Utilization of waste of coal-mining enterprise in production of building materials

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Abstract. Wastes of coal producers often include substances allowing treating such wastes as valuable feeds for metallurgy, chemical and construction processes. This study concerned elemental and phase composition of samples obtained by calcination of bottom sediments of the coal producer spoil bank. The research has shown that the samples contain significant amounts of carbon, iron, silicon, aluminum and other valuable components.

1. Introduction

Operation of coal-mining enterprises is accompanied with creation of significant amount of wastes that adversely affect the environment. Currently, more than 10 million metric tonnes of different types of coal are produced in Irkutsk Oblast annually, a number that defines the scale of the waste recovery problem. At that, total mass of contaminants added by coal producers of the region amounts to tens of tonnes, including up to 45 tonnes of suspended solids, more than a tonne of sulfates and chlorides and about 0.3 tonnes of petroleum and petroleum products, etc. [1]. Development of a recovery technology that uses coal production wastes as feed is a top-priority task.

It is known that out of more than 2 billion tonnes of total quarried rock, coal constitutes only 20%, the rest is directed to colliery wastes. Waste dumps and quarries occupy vast areas; however, the degree of recovery does not exceed 4% currently [1–3]. Mineral materials pushed to dumps usually contain a significant amount of valuable raw materials, which are potentially suitable for a diverse range of production processes. Iron and other metals, including rare, rare earth and scattered metals are lost with the rock refuse, as well as significant amounts of sulfur [3]. The recovery of coal producer waste allows not only having cheap feed, but solving environmental problems as well [4–6]. For instance, aggregates (rocks, clays, sands) may be used in construction. Experience with operating industrial producers shows that waste may serve as a feed in production of expanded aggregate for concretes, construction brick, finishing mortar, brick mortar, road metal and other materials [7]. High silica and alumina content allows using the waste as a feed for manufacturing refractory materials and ceramics [8].

The work objective is to determine prospects for using bottom sediments from the quarry of Tulunugol open-pit coal mine, a coal producing branch of Vostsibugol, basing on the component analysis of the waste.

2. Materials and methods

The subject of research was formed by samples, obtained by calcination of bed deposits from the open-pit coalmine. The calcination was performed at a temperature of 100 °C and lasted for about 2 hours, until stabilization of mass.
Large inclusions with sharp edges are evident in the photos of initial samples, they are identified as lignite coal; the space between the inclusions is filled with fine-grained porous rock (Figure 1).

![Figure 1](image1)

**Figure 1.** Bed deposits of an open-pit coal mine.

A detailed image was obtained with a scanning electron microscope (Fig. 2).

X-ray analysis employs automated X-ray diffractometer D8 ADVANCE provided with a Hoebel mirror and a VANTEC-1 PSD detector. The diffraction patterns were computed with the diffractometer’s software. The database of powder pattern PDF-2 was used to identify patterns. The content of mineral components in a sample was calculated in TOPAS software.

Sieve analysis was undertaken to determine grain size of principal fractions of the bed deposits, employing a standard set of sieves. The grain particle size was estimated from parallel experiments with 2-3 samples, the accuracy was within 0.05%.

3. **Investigation of elemental and phase compositions of the coal-mining enterprise waste**

Figure 2 shows the electronic microscopy results for one of the sediment samples.

![Figure 2](image2)

**Figure 2.** Electronic image of the sediment at different magnification: 1–20 micron; 2–10 micron

The study determined principal elements present in the calcinated bed sediments. The study determined quantitative relationships with respect to content of carbon, silicon, iron, aluminum, titanium, copper, manganese and other elements. (Table 1).
Table 1. Data from elemental analysis of the bed sediments

| Element | Content, % wt | Element | Content, % wt | Element | Content, % wt |
|---------|---------------|---------|---------------|---------|---------------|
| O       | 49.53-33.60   | Si      | 17.68-12.83   | Ti      | 0.76-0.1      |
| C       | 24.94-19.91   | Al      | 7.78-4.16     | Cu      | 0.43-0.25     |
| S       | 22.14         | Mg      | 1.96-0.50     | Ca      | 0.34-0.22     |
| Fe      | 20.53-18.75   | K       | 1.49-0.23     | Mn      | 0.13          |

The carbon content in the studied samples reached up to 25 % wt which is about one fourth of the sample mass is lignite. Presence of lignite inclusion may be registered visually (Fig. 1), which is hardly surprising, because coals of the Azeyского deposit are humic lignites and by their natural moisture content pertain to technical Group B-3 [9]. Pure lignite coals contain 65–70% of carbon and are used only for energy generation.

Besides, the samples had shown significant amounts of iron, silicon and aluminum. Most likely, these elements are in the form of different oxides, which is supported by oxygen content close to stoichiometric and X-ray analysis results. Besides that, the sediment contains such valuable metals as titanium, copper and manganese.

X-ray analysis was performed to determine the general phase composition of the samples (Fig. 3).

![Figure 3. Diffraction pattern](image)

From the results of the X-ray analysis it is found that the sample contains significant amounts of quartz SiO₂, which is a polymorphic modification of silicon dioxide, as well as impurity minerals – feldspar Ca₀.₆₆Na₀.₃₄Al₁.₆₆Si₂.₃₄O₁₀, illite 2K₂O·3MgO·Al₂O₃·24SiO₂·12H₂O and chlorite. The chlorites are largely represented with clinkstone Mg₅Al₃(Si₃Al)O₁₀(OH)₆. The results obtained show good correlation with the elemental composition of the sediment shown in Table 1.

The analysis of the results shows high content of silica and alumina, thus opening prospects for using such wastes as feed in construction material manufacture, for it is known that silica and alumina,
being fragmented and ground, obtain an ability to form a plastic mixture with water, which is then used to produce adobe brick [10].

It is evident that presence of elements, which is usually absent from traditional mixtures used in construction material manufacture, will influence certain characteristics of final products in comparison with those produced from common clay. At that, there are reasons to assume that use of non-traditional composition for construction material manufacture may actually improve the quality of the final product [10]. A special role in this process is evidently played by lignite: lignite residues present in the samples may be an effective binder and fuel (combustible) component, which burns out of the formed clay mass.

4. Conclusion

The elemental and grain composition was determined for slug, obtained by calcination of coal producer bed sediment. It was found that the studied samples have significant amount of carbon up to 25% wt, silicon and aluminum - 18 and 8 % wt respectively, as well as valuable metals, such as titanium, copper and manganese.

X-ray analysis has shown that the studied sample contains significant amounts of quartz SiO$_2$, which is an apomorph modification of silicon dioxide, as well as impurity minerals: feldspar, illite, chlorites.

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