On the content of total sulfur in raw coals of various grades

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Abstract. The environmental safety of using coals and their combustion efficiency depends on the total sulfur content. The author analysed the sulfur content of the coals of the Irsha-Borodinsky, Altai, Irkutsk and Kuznetsk deposits. Gravimetric analysis was used as analytical methods. The results of the study showed that the coals taken from the boiler houses contain from 2.7% to 3.9% of total sulfur and belong to the sulphurous group. These coals are noticeably inferior to the high-quality coals of the world market in terms of their sulfur content. This means that the fuel does not meet the high requirements for environmental friendliness when burning and can harm the ecosystem.

1. Introduction
Thermal power plants or enterprises in the Russian Federation account for about just over three-quarters of the country’s electricity production. The widespread use of coal is due to its cheapness and availability. Today, up to 40% of the world’s electricity is generated by burning coal. Production growth and widespread fossil fuel consumption are projected. Thermal energy is obtained from coal, ranging from private stoves to an industrial scale, which poses a threat of atmospheric pollution [1].

Cities that are far from large rivers, where there is no opportunity to receive energy from hydroelectric power plants, are especially affected. By purchasing low quality coal [2], which is characterized by a high sulfur content, thermal power plants emit into the environment not only a large volume of low-crushed dust, but also sulfur compounds - the most dangerous component for public health. Coal contains moisture and mineral impurities. Moisture in coal reduces the heat of combustion. The most harmful impurity in coal is sulfur in various compounds (pyrite, calcium, ferrous sulphate). When coal with sulfur compounds is burned, sulfur dioxide is formed.

The annual total emission of sulfur dioxide into the atmosphere of our planet is about 108 tons / year. According to literature data, such compounds, which include sulfur, such as SO2 and SO3, H2SO4, H2S irritate most of the respiratory tract, causing bronchitis, emphysema and asthma. There are many cases of deterioration of health and even death of people living near industrial enterprises as a result of emissions of sulfuric anhydride. According to researchers, economic losses from air pollution, including the cost of treatment, amount to 2-4% [3]. According to the World Health Organization, nine out of ten people breathe air with a high concentration of pollutants. Suspended particles formed during combustion are capable of penetrating deep into the lungs and cardiovascular system, and provoke diseases such as stroke, lung cancer, and respiratory diseases, including pneumonia [4]. A study by the American Cancer Society (ACS) found a direct relationship between SO2 in the air and mortality. The study was conducted in 126 large urban areas in the United States from 1982-1998, with an average recorded SO2 concentration of 18 µg / m³ and the highest recorded at...
85 µg / m³. Sulfur compounds also have a negative impact on the environment. When oxygen and light act on sulfur dioxide, sulfuric anhydride is formed. The end product, when combined with water vapor, can condense in the form of “acid” rain. It has been proven that sulfur dioxide acidifies soil, water bodies and inhibits living organisms.

The composition of coal largely depends on the conditions in which it was formed. It is a sedimentary product and represents decomposed organic remains of plants (treelike horsetails, earth moss, tree ferns and the first gymnosperms). Each of the types of coal differs in the ratio of the constituent elements, on which the heat of combustion directly depends, in the presence of a number of organic compounds with harmful and negative carcinogenic properties. The quality of the mined coal is formed under the combined influence of a large number of factors that are combined into groups: natural, economic and technological.

The mined coal has a number of unique quality properties, among which, from the point of view of the consumer, one can distinguish useful, harmful and neutral. One of the significant harmful qualities of coals from various deposits in Russia is the increased sulfur content [5].

Not all grades of coal contain the same amount of sulfur in their composition. The amount of sulfur-containing compounds in coal can vary from insignificant to 5-8% and depends on its type and on the place of extraction. The sulfur content in brown coal is 0.53%, in hard coal - 0.61-8%. It was revealed that high-sulfur coals predominate in the European part of the country, high-moisture and high-sulfur brown coals of the Kansk-Achinsk basin, and coal of the Kuznetsk basin, in Siberia and the Far East. Coals are classified into the following groups: low-sulfur, medium-sulfur (1.5-2.5%), sulfur (2.5-4%), high-sulfur (over 4%) [6].

The content of sulfur dioxide in the atmosphere of the background regions of the European part of Russia in the cold season varies from 0.0046 mg / m³ in the northwest to 0.007 mg / m³ in the south-eastern part of the region. In the warm season, the concentration of sulfur dioxide is 2 - 8 times lower. An increase in the concentration level in winter is due to the deterioration of the meteorological conditions for the dispersion of impurities, an increase in the amount of industrial emissions, and a slowdown in the chemical transformation processes of substances at low air temperatures. According to Roshydromet, on the territory of Russia (with the exception of the North Caucasus region, the Republic of Kalmykia and the Astrakhan region), 4.22 million tons of sulfur fall out per year.

In the Arkhangelsk region there are a number of the largest enterprises, which account for the bulk of the emissions of sulfur compounds of the region: these are, first of all, enterprises of the pulp and paper industry (Arkhangelsk, Kotlassk and Solombala pulp and paper mills), Arkhangelsk and Onega hydrolysis plants, more than 60 woodworking enterprises, thermal power plants, Plesetsk cosmodrome, nuclear shipbuilding centres FSUE PO Zvyozdcheka and FSUE PO Sevmash, in addition, boiler houses for housing and communal services, etc. [7]. For 2018, emissions amounted to 321.48 thousand tons, of which 165.9 thousand tons are sulfur compounds. This means that all sulfur compounds in the Arkhangelsk region are of industrial origin, and the proportion of naturally occurring sulfur compounds is insignificant [8].

An interesting fact is that many thermal power plants receive coal with a higher ash content and a lower calorific value than provided for by regulatory documents [9].

The most important indicator is the total sulfur in the coal. The indicator is the total sulfur content in all sulfur compounds in terms of elemental sulfur, in relation to the mass of the test coal [10].

The sulfur content of the coals of various deposits, first of all, depends on the form of its occurrence and the characteristics of its distribution in coals.

2. Rationale
The development of coal-fired energy technologies and the tightening of environmental requirements and standards for emissions of harmful substances into the atmosphere require new combinations of economic and environmental conditions.
The problem of reducing the content of sulfur dioxide in the flue gases of coal-fired power plants is very relevant for the domestic energy sector, especially for the regions of the country, the nature of which is most susceptible to the negative effects of this substance.

3. Goal of research
Study of coals from different deposits for the content of total sulfur and study of the dependence of the concentration of acids and ash content of coals.

4. Materials and methods
The gravimetric method (GOST 8606-93 (ISO 334-92)) was used to represent the real position of the total sulfur content in the coals. The analysis of coals from various deposits - Irsha-Borodinsky, Altaysky, Irkutsk and Kuznetsk.

To solve the set tasks, a database was initially created, which includes information on the composition and quality of coals. The table was supplemented with the results of our own research. Data processing was carried out using the STATISTICA 6.0 software package (StatSoft, USA).

According to the technique used, several samples were taken from the total mass of coals. The mass was crushed until a homogeneous state was obtained. Then, an analytical sample of the fuel was taken together with the Eshch mixture and burned in an oxidizing medium in order to remove the combustible mass and convert sulfur into sulphates [11]. Sulphates were extracted with hydrochloric acid solution and determined gravimetrically after precipitation with barium chloride.

For each coal, the harmful effects of its main impurity, total sulfur, were assessed. Quality coal from the world market was taken as a control.

5. Results
As a result of the analysis of the samples, we found that all the studied coals from various deposits belong to the sulphurous group (2.7-3.9%) and are noticeably inferior to high-quality coals of the world market in terms of their sulfur content. This means that these coals do not meet the high requirements for environmental friendliness of fuels during their combustion and can harm the environment.

The sulfur content, along with the calorific value, has a decisive influence on the cost of coal, and most often unscrupulous suppliers change the declared characteristics in their favour.

It is interesting to note that the coal from the Irsha-Borodinsky deposit is declared unique in terms of its record low sulfur content - only 0.2%. Coals of some deposits of the Irkutsk basin are characterized by a very high, more than 10%, sulfur content, which makes them unsuitable for use in heat power engineering. However, according to the data obtained, coal can be attributed to the sulphurous group, not to the high-sulfur group (table 1).

Table 1. Assessment of the harmfulness of the studied coals combustion products by total sulfur.

| Coal deposit              | Coal grade | Working heat of combustion, in fractions of equivalent fuel | Total sulfur content in working fuel,% | Declared characteristics | Content of total sulfur in working fuel,% revealed indicators |
|---------------------------|------------|-----------------------------------------------------------|--------------------------------------|--------------------------|-------------------------------------------------------------|
| Irsha-Borodinsky          | B2         | 0.49                                                      | 0.2                                  | 2.771604                 |                                                             |
| Altaysky                  | BR         | 0.69                                                      | 0.76                                 | 3.98622                  |                                                             |
| Irkutsk (Cheremkhovsky)   | D          | 0.52                                                      | 0.3-0.4 до 7-8                       | 2.977236                 |                                                             |
| Kuznetsk (Kuzbass)        | 2 DG       | 0.77                                                      | 0.4                                  | 2.92824                  |                                                             |
Differences between the revealed indicators of total sulfur in the studied coal samples from the declared characteristics can be explained by the factor of mixing fuel of different batches or the influence of weather conditions during storage in open warehouses, as well as the desire to save suppliers of products. There are cases when, often, due to the depletion of deposits and changes in the quality of solid fuel, as well as the market conditions of an energy enterprise, non-design fuels and mixtures are used.

As part of the work, the dependence of the concentration of acids for treating coals was studied in order to reduce the ash content of coals. Hydrochloric acid (HCl) was chosen as the coal treatment [12]. Because other acids, such as phosphoric and sulfuric, can form insoluble salts in water with some of the ions contained in coal ash and increase the amount of minerals.

The results show that with increasing acid concentration, the ash content of the coal decreases (figure 1).

![Figure 1. Dependence of the acid concentration influence on the ash content of coal.](image)

It was found that when treating the coals of the Altai deposit with a 1M HCl solution, the ash content decreases by 14.32%, mainly due to the dissolution of the calcium and magnesium compound, partly with iron and aluminium. With a further increase in the HCl concentration, the result did not change.

Thus, the use of acidic reagents of low concentration has shown high efficiency for reducing ash content in coals.

### 6. Conclusion
As a result of the study of run-of-mine coals of various grades, due to both natural and mining-technological factors, it was found that the maximum content of total sulfur was recorded in the coals of the Altai deposit of 3.98%, the minimum content was found in Irsha-Borodinsky - 2.77%. The obtained values contradict the declared characteristics.

The most effective way to protect the atmosphere from sulfur dioxide pollution is to use low sulfur fuels. However, there are very few such fuels. As an analogue - reducing the use of energy and
creating power plants that do not use mineral fuel, or removing sulfur from the fuel using filters, regulating combustion processes, or using low concentration acid reagents.

It is the low efficiency of coal combustion, the lack of cleaning technology and its high proportion of direct combustion that are the main problem. By using acidic reagents of low concentration, the sulfur content can be reduced by 12-14%.

Environmental legislation does not have the tools to completely eliminate the combustion of high sulfur coals. Due to the ongoing extensive economic growth and the increasingly wasteful consumer behaviour of the majority of the population, environmental protection measures do not keep pace with the pace of environmental destruction. In this regard, an active search is under way for systems of indicators that allow comprehensively reflecting environmental losses.

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