

PAPER • OPEN ACCESS

## Gas explosion hazard in underground coal mining in Kuzbass

To cite this article: EA Kozlovsky *et al* 2019 *IOP Conf. Ser.: Earth Environ. Sci.* **262** 012036

View the [article online](#) for updates and enhancements.



**IOP | ebooks™**

Bringing you innovative digital publishing with leading voices to create your essential collection of books in STEM research.

Start exploring the collection - download the first chapter of every title for free.

## Gas explosion hazard in underground coal mining in Kuzbass

**EA Kozlovsky<sup>1</sup>, GN Sharov<sup>1</sup>, AE Kontorovich<sup>2</sup>, GI Gritsko<sup>2</sup>, FA Kuznetsov<sup>3</sup>,  
MV Kurlenya<sup>4\*</sup>, VA Kovalev<sup>4</sup>, VI Rostovtsev<sup>4</sup>, IM Belozherov<sup>5</sup>,  
VA Tchernook<sup>5</sup>, VA Minin<sup>6</sup> and NYu Vashlaeva<sup>7</sup>**

<sup>1</sup>Institute of Geological-Economical Problems, Russian Academy of Natural Sciences, Moscow, Russia

<sup>2</sup>Institute of Gas-Oil Geology and Geophysics, Siberian Branch, Russian Academy of Sciences, Novosibirsk, Russia

<sup>3</sup>Institute of Inorganic Chemistry, Siberian Branch, Russian Academy of Sciences, Novosibirsk, Russia

<sup>4</sup>Chinakal Institute of Mining, Siberian Branch, Russian Academy of Sciences, Novosibirsk, Russia

<sup>5</sup>Novosibirsk Branch of the State Specialized Design Institute, Novosibirsk, Russia

<sup>6</sup>Institute of Geology and Mineralogy, Siberian Branch, Russian Academy of Sciences, Novosibirsk, Russia

<sup>7</sup>Kemerovo Region Administration, Kemerovo, Russia

E-mail: \*kurlenya@misd.ru

**Abstract.** The data on gas compositions are obtained in a Kuzbass mine by the Novokuznetsk Detached Force of Militarized Mine-Rescue Unit. The analysis of 1200 mine air samples, as for instance, in Alarda mine, shows that the extreme values of fire-hazardous gas contents are (% by volume): max 0.8 for hydrogen, max 28.3 for methane, and min 0.8 for oxygen. The conclusions are drawn about possible concept of neutron–proton structure of the core being the source of hydrogen and hydrocarbon-bearing gases releasing from the subsoil of the Earth as well as about potential applicability of chemical technology for removing hydrogen from the gas mixture to increase its explosion safety.

### 1. Introduction

Media systematically inform on tragedies connected with explosions of combustible gases and mass deaths of people in coal mines both in Russia (Kuznetsk, Pechora, Sother Yakutia coal basins, etc.) and abroad (Kazakhstan, China, New Zealand, Ukraine, etc.). For example, Central mine (Darasun, Chita Regiona) in September 2006, Ulyanov mine in Kuzbass in March 2007, or Rospadskaya mine in Kuzbass as well in May 2010. Unfortunately, this list is to be continued.

Today any more or less educated man would routinely explain explosion of gas mixture in coal mine as a blast of methane-and-air mixture containing airborne coal dust. Is this true? Let us analyze the situation more carefully. Air with sufficient content of oxygen enters underground excavation from ventilation system, the origin of dust is clear too. The source of methane formation is yet obscure.



## 2. The content of gases in the mine atmosphere according to the measurement results

We address geo-sciences and physical chemistry. Methane  $\text{CH}_4$ , as natural combustible gases of propane  $\text{C}_3\text{H}_8$  and butane  $\text{C}_4\text{H}_{10}$ , currently produced in colossal amounts, are the chemical compound of two elements—carbon C and hydrogen H (sometimes with small additions of other elements—oxygen, nitrogen and sulfur). These are typical hydrocarbons [1, 2]. In a natural variety of hydrocarbons, methane is chemically distinct by being a saturated limit substance molecule of which contains maximum number of hydrogen atoms—4—per one atom of carbon as hydrogen occupier all 4 possible valence bonds of carbon. Naturally, such substance of limit composition, in accord with the chemical laws, can be originated under conditions when one of the compounds is in essential excess—hydrogen in our case [1, 2]. Put it otherwise, methane in any natural gas is a reliable sign of the presence of hydrogen. This thesis was illustrated by the Academician RAS Adushkin who with his scholars found that the composition of combustible gases which heavily emitted in the open pit mine at Udachnaya kimberlite pipe in the south-west of Yakutia was “to 50% hydrogen and the rest was methane” [3]. By the data of ZapSibGeologiya geologica service, gas emissions from jointed dolerite and sandstone in Southern Kuzbass at a depth of 2200 m contain up to 8.5% hydrogen. There are many such examples.

Where carbon is from in coal mines is a rhetorical question as the mechanism of centuries-long circulation of carbon and its transformation, through carbon dioxide (owing to biosynthesis), to coal, among other things—a mineralized product of natural origin. The puzzle is presented by hydrogen which, aside from the known natural circulation mainly through water, has permanently been escaping the Earth in huge amounts (round 1 Bt annually) [4–10] in the form of light gases (hydrogen and methane) for 4.5–5 billion years. (Classical geo-sciences have sadly little opportunity to explain the origin of this hydrogen and only offer a theoretical hypothesis on capture of gas from a once breathing protoplanet cloud). At the present time, escape of hydrocarbons and light gases (hydrogen, helium) from the subsoil is energetically investigated and discussed in the framework of scientific conferences held by the Russian Academy of Sciences (Institute of Petroleum Problems, Schmidt Institute of the Earth's Physics) [7, 8, 10]. It is worthy of mentioning that, owing to the research findings of the Skobel'syn Research Institute of Nuclear Physics at the Lomonosov Moscow State University, Geophysical Center of the RAS and other scientific institutions [11–14], a neoteric hypothesis has been put forward to explain the described phenomena and their infinite horizon [15, 16, 1, 6, 17].

According to this hypothesis, hydrogen, which forms inside the Earth during natural self-decomposition of free neutrons outflowing from the Earth's interior, and which is partly in the transient state of extremely chemically active atomic form [1, 2], continuously hydrogenates, including carbon-bearing components of coal, up to the limiting methane state, and turns into a more stable molecular form. When methane and hydrogen enter mine air, a three-component mixture of methane, hydrogen and air is appears.

It is known that, by explosibility, properties of oxygen or air mixed with hydrogen or methane strongly differ. Figuratively, stoichiometric mixture of oxygen (air) and hydrogen, called a detonating mixture, might be primed by a patch of sunlight. In the meanwhile, a methane-bearing mixture (similarly to household propane–butane in a kitchen) to be fired needs a temperature of a burning match. The temperature difference in initiation of interaction between hydrogen- and hydrocarbon-bearing mixtures is 150–200°C to the disfavor of the latter [1, 6, 2]. For this reason, it seems justified to suppose that combustible gases play different parts in the three-component air+methane+hydrogen mixture. Hydrogen is a detonator (it is primed first), while methane (similarly to coal dust), even at excessive concentration, acts as a fuel, though it definitely can detonate under more complex conditions (concentration, temperature, etc.), and so does a pure methane-and-air mix. This fact supposedly offers a way of improving coal mine safety by maximum possible reduction of hydrogen concentration in the gas mixture. Naturally, this theory needs experimental approval with all testing, project and other procedures. Considering properties of two-component methane-and-air mixture, it would be naïve to expect the the risk of explosion would completely vanish with hydrogen removed from from the gas mixture. Still, a noticeable increase in explosion safety of coal mining is quite realistic [9].

Regarding coal dust, it would be very unwise to treat it as a fuel during experiments. Initially organic, coal (and coal dust, accordingly) cannot but have micro-porous volumetric structure featuring sensible absorption capacity in dry air. As a consequence, that any gas component reaches higher concentrations in bulk or on the outward surface of a coal particle (dust). In this case, the coal particle saturated with hydrogen and/or methane can be a provoker and/or catalyst of an undesirable voluminous process. It is also expedient to emphasize that adsorption properties of coal differ per mines, which would require preliminary absorption tests to be carried out in specific coal mines.

The methane–hydrogen concept of gas explosion hazard in underground coal mining was to be checked, in particular, it was required to find hydrogen in coal mine air. To this end, the comprehensive analysis was undertaken to dig the data obtained in January–April 2011 in operating Alarda mine of Yuzhkuzbassugol. The gas composition of mine air was determined at the Novokuznetsk Detached Force of Militarized Mine-Rescue Unit and kindly provided by second in command of the brigade, General A. P. Eruslanov through the assistance of S. V. Popov, head of Research Laboratory.

In the bulk of the mine air samples, 41.0 % of the samples were taken routinely; 25.7 %—as a matter of urgency; 33.3 %—in an emergency. A specific flow sheet of coal mining was characterized by 1195 samples. The basic data in the sample analysis were the contents of oxygen, methane and hydrogen. The picture to describe gas explosion risk in Alarda mine is presented in Table 1.

**Table 1.** Gas composition of air in Alarda mine.

Place in the mine	Sampling point	Sampling number			Extreme contents, % by volume			Fire events
		Total	Including hydrogen		min O <sub>2</sub>	max H <sub>2</sub>	max CH <sub>4</sub>	
		samples	samples	%				
Near the actual operation site	Underground	14	10	71.4	13.6	0.4	8.6	—
Gus suction from longwall no. 6-1-14	Ground surface	100	70	70.0	18.6	0.032	2.9	—
Conveyor roadway 3-39; railway incline 3-3	Entrance	105	66	62.9	15.2	0.22	9.8	—
Behind brattices	Underground	545	297	54.5	0.8	0.79	28.3	105
Hole from the mined-out void of longwalls	Ground surface	61	21	34.4	1.7	0.17	19.4	19
Hole no. 8065	Ground surface	107	72	67.3	5.0	0.77	17.9	8
Other	Underground	6	5	83.3	4.6	0.24	15.5	—
Total		938	541	57.7	0.8	0.79	28.3	132

It is seen in Table 1 that:

- hydrogen is present in more than 50 % of the samples;
- oxygen content reduces from natural ( $\approx 21$  % by volume) to 0.8–5 % by volume in some places; the maximum decrease is observed in the mined-out and poorly ventilated void;
- hydrogen concentration grows from 0.032 % by volume (at the gas suction from operating longwall) to 0.79 % by volume (in mined-out void);
- methane content grows from 2.9 % by volume in the longwall to 28.3 % by volume in the mined-out area;
- each 6th sample was taken during gas combustion with the majority of fires (round 80 %) took place in the mined-out unventilated voids behind brattices.

It follows from the aforesaid that the critical situations with approaching overall combustion of gases intervene in mined-out area behind brattices which are unventilated or ventilated via holes.

The available information enables assessment of gases in the mined-out voids. In Alarda mine, there were 63 mined-out voids, in three voids (behind brattices nos. 115, 1187 and 1189), long-lasting fires took place. These voids, according to the database at hand, were under systematic monitoring by the Novokuznetsk independent mine rescue brigade, and 287 samples (53 % of the overall sampling) were taken in them. Out of 63 voids, hydrogen was present in 297 cases (54.5 % of total number) in 27 voids (42.9 %). The gas composition of air behind brattices in these three critical voids is characterized in Table 2.

**Table 2.** Gas composition of air behind brattices in critical mined-out voids in Alarda mine.

Brattice no.	Sampling			Extreme contents, % by volume			Fires	
	Total	Including hydrogen		min O <sub>2</sub>	max H <sub>2</sub>	max CH <sub>4</sub>	events	%
	samples	samples	%					
1115	87	40	46.0	1.0	0.02	28.3	20	23.0
1187	113	106	93.8	0.8	0.69	24.4	24	21.2
1189	87	85	97.7	1.4	0.79	24.9	24	27.6
Total	287	231	80.5	0.8	0.79	28.3	68	23.4

It follows from Table 2 data that these three critical voids encompass all extreme values of the analyzed parameters, namely, hydrogen presence in the samples (to more than 90 % of cases), extreme concentrations of oxygen (minimum) as well as hydrogen and methane (maximum) in the samples.

Thus, the information on Alarda mine discloses that:

—hydrogen is present at various concentrations in the majority of the samples taken at different points in the mine;

—the critical mined-out voids behind brattices being damaged or failed can be the source of accidents and emergencies in the mine.

The presented concept of unavoidable origination of fire and explosion hazards in coal mines and the illustrative data obtained in an operating mine proved another outlook of the nature and mechanism of hazardous gas mixtures. The change in vector of activities in the field of coal mine safety from methane to hydrogen, or, more specifically, hydrogen-and-methane, is an absolute innovation and will surely bring new beneficial effects. This certainty ensues from the fact that early in the 21st century, which can be regarded as the age of oncoming hydrogen energy generation, scientists and practitioners in many countries created and successfully operated systems and facilities capable to ensure complete safety of operations with much amounts of hydrogen (power generation, chemistry, metallurgy, space technologies, etc.). It is quite justified to assume that adaptation of such technologies and equipment to methane–hydrogen and other similar gas mixes in underground mineral mining will be one of the top-priority avenues of R&D for many research institutions in mining and the related sciences.

### 3. Conclusions

The resonance problem of occupational safety improvement in mining runs beyond the territorial borders of west Siberia and Russia as a whole. Accordingly, this problem can and is to be solved only if backed up by a solid foundation provided by science, physical infrastructure and finance with all-support of the government. By now, this problem can be handled by such a mighty scientific institution as the Russian Academy of Sciences represented by its Siberian Branch and, first of all, by the Kemerovo Research Center with the created Coal Science City technologically and financially bolstered by the whole Kuzbass. Successful management and advance in this area requires dedicated administration and research headquarters, an experimental test ground as one or a number of operating mines, as well as an

extensive program of time-urgent R&D projects. A special emphasis should be laid on prompt authorization of data obtained by the domestic researches and designer within the framework of these projects.

Innovative approaches and knowledge require that society acknowledges them and undertakes vigorous measures toward their vivid advancement. To be fair, this concept of hydrogen and hydrocarbon formation in coal mines is not equally supported by this paper co-authors. However, this is not an obstacle for the co-authors team in integrating efforts in the analysis of the proposed mechanisms of fire and gas explosion risk in coal mines with intent to find ways of reduction (and, maybe, elimination) of these fatal hazards, which is an absolute priority.

## References

- [1] *The Great Soviet Encyclopedia* 1970–1978 Moscow: Sovetskaya Entsiklopediya Vols 1–30 (in Russian)
- [2] *Condensed Chemical Encyclopedia* 1961–1967 Moscow: Sovetskaya entsiklopediya Vols 1–5 (in Russian)
- [3] Adushkin VV, Kudryavtsev VP and Khazins VM 2006 Hydrogen degassing of the Earth and ozone anomalies Dokl. Akad. Nauk Vol 406 No 2 pp 241–243
- [4] Uchitel AD and Gushchin VV 1981 *Vibratory Discharge of Rocks* Moscow: Nedra (in Russian)
- [5] Voitov GI 1986 Chemistry and the scale of modern flow of natural gases in different geostructural zones of the Earth *Zhurnal Ross. Khim. Ob-va im. D.I.Mendeleeva* Vol 31 no 5 pp 53–60
- [6] Kozlovskiy EA, Belozero IM, Minin VA and Sharov GN 2011 Gas explosion hazard in underground coal mining *New Ideas in the Earth Sciences: X International Conference Proceedings* Moscow: Extra-Print Vol 2 (in Russian)
- [7] Larin VN and Larin NV 2008 Hydrogen degassing on the Russian Platform *Degassing of the Earth: Geodynamics, Geofluids, Oil, Gas and Their Paragenesis—All-Russian Conference Proceedings* Moscow: Geos pp 267–269 (in Russian)
- [8] *Degassing of the Earth Geotectonics, Geodynamics; Oil, Gas; Hydrocarbons and Life—All-Russian Conference Proceedings* Moscow: Geos 2010 (in Russian)
- [9] Portnov AM 2010 Volcanoes—hydrogen reservoirs *Prom. Vedomosti* no 10–12 (158–161)
- [10] Syvorotkin VL 2002 *Deep Degassing of the Earth and Global Catastrophes* Moscow: Geoinformatsentr (in Russian)
- [11] Volodichev NN, Kuzhevskiy BM, Nechaev OYu et al 2002 Earth's crust—An active source of neutrons *Vestnik MGU. Fizika. Astonomiya* No 5 pp 69–73
- [12] Gorshkov GV, Zyabkin VA et al 1996 *Natural Neutron Background of the Atmosphere and Earth's Crust* Moscow: Atomizdat (in Russian)
- [13] Kuzhevskiy BM 2011 Gravity of celestial bodies and neutron flows *Nauka v Russii* No 5 (125) pp 12–19
- [14] Shestopalov IP and Kharin EP 2006 Time-to-time variability of the relationship between the Earth seismicity and different duration cycles of the Sun activity *Gefiz. Zh. Inst. Geofiz. NAN Ukrainy* Vol 28 no 4 pp 59–70
- [15] Belozero IM 2008 Nature through the eyes of physicist *International Scientific Journal for Alternative Energy and Ecology (ISJAEE)* No 12(68) pp 8–58
- [16] Belozero IM, Mezentev LN, Minin VA and Mitkin VN 2011 The Earth—an active source of neutrons and hydrogen *State-of-the-Art in the Earth Sciences: Proceedings of the International Conference devoted to V. E. Khain memory* Moscow: MGU pp 211–215 (in Russian)
- [17] Emelyanov VS (Ed) 1958 *Condensed Encyclopedia of Atomic Energy* Moscow: Bolshaya sovetskaya entsiklopediya (in Russian)