coal mines, which may lead to the development of the large-scale high-tech coal-mine methane collection (e.g. NAWRAT ET AL., 2012), and coal-bed methane collection, i.e. from undeveloped coal deposits (e.g. GONET ET AL., 2010; KĘDZIOR ET AL., 2007; KWARCIŃSKI & HADRO, 2008).

While estimating the total volume of methane emission into the atmosphere, the post-mining processes and coal storage should not be ignored. Taking into account the mentioned post-mining activities and coal processing, which constitute 14% of total emission (GAWLIK & GRZYBEK, 2002), it can be estimated that the total methane emission to the atmosphere in the years 1997 to 2011 amounted to 1951.1 million m^3. In comparison, over a similar period in the southern part of the Upper Silesian Coal Basin, from the mines owned by Jastrzębie Coal Company (JSW) and a few mines of Coal Company (KW) approximately 4,000 million m^3 of methane were emitted, which is more than twice as much (KĘDZIOR, 2009b). It should be stressed, however, that the southern and south-western parts of the basin are characterized by the most complicated methane conditions and the highest methane-bearing capacity of the deposits across the entire basin.

Fig. 4a and b and Table 3 show the values of absolute methane emission, methane emission to the atmosphere and the utilization of the captured gas for the whole Polish part of the USCB. As it can be seen from these figures, the annual amount of methane emission to the atmosphere remained at a constant level, slightly exceeding 600 million m^3 by 2002; and in the following years there was an upward trend to almost 725 million m^3 in 2008, then there was observed a decline to 662.5 million m^3 in 2011 (Fig. 4a). The increase in methane emissions to 2008 occurs despite a decrease in the coal extraction, just like it was in the case of KCHC (Fig. 4b). It shows that the vast majority of the USCB mines are beset with the problem of extracting coal from the coal seams with a high methane content, located at greater depths (oscillating around 1000 m). The progressive concentration of coal mining is also not insignificant.

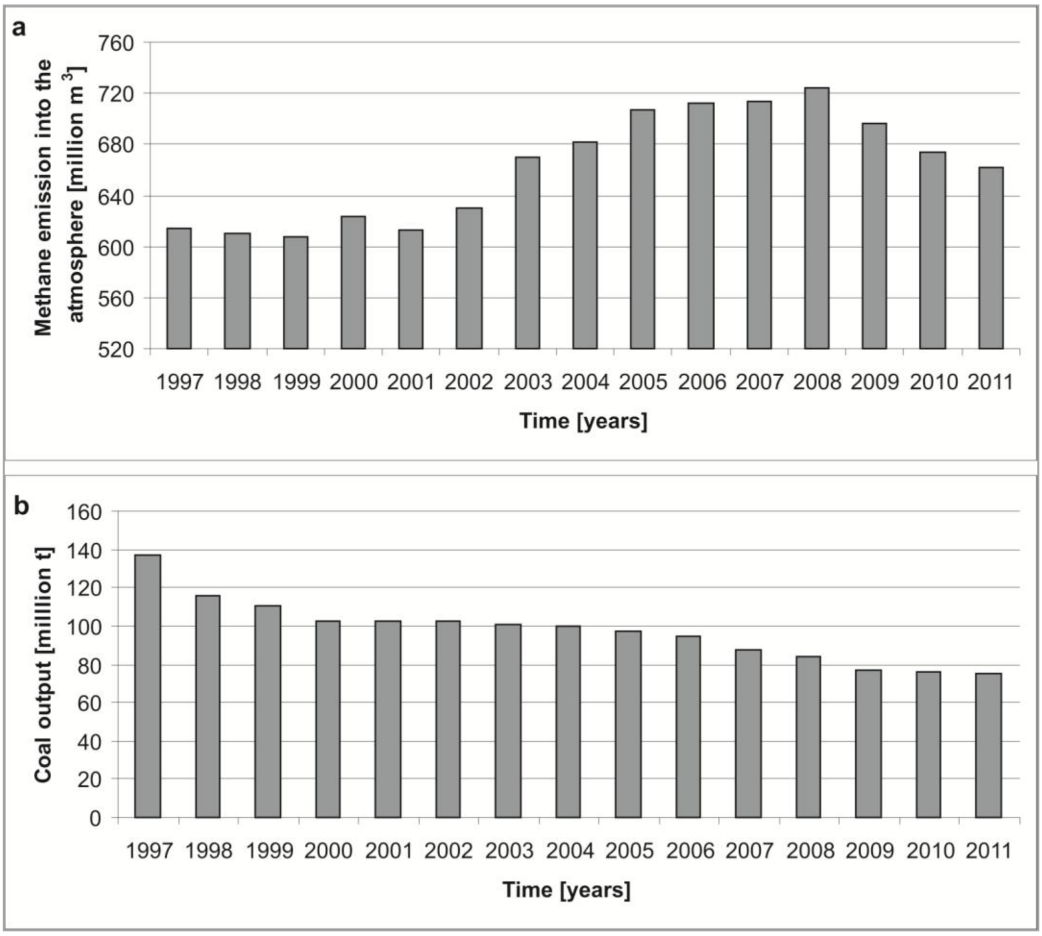

Fig. 4. Methane emission into the atmosphere from the coal mines of the USCB (a) compared to coal output (b), after Krause & Sebastian (1998-2012)

Table 3. Absolute methane emission and the quantity of methane collected, utilized and emitted into the atmosphere in the USCB, after Krause & Sebastian (1998-2012)

Year	Absolute methane emission [million m^3/year]	Methane quantity [million m^3/year]			Number of coal mines	Coal output [million t]
		collected	utilized	emitted into the atmosphere		
1997	748.4	192.5	134.4	614.0	61	137.1
1998	763.3	203.6	152.7	610.6	57	115.9
1999	744.5	216.1	136.9	607.6	47	110.4
2000	746.9	216.1	124.0	622.9	42	102.5
2001	743.7	214.3	131.5	612.2	42	102.6
2002	752.6	207.3	122.4	630.2	42	102.1
2003	798.1	227.1	127.8	670.3	41	100.4
2004	825.9	217.2	144.2	681.7	39	99.5
2005	851.1	255.3	144.8	706.3	33	97.1
2006	870.3	289.5	158.3	712.0	33	94.3
2007	878.9	268.8	165.7	713.2	31	87.4
2008	880.9	274.2	156.5	724.4	31	83.6
2009	855.7	259.8	159.5	696.2	31	77.3
2010	834.9	255.9	161.1	673.8	32	76.1
2011	828.8	250.2	166.3	662.5	31	75.5
Total	12124	3547.9	2186.1	9937.9		1461.8

The question is whether does the observed decrease in absolute methane emission and methane emission into the atmosphere (in the USCB after 2008 and in the KCHC mines after 2010) means the reversal of the growth trend and steadying of the dynamics of the methane release from the mines or a temporary transitional fluctuation only?

In the view of analysis of the growth trends of the intensity of methane release from the USCB mines in 2006-2008 and from KCHC mines in 2006-2010, and consequently its emission to the atmosphere (Figs. 3 and 4), it cannot be ruled out, however, that this phenomenon will exacerbate in the coming years, which certainly will not be indifferent to the air quality in the region and the greenhouse effect. Profitable methane utilization as local fuel is the one way to permanently stunt the growth of methane emissions from coal mines, which along with the positive environmental aspects brings also economic benefits. Other ways should include, among others: intensification of degassing of coal seams in underground hard coal mines, utilization of methane from the mine ventilation air and – following in other countries' footsteps – the legislative recognition of methane as a fuel from renewable sources (Nawrat, 2011).

6. Conclusion

The methane accompanying the deposits of hard coal emitted from the mines into the atmosphere is second only to carbon dioxide the main greenhouse gas, with a radiative forcing capacity 21-25 times greater than CO_2. Methane emission from hard coal mines is therefore a major environmental problem. In the years of 1997-2011, the mines of KCHC released a total of 1951.1 million m^3 of methane, the largest part of which – 1494 million m^3, came from the ventilation shafts. From 2006 to 2010, there has been observed an increase in the methane emissions from the coal mines of KCHC despite the decline in coal extraction, which points out that the mining activity was carried out at increasingly great depths, where the amount of methane in the seams was larger. Although there was a slight decline in the methane emission in 2011, its intensification in the future cannot be excluded. Therefore one of the ways to mitigate this phenomenon there is a profitable utilization of the methane captured by degassing stations to meet local needs. Currently, the average rate of methane utilization in the mines of KCHC is low – only 41.5%, which reflects, among others, economic and legislative problems related to the reconstruction of the degassing stations and selling the collected methane. The proposed amendments to the Energy Law, consisting in categorizing coal mine methane as a non-conventional and renewable source of energy, should help to intensify the use of mine methane. The measure will have an environmental dimension, since each tonne of methane combusted is the equivalent of effective reduction in emissions by more than 18 tons of carbon dioxide, if the difference in the radiative forcing power of both gases is taken into consideration. The described growth trend in the methane emissions from the coal mines along with a decline of coal extraction is characteristic for the entire Polish part of the USCB and compels adopting an integrated approach to this problem, since the mitigation of this greenhouse gas emissions into the atmosphere will bring not only environmental but also economic benefits.

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