Tools available for methane recovery from mines belonging to C.E.H. Petroşani

Emeric Chiuzan[1] and *Adrian* Matei[1]

[1]National Institute for Research and Development in Mine Safety and Protection to Explosion – INSEMEX, 32-34 G-ral Vasile Milea Street, Petroșani, Hunedoara, Romania

Abstract. Mine gas is present both in coals and in the surrounding rocks and basically consists of methane (some-times almost 100%) mixed with carbon dioxide (up to 5%) with nitrogen (a few percent) and traces of carbon monoxide. The genesis of mine gas can be related to the biochemical transformation of vegetation during the carbonization process.

The degassing of coal bed has been established as an active method of reducing methane emissions due to the need to ensure the exploitation of the bed with high productivity and in safe conditions.

The methane gas existing in the coal bed is captured through various types of drilling executed for this purpose, being directed through a system of pipes to the surface to the central degassing station from where it can be taken and directed for use for a specific purpose.

From an economic point of view, it has been proven that methane recovery from coal mines is again a profitable activity for both the mining company and a possible investor. The volume of methane from the coal deposits in Jiu Valley is very large and can provide large quantities for the recovery of this gas. At the same time, there was already a market for this product in Jiu Valley made up of industrial and individual consumers.
Keywords: coal, methane, ventilations

1. Methane gas

Methane (CH_4) is the main component of mine gas (fire damp mine) produced as a result of the anaerobic transformations of plant residues during the carbonization process.

Mine gas is present both in coals and in the surrounding rocks and consists mainly of methane (sometimes up to 100%) mixed with carbon dioxide (up to 5%), nitrogen (a few percent), hydrogen and with counterparts of methane (1% to 4%) and traces of carbon monoxide. The genesis of mine gas can be linked to the biochemical transformation of vegetation during the carbonization process.

The presence of mine gas in the surrounding rocks can be based on two causes, namely: either the migration of the mine gas from the coal to the accumulation rock, or the surrounding rock contained organic components that underwent the same biochemical and geochemical trans-formations as the coal (for example - the presence of coal shales).

Methane is a colorless, odorless and tasteless gas, with a density of 0.7168 kg/m^3. It is chemically inert and in small quantities is not harmful. Compared to air, it has a relative density of 0.554 and diffuses 1.6 times faster than it.

There are two forms of methane storage:

- free gas;
- bound gas.

2. Methane release

During exploitation, the gas stored in the cracks, at high pressures, migrates to areas of low pressure (cuts, exploitable spaces, galleries). The resulting pressure drop produces the desorption phenomenon that occurs either until the coal gas pressure approaches the mine workings air pressure or until rock recompression closes the cracks.

[1] Author to whom all correspondence should be addressed: E-mail: emeric.chiuzan@insemex.ro

A part of the destressed area corresponds to the daily progress of the mining front, but the release of methane from this part does not occur entirely during the same day, for the following reasons:

- the phenomenon of cracking occurs progressively over time;
- the flow resistance of the crack system opposes the release of methane, especially in remote areas;
- the release rate is limited by the desorption kinetics of the coal.

The influencing factors of methane emissions are:

a. Production
   a.1. Forward speed
   a.2. The length of the front
   a.3. The exposed surface
b. Mode of deviation
c. Mode of directing pressure
d. The thickness of the exploited layer
e. Barometric pressure

3. Degassing of coal bed and surrounding rocks

3.1. The need for degassing

The degassing of coal bed has been established as an active method of reducing methane emissions due to the need to ensure the exploitation of the bed with high productivity and in safe conditions [1].

The principle of degassing consists in capturing and draining a significant part of the amount of methane in the coal bed (the base layer or non-exploitable bed), from the sterile rocks or the exploited areas and the evacuation through sealed pipes to the surface (central degassing) or in a stream of contaminated air in which it is possible to dilute it, below the limits allowed by the rules (local degassing).

The use of degassing allows reducing the amount of air that must be introduced into the mine, thus reducing aeration expenses.

The expenses related to degassing can be covered and sometimes even obtaining benefits through the industrial exploitation of the captured methane.

To capture methane from coal bed in operation, prior degassing is applied with boreholes drilled in the layer. The most advantageous degassing schemes are those with ascending boreholes whose efficiency is 1.1 - 1.5 times higher than that of descending boreholes.

3.2. The situation of external degassing

The degassing of the neighboring unexploitable coal bed is based on the capture of methane from the bed influenced by the exploitation of the base layer. The method is more efficient in the case of bed with a low inclination, the degassing efficiency reaching 60-80%. In bed with high inclination, the efficiency of degassing of the rock package is at most 30 - 40 %. On a smaller scale, methane capture with drainage tunnels (Czech Republic and Germany) and capture with the help of holes drilled from the surface (Russia) are used.

The degassing of sterile methane bearing rocks is carried out with the help of boreholes, drilled approximately perpendicular to the natural cracking direction of the rocks. The process is used in Poland and the Czech Republic and reduces methane emissions by 30-80%.

The degassing procedures of the exploited spaces are limited by the local technical-mining conditions. The simplest procedure is the drainage of gases with the help of sections of drainage pipes inserted into the exploited space. In Russia, Germany, France and Poland, by isolating the old works, the efficiency of degassing increases to 50 - 60%.

The capture of gases behind the isolation dam that isolate the exploited areas is carried out with mixtures of 60 - 70% vol. CH_4.

The need for degassing must be linked to the increase in the level of security underground as well as to the reduction of aeration expenses as a result of the movement of the quantities of methane emitted, respectively to the possibility of the advantageous utilization of methane [2].

The mining front and their related galleries are sometimes areas of maximum choke of the aeration circuits. The particularly high resistances encountered in the exploitation areas cause the limitation of increasing air flows and additional expenses related to the proper ventilation of the works by digging new wells, reprofiling galleries and culverts.

Numerous researches and observations made in Poland and the Czech Republic during the large-scale application of degassing allowed to establish that at an absolute methane flow rate of 5-6 m^3/min in the secondary aeration circuits, the dilution of gases only by aeration is uneconomical and the degassing is the appropriate solution.

4. Application of deggasing

Determining the feasibility of degassing mines involves a detailed analysis of the complex of factors that influence methane emissions, a forecast of methane emissions, a diversified analysis of the aeration factor, a clear knowledge of the coal reserve and exploitation dynamics, as well as qualitative criteria and quantitative [3], [4].

For the specific conditions of the mines in Jiu Valley, these criteria are expressed by:

• the ability to dilute methane through aeration at the limit speeds imposed by the degree of comfort and to avoid raising coal dust;

• methane concentrations at the intersection of the mining front with the head gallery or in the exploited space and the limitation of the mining front production according to the maximum allowed concentration:

• prevention of gas-dynamic phenomena during the execution of mining works in the bottom of the bag.

4.1. Degassing in the central system

At the units belonging to C.E.H. Petroşani, degassing in the central system is applied to the Lupeni, Vulcan and Livezeni mines, which are equipped with such installations.

The central degassing installations are located on the surface of the mine, they are equipped with 4 groups of vacuum pumps for gas suction, they are of Polish origin and have the following characteristics:

- flow rate: Q = 25 m^3/min;
- maximum suction depression: H = 4.000 mm H_2O;
- maximum discharge pressure: P = 3.000 mm H_2O;
- engine power: N = 75 kw;
- speed: n = 735 rpm.

Degassing at the mentioned units was achieved by capturing methane from boreholes drilled underground and by capturing methane from old works (exploited space).

The research undertaken by INCD INSEMEX Petroşani over the years regarding the degassing of the massif of rocks, led to the development of framework methods for degassing depending on:

• the type of mining works;
• exploitation method;
• the thickness of the coal bed;
• tilting of the coal bed.

Among the existing degassing framework methods, the most used are:

- frame method, type "C" - which is applied to the execution of preparatory mining works that cross a coal bed of great thickness, or a package of bed;
- frame method, type "G" - which applies to coal bed with an inclination of up to 350, which are mined with frontal cuttings, the retreating method;
- frame method, type "H" - applies to coal bed with inclinations of up to 350 which are mined with front cuttings, the advance method.

5. Evaluation of methane from mines in Jiu Valley

From an economic point of view, it has been proven that methane recovery from coal mines represents a profitable activity both for the mining company and for a possible investor. The volume of methane in the coal deposits in Jiu Valley is very large and can provide large quantities for the recovery of this gas. At the same time, there was already a market for this product in Jiu Valley consisting of industrial and individual consumers [1], [5].

The methane gas existing in the coal bed is captured through various types of drilling executed for this purpose, being directed through a system of pipes to the surface to the central degassing station from where it can be taken and directed for use for a specific purpose.

Before sending the gas to the user, the water is separated from the gas.

Coal bed methane production must be continuous to ensure a gas flow of constant pressure and concentration to be commercially reliable.

The methane thus obtained at a central degassing station, with an average flow of 4 m^3/min, at an average concentration of 60% can be used for:

- production of domestic hot water;
- heating a living space or the space of a commercial company;
- heating a small residential area;

Table no. 1 and graph no. 1 show the amount of methane gas captured at the main degassing stations from the mines in Jiu Valley and the amount of methane utilized for energy production, during the years 2014-2021.

Table no.1 The amount of methane extracted through degassing

Nr crt.	Mine Unit	THE QUANTITY OF METHANE (tons/year)								Total	Total used
		2014	2015	2016	2017	2018	2019	2020	2021		
0	1	2	3	4	5	6	7	8	9	10	11
1.	**Lupeni**	34,08	60,47	48,32	69,15	66,05	60,31	62,55	121,96	522,89	396,53
2.	**Vulcan**	455,49	489,33	465,2	316,34	395,17	386,43	345,22	609,34	3.462,52	3.462,52
3.	**Livezeni**	503,15	523,25	550,43	420,67	389,60	143,44	148,19	133,44	2.812,17	--

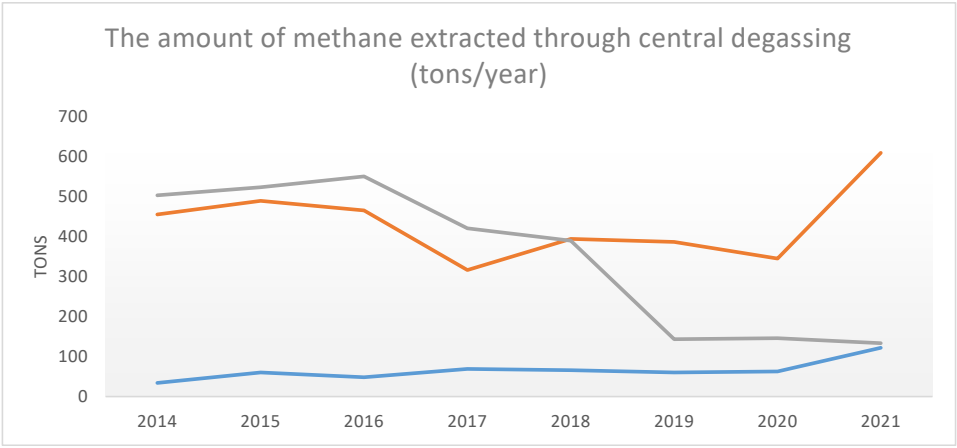

Chart no. 1 The amount of methane extracted by central degassing

The total amount of methane extracted by the three central degassing stations in the period 2014-2021 was 6.671.22 tons, of which the total used was 3.859.050 tons, approximately 70% of the total extracted.

At the same time, in the period 2014-2019, (2019 being the year the mine was closed), E.M. Paroşeni extracted a total amount of 3.110.530 tons of methane through central degassing, methane that was not used.

The quantities of methane extracted with the help of local degassing facilities from the mines belonging to C.E.H. over the years they were not accounted for, they were found in the flows from the central ventilation stations.

Currently, methane extracted with the help of central degassing plants is used as follows:

-At E.M. Lupeni - within the thermal power plant inside the mine equipped with two boilers for hot water.

-At E.M. Vulcan has in operation two boilers for heating domestic water from the miners' bathrooms.

-At E.M. Livezeni is the problem with methane recovery in the sense that the degassing station is at a great distance from the mine site. The only possibility would be to use methane gas at the nearby sawmill, for the production of domestic hot water and hot air necessary for the technological flow.

The coal production achieved at the three mines can be found in table no. 2 and graph no. 2.

Table no. 2 The amount of coal extracted

Nr crt.	Mine Unit	QUANTITY OF COAL MINED (tons/year)								Total
		2014	2015	2016	2017	2018	2019	2020	2021	
0	1	2	3	4	5	6	7	8	9	10
1.	**Lupeni**	448.445	365.723	164.494	217.764	180.791	120.992	86.234	47.292	1.631.735
2.	**Vulcan**	241.482	246.819	189.680	157.453	144.135	145.816	147.000	105.954	1.568.019
3.	**Livezeni**	242.834	181.338	190.867	110.503	118.364	108.419	132.586	58.992	1.143.903

The total coal production achieved during the period 2014-2021 by the three mining units was 4.343.657 tons.

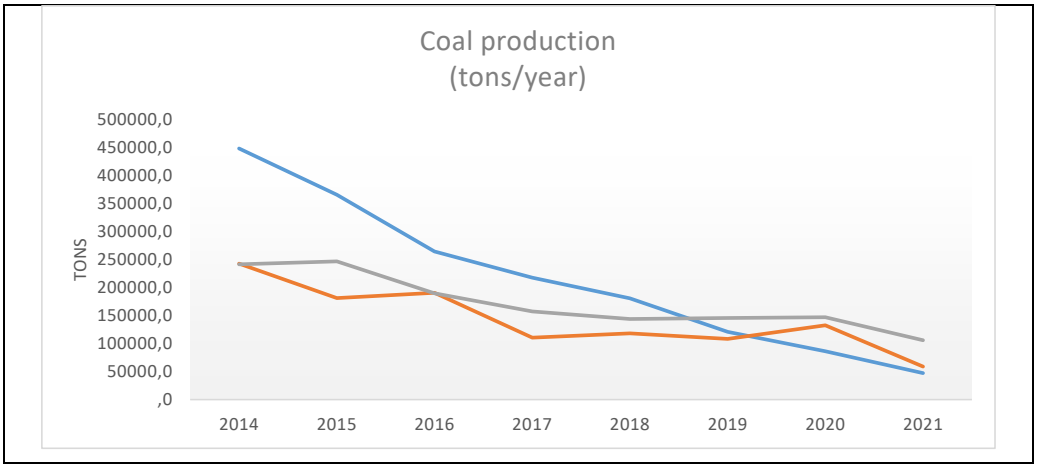

Chart No. 2 Coal production 2014-2021

6. CONCLUSIONS

1. Mine gas is present both in coals and in the surrounding rocks and consists mainly of methane (sometimes up to 99,9%) mixed with carbon dioxide (up to 5%), with nitrogen (a few percent), with hydrogen and with counterparts of methane (1% to 4%) and traces of carbon monoxide.
2. The degassing of coal bed has been imposed as an active method of reducing methane emissions due to the need to ensure the exploitation of the bed with high productivity and in safe conditions.
3. The degassing procedures of the exploited spaces are limited by the local technical-mining conditions. The simplest procedure is the drainage of gases with the help of sections of drainage pipes inserted into the exploited space. In Russia, Germany, France and Poland, by isolating the old works, the efficiency of degassing increases to 50 - 60%.
4. The total coal production achieved during the period 2014-2021 by the three mining units was 4.343.657 tons, of which;
-E.M. Livezeni 1.143.903 tons;
-E.M. Vulcan 1.568.019 tons;
-E.M. Lupeni 1.631.735 tons.
5. The total amount of methane extracted by the three central degassing stations in the period 2014-2021 was 6.671.220 tons, of which:
-E.M. Livezeni 2.812.170 tons;
-E.M. Vulcan 3.462.520 tons;

-E.M. Lupeni 396.530 tons.

6. Total methane reused at the Vulcan and Lupeni mines was 3.859.050 tons.

7. During the period 2014-2019, Paroșeni Mining, (2019 being the year the mine was closed), extracted a total amount of 3.110.530 tons of methane through central degassing, methane that was not exploited.

This work was carried out through the NUCLEU Program within the National Research Development and Innovation Plan 2022-2027, carried out with the support of MCID, project no. PN 23 32 02 03 - The superior valorization for energy purposes of coal deposits under the conditions imposed by environmental strategies (VSMET).

REFERENCES

[1] E. Chiuzan, Annual report to the Ministry of Water Environment and Forests, National Agency for Environmental Protection, INCD INSEMEX Petroșani

[2] ECONOMIC COMMISSION FOR EUROPE METHANE TO MARKETS PARTNERSHIP Best Practice Guidance for Effective Methane Drainage and Use in Coal Mines

[3] L. Jurca, Risk assessment and system development environmental protection regarding gas emissions explosive and toxic in mining areas with mines subject to closing process, INCD INSEMEX Petroșani

[4] C. Lupu, Methane in Coal Mines, INCD INSEMEX Petroșani

[5] D. Tamas, E. Chiuzan, Reducing methane emissions at the main ventilation stations at the mines in Jiu Valley by improving methods of its recovery and verification from the coal layers, INCD INSEMEX Petroșani