

Assessing the Unaccounted Environmental Pressure Caused by Endogenous Fires on the Rock Dumps of Kuzbass Overburden Rocks

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Abstract. A statistical data analysis is carried out to investigate the pollutant emissions in the largest cities of Kuzbass. The study found that gases such as methane, carbon oxide and hydrogen are the main pollutants. It has been explained that endogenous fires of coal producers mainly release the gases. The amount of releasing gases from the surface of the rock dump over the endogenous fire has been analyzed. Unaccounted environmental pressure caused by endogenous fires on the rock dumps of Kuzbass overburden rocks has been identified.

1. Introduction

In mining enterprises fires are one of the main causes of accidents leading to huge casualties, great economic losses and damage to the ecological environment. Among all types of fires, a special attention is paid to endogenous fires in coalmines that usually occur because of coal spontaneous combustion in the goaves [1, 2].

Endogenous fires take and develop due to coal accumulation in the goaves and under conditions of oxygen supply to the oxidizing surface area of the fractured coal. Coal accumulation can occur because of sinking equipment as well as fractures of the coal seams [3]. Rock pressure contributes to the destruction of the coal and the formation of its accumulations in goaves of whole coal. Such fires are difficult to detect at an early stage and determine the location of the fire source [4].

As a result, hazardous gases can release into the environment both previously contained in rocks and newly formed due to different components interaction [5, 6].

The works of many scientists, in particular, Skritsky V.A., Igishev V.G., Lindenau N.I., Portola V.A. [7-9] describe various methods for detecting endogenous fires at an early stage. One of the effective methods for detecting spontaneous combustion sites is considered to control indicator gases released from the surface of the earth [10]. Thus, gases released during combustion (CH₄, CO, H₂) are carried to the surface from the mine workings and form a so-called gas anomaly in the surface layer, which can be used to detect foci of endogenous fires and determine their location. Such anomalies can be detected with the help of superficial gas surveys, which are usually used when searching for deposits. However, in the literature there is almost no data on accounting for the amount of released gases. To date, there is only one method of superficial gas survey to determine the amount of hazardous gas emitted from the surface of the earth [11].

One of the most common gases in mines is methane that is formed in the result of metamorphism of vegetation. Methane releases into the environment in the process of broking coal and releasing of rock



pressure in coal seams. The main danger of methane is its ability to burn and explode from ignition source.

Leaking through the soil methane inhibits the activity of microorganisms and vegetation leading to their death. Methane is a greenhouse gas, which releases into the environment from mines and causes the increasing the planet's atmosphere temperature. Moreover, methane emitted into the atmosphere is 21 times more dangerous than carbon dioxide [12].

Toxic gas of carbonic oxide is intensively formed in underground fires, released during the destruction and low-temperature oxidation of coal.

Thus, when the endogenous fire occurs in in the goaf under conditions of lack of oxygen the concentration of carbon monoxide can reach 10 - 15 % with the maximum permissible concentration in the mine atmosphere of 0.0017 %. Additionally, carbon monoxide is a flammable gas capable of exploding at concentrations in the air from 16 to 74 %.

If sulfur impurities are present in the anthracides, SO₂ sulfur dioxide is formed during fires. The gas is highly toxic and one of the basic components of volcanic gases. As is well known, the greatest danger is the pollution of sulfur compounds that are released into the atmosphere by burning coal, oil and natural gas as well as by smelting metals and producing sulfuric acid.

When blasting takes place toxic nitrogen oxides are released into the mine atmosphere in small quantities. The main source of nitrogen oxides are combustion processes at temperatures over 1000 °C.

According to statistical data methane ranks first in Kuzbass in the total amount of recorded emissions from stationary sources. A statistical data analysis of emissions for the last decade indicates that methane emissions account for more than 50 % of the total mass of all emissions. Mezhdurechensk and Leninsk-Kuznetsky are the largest sources of methane emissions with 82 % and 81 %, respectively. The reason of the fact is that the coal industry dominates these areas. Thus, there are 6 mines, 5 mining plants and 5 dressing plants in Mezhdurechensk. Leninsk-Kuznetsky has billion tonnes reserves of coal. At present, coal mining is carried out in 4 mines that are part of the branch of Plc «SUEK-Kuzbass» [13]. The lowest methane emissions are recorded in Kemerovo. This is determined by the fact that Kemerovo is a central city of a region and has no operating mines. Therefore, manufacturers of electrical energy, gas and water distribution pollute the environment.

Obtained results allowed to conclude that the largest carbon monoxide emissions are observed in Novokuznetsk (> 60 %), the least emissions are recorded in Mezhdurechensk (6.75 %). Due to metallurgical production along with production, transmission and distribution of electrical energy, gas, steam and water Novokuznetsk has a large mass of CO emissions. The total CO emission is about 20 % of all other emissions in the region.

Compared to other emissions sulphur dioxide emissions in the region are about 8 % of the total. Moreover, the largest number of emissions is observed in Kemerovo (24.8 %), the smallest – in Mezhdurechensk (1.57 %). The analysis of nitrogen dioxide emissions showed that it is emitted about 5 % of the total emissions, the largest number again recorded in Kemerovo (more than 25 %); the least emissions are in Leninsk-Kuznetsky (1.57 %).

According to the results of the assessment of the components of gaseous emissions in the largest cities of Kuzbass for a 10-year period, it was revealed that the territory of the city of Novokuznetsk is exposed to the greatest pollution from stationary sources (Fig. 1). Significant emissions are also observed in Mezhdurechensk and Leninsk-Kuznetsky. The main contribution to air pollution is made by emissions of hydrocarbons (methane), in particular, in Mezhdurechensk, Leninsk-Kuznetsky and Prokopyevsk. In Novokuznetsk, the main share of emissions is carbon monoxide.

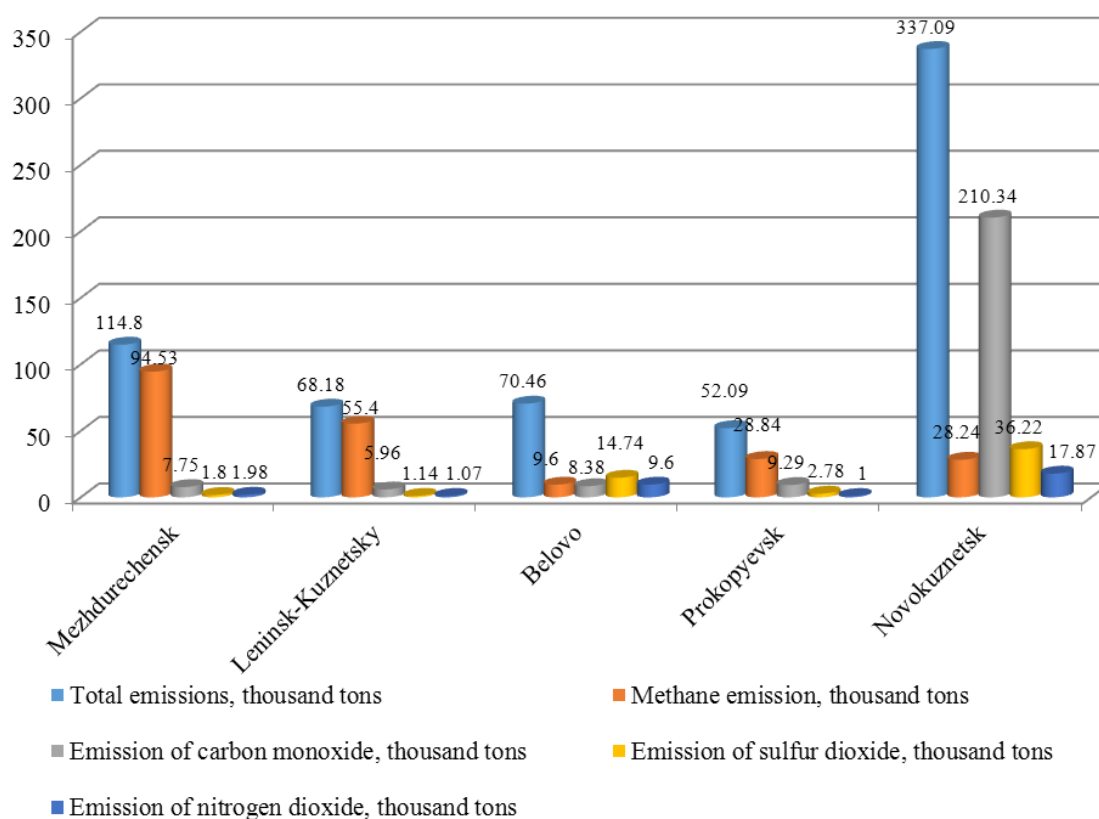


Figure 1. Averaged values of gaseous emissions over the period from 2006 to 2015 on cities of Kuzbass

It should be noted that the analysis was conducted only on organized emission sources. However, unorganized sources of emissions make a significant contribution to air pollution, in particular, accidental emissions caused by explosions and fires at enterprises, which have so far not been sufficiently taken into account when assessing the level of air pollution.

2. Materials and Methods

To evaluate the amount of hazardous gas emitted from the soil surface area, the method of gas surveying above ground was used [14] providing the installation special containers on the soil. The container has the following characteristics: its diameter is 16 mm and its height is 90 mm. The edges of the container are deepened into the soil and the gas is sampled through a special spout. The concentration of the gas emitted from the soil in the containers gradually increases and a portable gas analyzer carries out its measurement. The following relationships are used to determine the specific flow of gas evolution from the surface:

$$q = \frac{V_0 \cdot C}{S \cdot \tau_0} \quad (1)$$

where q – the flow of gas released into the atmosphere $\text{m}^3 / (\text{s} \cdot \text{m}^2)$;

V_0 – volume of the container, m^3 ;

τ_0 – the timing of the container before a measurement, s ;

C – the concentration of gas in the container after timing in the proportion of units;

S – contacting area of the container with the soil surface, m^2 .

As a result of the conducted researches [15], to measure the specific flows of gases on the soil surface area, it is sufficient to keep insulating containers from 30 seconds to 5 minutes. Therefore, it is possible to keep the containers 2 minutes (or 120 seconds).

To measure the total gas evolution from the entire surface of the gas anomaly (the place of a possible underground fire), it is necessary to divide the entire gas evolution zone into areas with approximately the same concentration of dangerous gas in the above-surface air layer. Then, at each site, the specific flow of the gas emitted from the surface is determined by the formula (1). It is proposed to determine the total flow of gas coming from the earth's surface by the formula (2):

$$Q_s = \sum_{i=1}^n q_i \cdot S_i \quad (2)$$

where n – number of areas on the earth's surface with gas evolution;

q_i – specific gas flow at the i -th area, $m^3/(c \cdot m^2)$;;

S_i – area of the i -th surface area, m^2 .

To assess the impact of emissions from rock dumps, a study was conducted on the mining allotment of LLC «Mine «Zenkovskaya» (Prokopyevsk), where the inactive burning rock dump is located. In 1950 the rock dump was put into operation. Its volume is $834700 m^3$, its height is 59 m and an area of base is $36400 m^2$, slope gradients are 38-400.

Studies on the release of carbon monoxide, hydrogen and methane from the surface of the rock dump were carried out on the area of an active fire. Determination of the content of carbon monoxide, hydrogen and methane in the air was carried out by a portable gas analyzer APG-1.

To determine the sampling points, a 10 m grid was placed over a total area of $600 m^2$ (Fig.2). In the grid nodes mining holes were drilled having a depth of about 30 cm and a diameter of 30 mm. On the surface of the well containers were established to measure the specific flow of gases. 12 check points were selected on the surface of the rock dump with different rock temperatures. The first measurement was carried out in June at an ambient temperature of $25 ^\circ C$. Repeated measurement was made in September at an ambient temperature of $15 ^\circ C$.



Figure 2. Sample points location on the surface of burning rock dump (Scale 1:2000)
The results of measurements and calculations of specific flow of gases are given in Table 1.
The following values were taken: the volume of the container – $0.018 m^3$, contacting area of

the container with the soil surface – 0.02 m², the time of keeping the gas in the container – 120 s.

Table 1. Results of subsurface gas survey and calculations of specific gas flow from the rock dump surface

Check points	Concentration CO, %	Concentration H ₂ , %	Concentration CH ₄ , %	Specific flow CO, 10 ⁻⁶ , m ³ /s·m ²	Specific flow H ₂ , 10 ⁻⁶ , m ³ /s·m ²	Specific flow CH ₄ , 10 ⁻⁶ , m ³ /s·m ²
1 June	0	0	0	0	0	0
September	0	0	0	0	0	0
2 June	0.001	0	0.01	0.075	0	0.75
September	0.001	0	0.01	0.075	0	0.75
3 June	0.003	0.001	0.01	0.225	0.075	0.75
September	0.0035	0	0.06	0.26	0	4.5
4 June	0.008	0	0.2	0.6	0	15
September	0.0042	0.0008	0.01	0.31	0.06	0.75
5 June	0.002	0	0.2	0.15	0	15
September	0.0005	0	0.01	0.037	0	0.75
6 June	0.0022	0.002	0	0.165	0.15	0
September	0.001	0.001	0.08	0.075	0.225	6
7 June	0	0	0.08	0	0	6
September	0	0	0.05	0	0	3.75
8 June	0.0005	0.003	0	0.037	0.225	0
September	0.001	0.004	0	0.075	0.3	0
9 June	0	0.016	0	0	1.2	0
September	0	0.015	0.07	0	0.125	5.25
10 June	0	0.008	0.1	0	0.6	7.5
September	0	0.0062	0.12	0	0.46	9
11 June	0	0.01	0	0	0.75	0
September	0	0.008	0.05	0	0.6	3.75
12 June	0	0.006	0.05	0	0.45	3.75
September	0	0.006	0.05	0	0.45	3.75

Taking into account that the area of the *i*-th surface area is 100 m², the total flows of gases coming from the earth were calculated. The total flow of the *i*-th gas was calculated from the maximum value of the two measurements. The results of the calculations are given in Table 2.

Table 2. Values of the total flow of hazardous gas emitted from the surface of the burning rock dump

Gas emitted	Value of the total flow, m ³ /s
Carbon monoxide	0.13·10 ⁻³
Hydrogen	0.366·10 ⁻³
Methane	6.9·10 ⁻³

According to present calculations, 11.232 m³ of carbon monoxide, 31.6 m³ of hydrogen and 596.16 m³ of methane are released from the investigated rock dump area per day. In terms of gross emissions, this is 0.09 t/year of CO, 0.018 t/year of H₂ and 2.83 t/year of CH₄. In total, this is about 3 t/year, i.e. 0.2 % of the recorded gross emissions of pollutants from stationary sources.

3. Conclusions

The results of statistical data analysis of the pollutant emissions indicate that the Kemerovo region is a territory with a significant anthropogenic impact on the environment. Among all recorded emissions methane emissions prevail (53.28 % of the total), significant are emissions of CO (21.12 %), SO₂ (about

8 %), along with the emissions of NO₂ (5 %). An analysis of the emission components revealed that the main emissions are methane and carbon monoxide. The most polluted areas were Novokuznetsk, Mezhdurechensk, Leninsk-Kuznetsky, Belovo and Prokopyevsk.

The concentration of gases released at some points of the rock dump surface can significantly exceed the permissible sanitary standards for working areas. Moreover, from an area of several thousand m² from underground fires in rock dumps in the atmosphere can receive tens of m³ per day of carbon monoxide, hydrogen and a significant amount of methane which is about 3 t/year or 0.2 % of the recorded gross emissions of pollutants from stationary sources.

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