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THERMAL REGIMES OF SPONTANEOUS FIRING COAL WASHING WASTE SITES

Abstract. Spontaneous firing is a typical phenomenon at coal washing waste dumps containing argillites, siltstones, sandstones, and coal. The study of the spatial and temporal variability of the heat temperature field on the sites of spontaneous firing a topical issue for further modeling and forecasting.

At the area of the rocky dump spontaneous firingof the coal washing plant "Chervonogradska" of the JSC "Lviv Coal Company" (Ukraine), temperature measurements were performed at depths 0.5 m, 1.0 m, 1.5 m, 2.0 m, and 2.5 m along three profiles distanced 8 m, 15 m and 28 m from the edge of the dump. The measurements were taken twice at two-week intervals. The temperature measurements were carried out directly at the measuring points by a thermometer with a thermocouple and remotely in the infrared range using a FLUKE TiS40 thermal imager and a partial pyrometer "Smotrych - 4PM1".The temperature measurements were used to construct horizon maps and sections. The regularities of temperature variations in the vertical and horizontal directions were explained. The temperature gradients were calculated, and they reach 14.5 °C/m. The dependences of the temperature gradients variation on the depth and the absolute temperature values in the thickness of the heap were validated statistically. The harmfulness of water supply into the thickness of burning rock dumps leading to the intense spread of heating along the laterals was justified theoretically and confirmed experimentally.

Keywords: coal washing waste dumps, spontaneous firing, thermal field, thermal gradient.

1. Introduction. Coal mining is associated with the excavation of large volumes of rocks, water, and gas onto the surface. As a result, large areas of fertile soils are occupied by rock dumps. Each thousand tons of mining generates 110-150 m^3 of rock wastes, and 100-120 m^3 are produced at the enrichment of a thousand ton of coal [1].

The waste dumps often contain hazardous substances, and storage of the rock wastes causes a formation of the specific man-induced geochemical systems: "waste dump – soil – underground water (mining water) – surface water – soil" in the shallow horizon of the lithosphere.

Even greater amounts of pollutants are released into the environment in case of spontaneous firing of coal and coal washing stones. The issue of coal fires is typical of many countries of the world, including China, India, the USA, South Africa, Australia, France, Russia, Poland, and Ukraine [2-5].

The study of the process of coal mine dumps spontaneous firing is an actual issue of our time. The spontaneous firing of waste dumps causes environmental pollution due to the evaporation of toxic gases, formation of chemicals polluting aquifers, burnout of rock, and downwarping formation. As a result of this process, oxides of sulfur, chlorine, ammonium, hydrogen sulfide, phenols, and mercury are emitted [6, 7]. A significant proportion of these gases can cause a greenhouse effect. It is estimated that [8] coal combustion in China generates about 0.1% anthropogenic greenhouse gases.

Many scientists studied changes in the migration of chemical elements and compounds [4, 7, 9, 10], temperature conditions and kinetics of spontaneous firing of coal in laboratory conditions[11, 12], mineralogens [3, 13, 14], and relief formation [2, 4] in burning waste dumps, and their recultivation [15]. The studies of temperature features are rare; the majority were the remote measurements in the visible firing zones on the surface [8]. The authors did not find any scientific works dealing with the detailed analysis of the structure and dynamics of the fire thermal field of the waste dumps of coal washing factories. This article aims to contribute to the understanding of space and time temperatures distribution within the burning sections of the rock dumps of coal mining factories.

The researchaimis to establish the spatial and temporal variability of the temperature field of the rock dump #4 of JSC “Lviv Coal Company” as a scientific basis for the dump thermal state monitoring.

Control of the rock dumps thermal state is carried out for:

a) the timely detection of spontaneous heating zones on the existing dumps and taking measures to prevent spontaneous firing;

b) assessing the effectiveness of measures aimed at reducing the intensity of burning rock dumps;

c) obtaining initial data for the development of projects for rock dumps extinguishing or picking.

The study of the spontaneous firing processes was carried out within the dump of the coal washing factory of JSC “Lviv Coal Company."

2. Area description. In Ukraine, coal extraction is concentrated in three basins: Donetsk, Lviv-Volynsky Coal Basins, and Dnieper Brown Coal Basin. The Lviv-Volynsky Coal Basin (LVB) is located in the western part of Ukraine near the Poland-Ukraine border. Coal of the basin is mined by the underground method and enriched at the Chervonogradska enrichment plant of JSC “Lviv Coal Company”.

2.1. Geological structure. The geological environment of the investigated territory is considered to be a part of the Volyn-Podolsk Plate of the Western European Platform, where the Paleo-Mesozoic-Cenozoic complex of terrigenous-carbonate and fluvio-glacial deposits of the Lviv-Volynskyi Coal Basin underlay. Coal layers are located in the rock mass of the coal formation lying in the secondary synclinal folds formed as a result of the Carpathians formation and the subduction of the East European platform for the Western European one. Coal formation of the Tournaisian, Visean, Serpukhovian stages of the Lower Carboniferous is carbonous one. The Serpukhov Stage is characterized by the primary productive carbonous stratum. *Quaternary deposits* are composed mainly of loessial (5-6 m),fluvio-glacial and alluvial rock complexes with a total thickness of 0.5 to 36 m.

The terrain in the region is mild, with the difference in elevation of 15-20 m per km in all directions.

2.2. Hydrogeology. In hydrogeological terms, the Chervonogradskyi geological and industrial area is the part of the Volyn-Podilskyi artesian basin. Here, the following parts are distinguished: a non-pressure aquifer in Quaternary deposits, and pressure, namely the Senonian aquifer complex, which serves as the main source of drinking water supply, the aquifer of the Jurassic and Carboniferous sediments, and the aquiferous complex of the Devonian deposits.

2.3. Hydrology. The research area is located within the Western Bug river basin, which flows into the river Vistula. The river flow rate is 0.2-0.6 m/s. As a result of prolonged coal mining, a significant part of the research area has suffered subsidence, resulting in frequent flooding and swamping terrain. The rivers of the study area are contaminated with organic substances, nitrogen compounds, and heavy metals [16].

2.4. Administrative affiliation of the territory. The Chervonogradska enrichment plant is located in the Lviv region in Western Ukraine, 60 km north of Lviv and 65 km east of Tomaszow Lubelski in the Lublin Voivodeship of eastern Poland.

2.5. Characteristics of the rock dump of the coal washing plant. The area of the industrial estate of the coal washing plant is 36.0 hectares. The waste dump in the area of 73.7 hectares was put into operation in 1979. The height of the central part of the dump is 60 m, the area of the base is 650 thousand m^2; perimeter on the bottom layer is 3300 m. The volume of deposited rocks is 30 million m^3; hoisting slopes are about 31°.

Solid waste of coal washing is transported by cars and poured into the rock dump, distanced by 0.2 km from the company's industrial site.

Waste coal is a mixture of mudstones, siltstones, sandstones, marl, and coal. In the waste composition, pyrite is present. The specific weight of waste is 2.6 g/cm^3.

The object of the research is the temperature field of fire banks of coal washing plants.

3. Materials and methods. Temperature measurements were carried out by remotely in the infrared range with a thermal imager, with a pyrometer, and directly in the place of contact with the rock with a special thermometer.

3.1. Remote sensing methods. The reconnaissance temperature survey of the dump surface was carried out remotely at a distance of 1.5-20 m from the surface in the infrared range of 7.5 - 14 μm using