Methods and approaches to the determination of the carbon-containing dust concentrations in the atmospheric air during coal mining and processing

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Abstract. An overview of russian and foreign methods and approaches to control carbon-containing dust in the atmospheric air in the influence zone of coal mining and processing enterprises is presented in this paper. The main composition of suspended substances (coal dust), entering in the atmosphere in the processes of coal mining and processing, consists of an inorganic part, represented by the main rock-forming oxides, toxic elements, mineral particles PM2.5 and PM10, also organic substances, which include soot (carbon), organic matter of coal, benz(a)pyrene and other PAHs. The capabilities of modern physical and chemical analysis methods, which significantly increase the accuracy, reliability and information content of monitoring the state of atmospheric air, are still poorly used in industrial environmental control. Information about the composition and properties of coal dust obtained from research of Kuzbass coals, its mining and processing waste should be used in the development of industrial environmental monitoring programs by industry enterprises.

1. Introduction

Coal mining and coal processing enterprises provide a great load on the entire environment of Kuzbass. Air pollution is one of the main environmental problems in the region. At the moment work on the assessment of the environmental load on the atmospheric air by enterprises of the coal mining and processing industry are carried out according to traditional schemes that have not changed for decades and in many respects do not meet modern requirements. Practically there are no methodological approaches to the analysis of multicomponent natural systems for differentiated quantitative determination of individual pollution indicators. The capabilities of modern physical and chemical analysis methods, which significantly increase the accuracy, reliability and information content of monitoring the state of atmospheric air, are still poorly used in industrial environmental control.

An overview of national and foreign methods for monitoring the concentrations of carbon-containing dust in the atmospheric air in the area of coal mining and processing enterprises, the use of which is relevant in accordance with modern changes in environmental legislation, is presented in this article. Information about the composition and properties of coal dust obtained from research of Kuzbass coals, its mining and processing waste should be used in the development of industrial environmental monitoring programs by industry enterprises.

In international researches aimed at studying the environmental problems of the coal industry [1], the authors consider coal dust as a source of a specific variety of toxic compounds for humans and the environment. This variety includes:

- fine-dispersed material that is characterized by a certain content of silicon dioxide (up to 5% or more of this value) and the distribution of particles of small classes in size (from 1 to 10 microns);
- toxic metals that are pollutants of atmospheric air (mercury, lead, etc.), as well as contributing to the formation of reactive oxygen species in the human body (iron, copper, etc.);
– polycyclic aromatic hydrocarbons (PAHs) from the list of 16 priority compounds, including benz(a)pyrene, benz(a)anthracene, chrysene;
– tricyclic PAHs, including phenanthrene and its alkyl-substituted derivative.

Therefore, the main composition of suspended substances (coal dust) entering the atmosphere in the processes of coal mining and processing consists of the inorganic part, represented by the main rock-forming oxides, toxic elements, mineral particles of class less than 2.5 microns (PM2.5) and class less than 10 microns (PM10), and organic substances, which include soot (carbon), coal organic matter, benz(a)pyrene and other PAHs.

Currently, in the field of studying the composition and properties of dust produced during the mining, processing and transportation of coal there are the following problems:
- the main analytical data on the elemental composition of coals and products of its mining and processing was obtained predominantly by semi-quantitative spectral analysis methods and requires clarification;
- the content of toxic individual polycyclic aromatic hydrocarbons in coal, products of coal mining and processing is not determined;
- determination of small classes particles (PM2,5 and PM10) in coal dust is not carried out during environmental monitoring of atmospheric air and industrial emissions.

Reliable methodological support for the assessment of fine carbon-containing materials (coal dust, sludge, emissions into the atmosphere of coal-processing plants, etc.), and for the determination of organic pollutants (components of explosives, reagents used in dust suppression, in the fight against freezing during storage and transportation of coal) it is not available and thus the development of appropriate methods of determination is relevant and in request.

2. Discussion

CARBONACEOUS ELEMENTS IN COAL AND COAL DUST

Based on the analysis of literature data, a priority range of toxic elements can be proposed for determination in environmental objects in the area of coal mining and processing enterprises. The list should contain toxic elements and potentially toxic elements of coals (As, Be, Cl, Co, Cr, F, Hg, Mn, Ni, V, Pb, Sr, Sb, Se, Tl, V, Zn, U, Th, Ra, Rn) [2]. This range can be supplemented with elements that are highly carboniferous (Ag, Sb, Tl, As, Mo, I, Ge, Hg, Bi, Se), carboniferous (Ni, Hf, Sn, La, Co, Ba, Sc, Nb, Sr, Th, Ga, Cu, Zn, W, Au, In, Pb, U, B, Be), weakly or moderately carboniferous (Ti, Zr, F, Cd, V, Ta, Cr, Y, Li, P) [3].

It is also necessary to take into account the list of pollutants that are subject to state regulation in the field of environmental protection [4] when carrying out environmental monitoring in the zone of influence of coal mining and processing enterprises.

This normative document contains lists of toxic elements for their determination in atmospheric air (V, Cd, Co, Mn, Cu, As, Ni, Hg, Pb, Cr, F, Cl), water (Be, B, Bi, V, W, Cd, Co, Li, Mn, Cu, As, Ni, Hg, Pb, Sb, Se, Sr, Cr, F, Zn), soils (V, Cd, Co, Mn, Cu, As, Ni, Hg, Pb, Sb, Cr, Zn) [4].

The content of toxic elements in coals can vary significantly even within a single coal deposit, so the study of the elemental composition of coals in the Kuznetsk coal basin and processing products should be carried out in order to develop new geotechnologies for integrated exploration of coal deposits and planning monitoring of environmental objects in the influence zone of coal mining and processing enterprises.

For example, arsenic is one of the most significant carbonaceous elements that pollute the environment in the Kemerovo region. Table 1 shows information about the concentrations of this element that are found in soils in the zone of influence of coal mining enterprises in Kuzbass.

| Coal deposit   | Minimum total content of arsenic, mg/kg | Maximum total content of arsenic, mg/kg |
|----------------|----------------------------------------|---------------------------------------|
| Urupskiy       | 14.7                                   | 350.6                                 |
| Bungursky      | 11.9                                   | 26.6                                  |
| Taldinskaya    | 12.2                                   | 673.4                                 |
| Zhernovskoe    | 13.2                                   | 23.7                                  |
| Novo Kazansko  | 23.3                                   | 581.0                                 |

In accordance with the hygienic standards GN 2.1.7.2511-09 [5], the following standards for arsenic MPC were established for various types of soils: sandy and sandy loam-2 mg/kg; acidic (loamy and clay),...
pH KCl < 5.5 – 5 mg/kg; close to neutral, neutral (loamy and clay), pH KCl > 5.5 – 10 mg/kg. Therefore, it is necessary to control the content of this element both in coal deposits and in coal dust.

The distribution of the main rock-forming elements and microelements in Kuzbass coals, mining and processing wastes was considered earlier in studies [6-8].

It should be noted that elements such as iron and manganese are typical for coals and overburden and host rocks of the Kuzbass coal deposits. The determination of these elements as a component of coal dust entering the environment as part of coal dust should also be included in the atmospheric air monitoring programs.

POLYCYCLIC AROMATIC HYDROCARBONS IN COALS

Polycyclic aromatic hydrocarbons (PAHs) are part of the organic mass of coals and are persistent ecotoxins. The content of individual PAHs in coals depends on the nature of the original plant material involved in the stages of carbon formation, and the thermodynamic conditions of this process [9]. The study of PAH content in coal is relevant for a number of reasons, including to clarify the structure of the organic part of coal, which partially consists of fragments of PAH molecules, as well as to determine the degree of toxicity of raw materials, products and atmospheric air of coal-mining and coal-processing enterprises. In studies [10-15], analytical methods for determining PAHs in coals and features of the distribution of this class compounds representatives are considered.

During the study of PAHs distribution in the Kuzbass soils at the borders of sanitary protection zones of open and closed coal mining enterprises, it was shown that the content of phenanthrene is in the range from 0.0012 to 0.0031 mg/kg, and benz(a)pyrene is not detected in the soils.

Another distribution of PAHs in soils is observed in the zone of influence of coal processing enterprises: the content of phenanthrene is in the range from 0.0015 to 0.0432 mg/kg, the concentration of benz(a)pyrene is from <0.001 to 0.0390 mg/kg (2 MPC) [16]. Therefore, the coal processing plants are sources of PAHs entering the environment, including the carcinogenic benz(a)pyrene.

Today in the Russian Federation there are methods approved for the purposes of environmental control that allow determining all 16 priority PAHs in atmospheric air, industrial emissions, water, and soils, however, the MPC values for these objects are set only for benz(a)pyrene and naphthalene.

Thus, the imperfection of the normative base leads to biased estimates of the level of carcinogenic compounds in environmental objects. This information is especially relevant for coal mining and processing enterprises, given the fact that coals of different ranks may contain significant concentrations of PAHs [17, 18].

At present much attention in national and international sources is paid both to the study of coals that are the source of PAHs input into the environment [19], and to the environmental objects themselves that are polluted with PAH (atmospheric air [20-24], water of natural origin [16, 25-28], soil [29-31], plant cover [32, 33]).

FINE PARTICLES OF SMALL CLASSES COAL DUST (INCLUDING PM2.5 AND PM10)

Human health is affected by particles with a diameter of less than 10 microns (PM10) and particles with a diameter of less than 2.5 microns (PM2.5). PM2.5 particles are fine suspended particles; this category also includes ultra-fine particles with a diameter less than 0.1 microns. The main problem with fine particles is that particles with a diameter of 0.1 microns to 1 microns can remain in the atmospheric air for many days and weeks, and as a result, the particles are transported through the air over large distances.

The world health organization (WHO) considers dust particles in the air to be one of the most serious dangers and causes of many diseases of the respiratory tract and cardiovascular system. The maximum concentrations of PM10 and PM2.5 particles in the air are set in a document called "Air quality guidelines" in the form of average daily and average annual values [34], in the Russian Federation their content is given in the document [35].

According to WHO experts, only achieving such levels of dust concentrations in the air can reduce mortality from lung and heart diseases associated with air pollution. Adopted in 2010 Russian standards are less demanding on the quality of atmospheric and indoor air. However, it should be understood that the WHO recommendations are just "an ideal to aspire to".

Determination of suspended PM10 and PM2.5 particles in atmospheric air should be obligatory for coal mining and processing enterprises. The content of these particles in the atmospheric air is normalized, determination methods have been developed, and measurement tools are available. However, on the territory of the Kemerovo region, the determination of these indicators in the atmospheric air of populated areas and on the borders of sanitary protection zones of industrial enterprises is not carried out. Although
suspended particles PM10 and PM2.5 in the Russian Federation are also included in the list of pollutants that are subject to state regulation in the field of environmental protection [4].

Table 2. WHO recommendations on target levels of PM10 and PM2.5 solid particle concentrations and standards adopted in the Russian Federation (RF)

| Parameter/value | Maximum single concentration, mg/m³ | Average daily concentration, mg/m³ | Average annual concentration, mg/m³ |
|-----------------|------------------------------------|----------------------------------|-----------------------------------|
| Solid particles PM2.5 | 0.16 | 0.025 | 0.035 | 0.010 | 0.025 |
| Solid particles PM10 | 0.30 | 0.050 | 0.060 | 0.020 | 0.040 |

It is necessary to measure the particle size distribution and determine the proportion of the most dangerous classes to assess the toxicity of fine coal systems. The laser diffraction is the most informative and reliable method for these purposes [36].

3. Conclusion

In the Russian Federation a wide list of normative documents is used to determine the total concentration of dust, coal dust and soot in air environments. Because the dust formed during the processes of coal mining and processing is a complex mixture of inorganic compounds (the main rock-forming oxides and trace elements), organic matter of coal and soot, the selectivity of analytical methods of analysis relative to these components should be significant. Determination of the coal dust concentration in the atmospheric air is a complicated analytical task that can be solved using methods that allow unambiguous identification of coal particles in the sample (petrography, scanning electron microscopy).

Thus, in order to obtain objective information about atmospheric air pollution in the zone of influence of coal mining and processing enterprises, it is necessary to control a whole range of parameters, including the determination of coal dust, suspended particles with dimensions less than 10 microns (PM10) and with dimensions less than 2.5 microns (PM2.5), polycyclic aromatic hydrocarbons, and toxic carbon-based elements.

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