Gas drainage in coal mines: current condition and prospects

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Abstract. The article reviews scientific and engineering information on history, current
condition and prospects of use for various technologies of gas drainage in coal mines,
including the use of methanotrophs.

1. Introduction

Methane is one of the main products of plant fossil conversion into coal and is therefore present in all
carbonic formations. Generation and further geological history of coal seams govern natural gas
content of coal, which varies in wide ranges—from units to hundreds cubic meters of methane per ton
of coal. Gas volume in coal mines is measured in cubic meters of methane per ton of produced coal; it
depends both on natural gas content of coal and on the mining system, in particular, on pre-mining gas
drainage efficiency [1]. With increasing depth of mining, a stable upward trend in methane content
and methane migration to roadways, as well as in probability of coal and gas outbursts is observed in
mines. Experts assess methane emission from coal seams as up to 30 billion cubic meters, which is
commensurable with recovery volume of associated petroleum gas in oil fields in Russia, including
25.5 cubic meters of methane emission in underground coal mining. Not more than 5% of this gas
volume is annually processed [2].

2. Drainage technologies

Currently there is a number of coal seam methane drainage techniques based on the idea of re-
distribution of stresses and strains and alteration of physical and mechanical properties of rock mass.
These techniques include overmining and undermining of coal seams, hydraulic fracturing and
dynamic treatment of rock mass to stimulate methane flow. The recent research and development
projects deal with technologies for gas drainage in unloaded coal seams before mining is started, with
a view to scale-up production of coal mine methane. However, the methods of methane content
reduction in coal mines are not always effective, thus, new techniques and approaches are required to
reduce methane content in coal-bearing strata and in mined-out longwalls.

In particular, Kirov and Kotinskaya mines of SUEK Company implement in-mine methane
drainage using boreholes drilled from ventilation and (or) conveyor drifts. The boreholes spaced at 15
m are connected to a main pipeline to pump methane out to ground surface. The lifetime of the
boreholes until approach of longwall face is from a few months to a half a year. Successful wellhead
sealing ensures methane content at a level of 60–80% in recovered gas.

Integrated gas drainage technology seems to be of considerable interest. In this case, permeability
of a coal seam is improved by hydraulic fracturing using surface boreholes, while methane is
recovered by means of in-seam boreholes. The in-seam drainage boreholes maintain high-rate methane flow as they intersect large fractures created in the course of hydraulic fracturing.

Coal seam gas drainage while mining is the most widely used technology. Economic soundness of concurrent mining and gas drainage is explained by short payback periods as drainage boreholes are introduced into service concurrently with coal production, within a few months [3].

The technology and procedure of pre-mining drainage of coal seams to ensure safe operation of miners and commercial-scale recovery of methane is applied in mines of EVRAZ. Pre-mining drainage in mines with super-high methane content uses an innovative technology of Plasma Pulse Treatment (PPT). This method involves treatment of a coal seam by plasma impulses. Treatment is carried out in liquid medium, and nothing is pumped in boreholes in this case. A shock wave is generated in liquid and is then initiated at points set across the whole thickness of a coal seam on a periodical basis. A gas bubble expands in liquid in the form of a shock wave, propagates radially and compresses the medium until the shock wave pressure becomes equal to the seam pressure. Then, the medium starts expanding toward the wave source. Compressive and tensile stresses induce secondary permeability in the seam by connecting natural cleavages into a single network. Furthermore, gas bubbles, after kinetic energy of fluid is lost, collapse in a micro second and induce hydrodynamic shocks with appropriate acoustic noise, which greatly stimulates microfissuring vertically and horizontally in the seam [4].

The PPT technology features zero encroachment on the stress–strain behavior of coal seams as against the methods of hydraulic splitting and hydraulic fracturing. Alternatively, periodic wideband plasma impulses generate compressive and tensile stresses, which improves permeability of coal without alteration of its physical and mechanical properties, or quality [5].

At the same time, scientists and experts think minor impacts are incapable to shake a coal seam, and the proposed technology is insufficiently backed up by practical results.

Thus, the current methods of methane content reduction in coal seams are not always efficient, and it is necessary to find new approaches to decreasing content of methane both in coal-bearing strata and in mined-out roadways.

Scientists-biotechnologists propose using methane-utilizing bacteria (methanotrophs) for this purpose. One scenario is pre-mining coal seam drainage by pumping suspension of methanotrophs in the seam and creating living environment for them. Another variant is treatment of mined-out voids with suspension of methanotrophs directly during coal mining. In this case, a bacteria filter is across methane flow from the neighbor coal seams as a result of drop in the coal pressure [7].

The use of methanotrophs for coal seam gas drainage was for the first time ever proposed by Soviet scientists in the 1930s [8]. Later on, a method of methane emission combating in mines by injection of methanotrophs in the seam together with nutrient was developed [9]. The team of the Moscow Mining Institute greatly contributed to geotechnical advancement of this problem [10]. Microbiology aspects were the area of concern for the research activities at the Zabolotny Institute of Microbiology and Virology, NASU, Ukraine [11], Institute of Protein Synthesis [12] and at the Skryabin Institute of Biochemistry and Physiology of Microorganisms, USSR Academy of Sciences [12, 14]. In this method, a coal seam is treated with suspension of methane-oxidizing microorganisms to create the favorable physicochemical environment. Microorganisms, while penetrating coal pores, intensely absorb methane. Microbiological treatment of coal seam can use in-mine boreholes as well as surface boreholes drilled before mining [15], including exploratory wells.

The use of methanotrophs seems to represent the most promising approach to reduction of methane concentration in mine air [10, 14]. In this method, a coal seam is subjected to air jetting after injection of suspension of methanotrophs in coal and to spraying of exposed rocks in mined-out area with such suspension. Bacteria lively absorb methane, and methane content of coal and mine air decreases by 30–70% as a result [13].

For the first time, microbiological treatment of coal was implemented in Yasinovskaya-Glubokaya mine by the Polyakov Institute of Geotechnical Mechanics, NAN of Ukraine, to test the ability of methanotrophs to reduce gas content in mined-out longwalls [7].
Thus, methanotroph-based biotechnologies can be applied to reduction of methane concentration in coal seams in two ways: in operating mines and in explored coal fields being prepared for mining. In the former case, the efficient methods to treat coal seams and roadways are injection and spraying of suspension of methanotrophs, as well as biosynthesis of gaprin in captured methane and air mixture. The latter way can involve biosynthesis of gaprin in captured methane and air mixture and biotechnology of methanotroph water flowing of coal seams, which is a nature-like biotechnology and, intrinsically, represents an in-seam bioreactor for chemostat-based biosynthesis of gaprin.

3. Use of methane
Methane captured in coal mines is of interest both for science and business. Methane is used already as a fuel for steam boilers and combustion engines, in metallurgy, as a feedstock for the chemical industry, in the public utility industries, in power generation and in manufacture of stone tiles [16, 17]. The economic efficiency of methane use projects was evaluated in [18] in two most popular technologies: power generation by gas generator plants and heat generation during methane combustion at package boilers.

From the evaluation, electric power generation needs much capital input at lower economic efficiency as compared with heat generation at package boilers. For another thing, economic efficiency of coal methane utilization projects is governed by many different factors, including electricity rates, heat supply rates, prices of power-generating coal and methane emission charges.

4. Conclusion
Due to objective causes, including scientific reasons, methanotrophs lack application in methane content reduction in coal mines, though, according to many experts, this trend seems to offer the best prospects in gas drainage improvement in coal mines [19–21].

References
[1] Kravtsov A I 1979 Gas Content of Coal Fields in the USSR (Moscow: Nedra) vol 1
[2] Tailakov O V, Zastrolov D N et al 2015 Vestnik KuzGTU 6(112) 41–46
[3] Ivanov Yu M 2011 Gorn. Inform.-Analit. Byull. 363–367
[4] Attack on methane Ugol Kuzbassa 2018 4 81–84
[5] Ageev B P, Ageev P G and Desyatkin A S 2105 Gorn. Prom. 5(123) 169–174
[6] Shiryaev S N, Ageev P G and Desyatkin A S 2020 Ugol Kuzbassa Jan.-Feb. 2020 70–73
[7] Myakenkii V I and Kudrish I K 1991 Microbiological Oxidation of Coal Mine Methane (Kiev: Naukova dumka)
[8] Yurovskii A Z et al 1939 Ugol 7(48) 41–45
[9] Ksenofontova A I et al 1964 USSR Author’s Certificate No 1888442
[10] Moskalenko E M and Nesterov A I 1975 Mikrobiologich. Prom. 22–24
[11] Kudrish I K et al 1976 Microbiological Approach to Reduction of Methane Content in Coal Mines (Tashkent)
[12] Grigoryan A N, Gorskaya L A et al 1968 Mikrobiologich. Sintez 4 50–56
[13] Galchenko V F 2001 Methanotrophs (Moscow: GEOS)
[14] Ivanov M B 1988 Vestnik AN SSSR 3 pp 70–73
[15] Mshenskii Yu N and Ilchenko V Ya 1976 Microbial Biophysics and BioEngineering: Collected Works (Leningrad: Nauka)
[16] Bulat A F and Chemeris I F 2002 Ugol Ukrainy 6 81–86
[17] Coal Seam Methane: Conversion of the Resources to Energy World Coal 2002 vol 11 no 12 pp 50–51
[18] Tailakov O V, Islamov D V and Zastrolov D N Gorn. Inform.-Analit. Byull. 7 71–76
[19] Nikitenko S M 2006 Innovatsii 4(91) 3–5
[20] Glukhikh S A 2014 Method to improve food security Kombikorma No 6 pp 18–23
[21] Glukhikh S A 2015 Kombikorma 5 31–36