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COMPLEX UTILIZATION OF TREATMENT WASTES FROM THERMAL POWER PLANTS

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The paper investigates present-day challenges related to accumulation, processing and disposal of the coal combustion wastes. The analysis of technogenic materials beneficiation practices using gravitation, magnetic and flotation beneficiation methods has been carried out. Quantitative and qualitative microscopic analysis of materials has been conducted. The study target were ash and slag wastes (ASW) from thermal power plant and coal combustion ash. Most metals are contained in coals and coal ashes in fine-dispersed (1-10 μm) mineral form. Various native metals and intermetallic compounds, sulfides, carbonates, sulfates, tungstates, silicates, rare earths phosphates and niobates have been discovered. Each metal may occur in several mineral phases, for instance tungsten may be in the form of wolframite, stolzite, ferberite, scheelite and represented by impurities. Not only composition of compounds is diversified, but also morphology of grains: well-defined and skeleton crystals, aggregates and polycrystalline structures, crystal twins and fragments; druses, globules and microspherules; porous shapes, flocculous and splintery clusters, lumpy aggregations, etc. Based on chemical silicate analysis of main ASW components the petrochemical properties of material have been assessed. Preliminary analyses have shown that concentration of ferrum-bearing components in ASW is around 5-11 %. The magnetic method of technogenic waste beneficiation with the help of high-gradient magnetic separation has been studied. The obtained evidences show that fine ASW are most efficiently separated in separators with high-gradient magnetic system.

The studies provided justification of a process flow for complex treatment of technogenic carbon-containing material, including flotation, gravitation separation, magnetic heteroflocculation enrichment and high-gradient magnetic separation. The determined complex utilization ratio has proven the efficiency of complex processing.

Key words: ash and slag material, high-gradient magnetic separation, complex processing, complex utilization factor.

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Introduction. Efficiency of all industries shall be estimated based on the balance between a mass of the ready-product and a volume of produced technogenic wastes. The most inefficient in this regard are the companies of fuel and energy complex, in particular, thermal power stations which are the sources of bulk polluting emissions and solid wastes (ash and slag materials). At present day in view of year-to-year reduction in proven subsoil resources the ash may become a source of minerals through its recycling [3, 4, 7]. The main ash components are silicon, aluminum, ferrum, calcium, potassium and titanium oxides. It is also known to contain some valuable elements: gold, platinum group metals, rare-earth elements, often reaching concentrations optimal for industrial processing. But diversified material composition, presence of unburnt coal (incomplete combustion), fine-dispersed particles of valuable elements occurring partially in colloidal form in the pore space of material require additional treatment plus to conventional technological stages [1, 2, 9, 10].

The main properties of ash and slag materials are predetermined by the following factors:

• coalbed formation (natural factors);

• processes of solid fuel combustion, ash handling and dust collection (technological factors);

• storage of ash and slag wastes (natural factors).

Study into possible complex processing of ash and slag wastes. The study target were ash and slag wastes (ASW) from thermal power plant and coal combustion ash. The qualitative and quantitative microscopic analyses of material have shown that the crystal fraction of ash and slag wastes may contain up to 150 minerals. The main minerals include meta- and orthosilicates, aluminates, ferrites, alumoferrites, spinels, dendritic clay minerals, oxides, including quartz, tridymite, cristobalite, corundum, alumina, calcium and magnesium limes and others. Quite often are small concentrations of ore minerals – cassiterite, wolframite, stannin and others; sulfides – pyrite, pyrrhotite, arsenopyrite and others, sulfates, chlorides, and very rarely – fluorides. As a result of hydro-chemical processes and weathering in the ash dumps secondary minerals may appear – calcium, portlandite, ferric hydroxide, zeolites and others.

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Of high interest are native elements and intermetallic compounds including: lead, silver, gold, platinum, mercury, ferrum, plessite, cromoferrites, cuprous gold, various copper, nickel, chromium (and silicon) alloys and others. Their sizes vary from one to tens of microns. When found in fresh ash they have traces of heat treatment (partial fusion, fusion with other minerals and aggregates). While in mature ash quite often are the cases of their self-purification.

Similar elements may be contained in the coal enclosing rocks, but in smaller concentrations. Most metals are contained in coals and coal ashes in fine-dispersed (1-10 μm) mineral form. Various native metals and intermetallic compounds, sulfides, carbonates, sulfates, tungstates, silicates, rare earths phosphates and niobates have been discovered. Each metal may occur in several mineral phases, for instance tungsten may be in the form of wolframite, stolzite, ferberite, scheelite and represented by impurities. Not only composition of compounds is diversified, but also morphology of grains: well-defined and skeleton crystals, aggregates and polycrystalline structures, crystal twins and fragments; druses, globules and microspherules; porous shapes, flocculous and splintery clusters, lumpy aggregations, etc. It shall be noted that the sedimentary rocks containing Au and PGE minerals are characterized with anomalous geochemistry (Fig. 1). This is expressed in a concurrent enrichment of metalliferous rocks with siderophilic, chalcophilic and lithophylic elements.

The wastes of thermal power plant are fine-sized with share of 40 μm particles reaching 20 %. Studies on technological properties of ash dumps in terms of recovery of precious metals have shown that the mass fraction of gold in the studied sample ranged from 0.1 to 0.9 g/t. The gold fraction is contained in free form and can be recovered by gravity methods. The quantity of gold extracted gravitationally varies from 5 to 45 % and sometimes may reach 70 %. Material from mature dumps contained more free gold, than material from current dumps. The samples collected at the furnace discharge contain a minimum amount of free gold, though in some instances "top-cut" gold content (up to 3-20 g / t) has been recorded. In such samples the largest gold particles have been found. Electron-microscopic analysis of beneficiation products (removal of unburnt carbon, flotation) have shown that the samples contain micron grains of native gold in complex technogenic alloy of gold and silver grains.

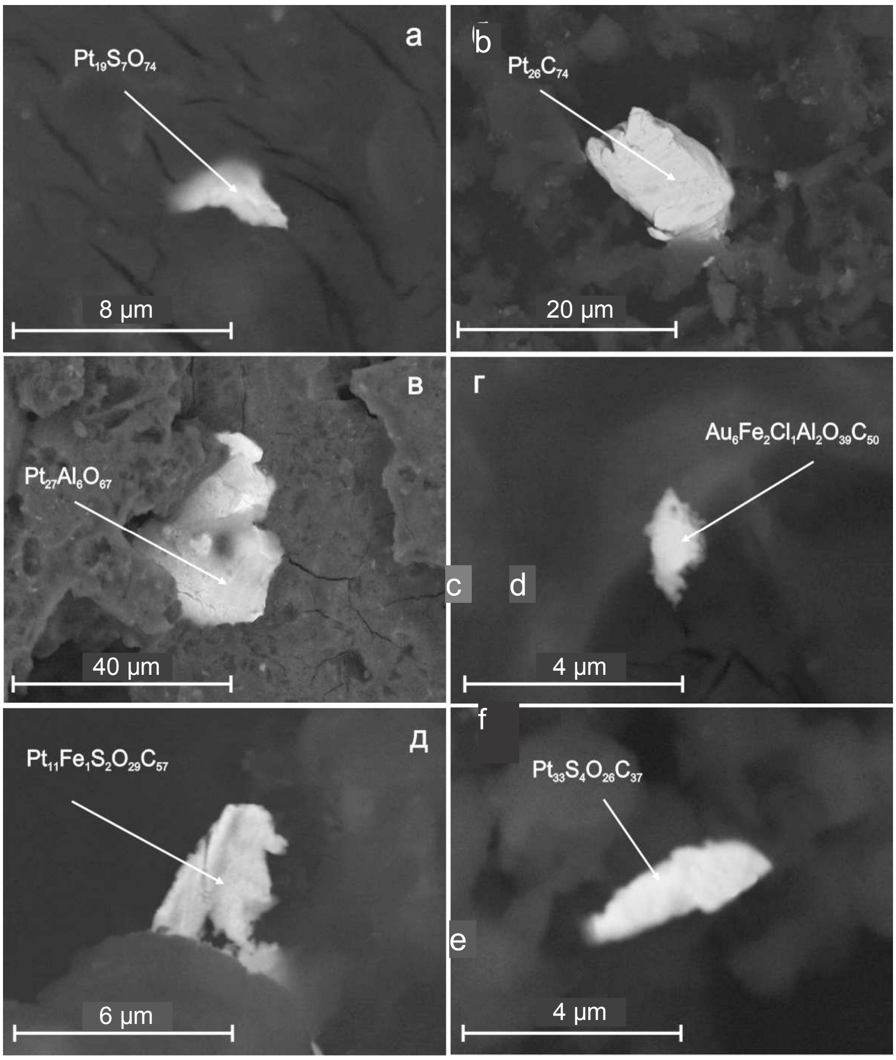

Fig.1. Inclusions of precious metals in ash and slag wastes of Khabarovsk Thermal Power

Based on chemical silicate analysis of main ASW components the petrochemical properties of material have been assessed: silicate module 1.82-1.99, an average of 1.882; basicity module 0.076-0.096, an average of 0.086; quality coefficient 0.02-0.04, an average of 0.03. In general the ash is high-silicon, acidic, with rather high content of aluminate. Preliminary analyses have shown that concentration of ferrum-bearing components in ASW is around 5-11 % (Fig.2).

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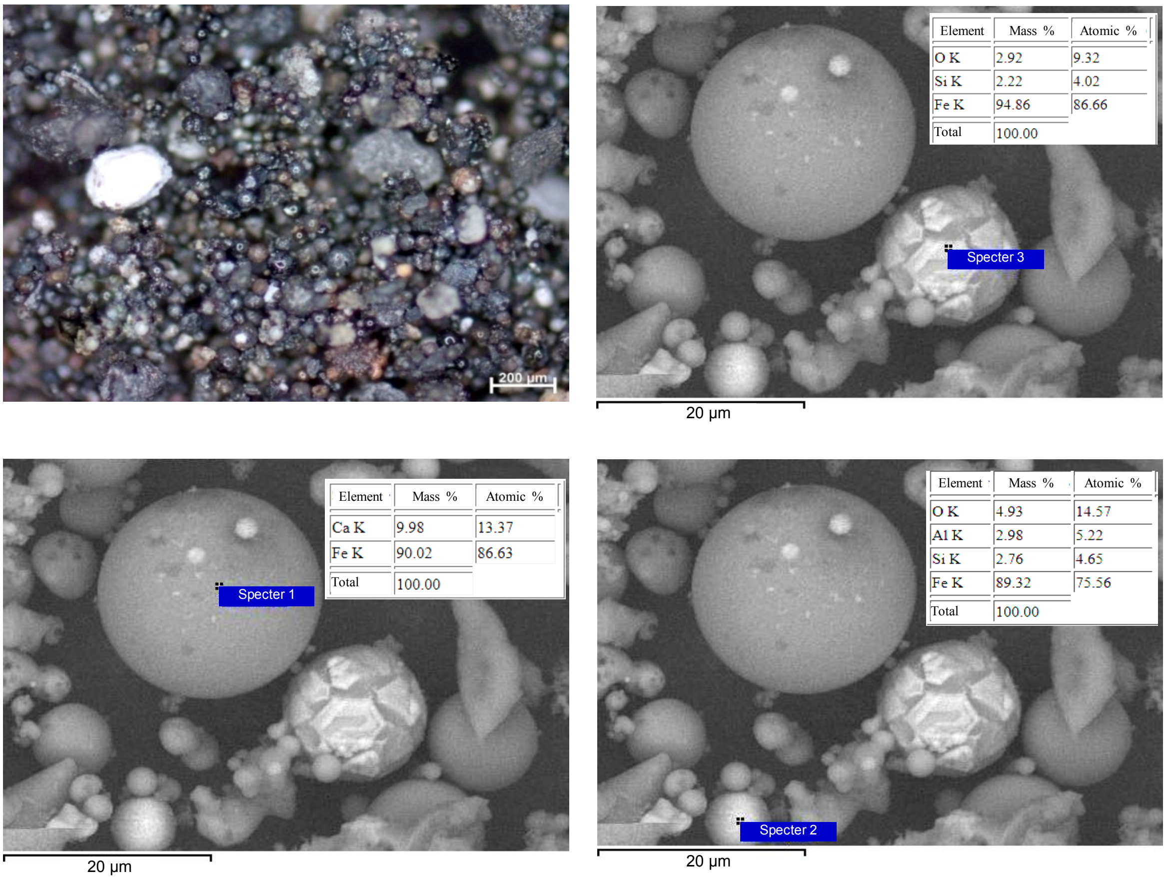

Fig. 2. Electronic image of magnetic concentrate

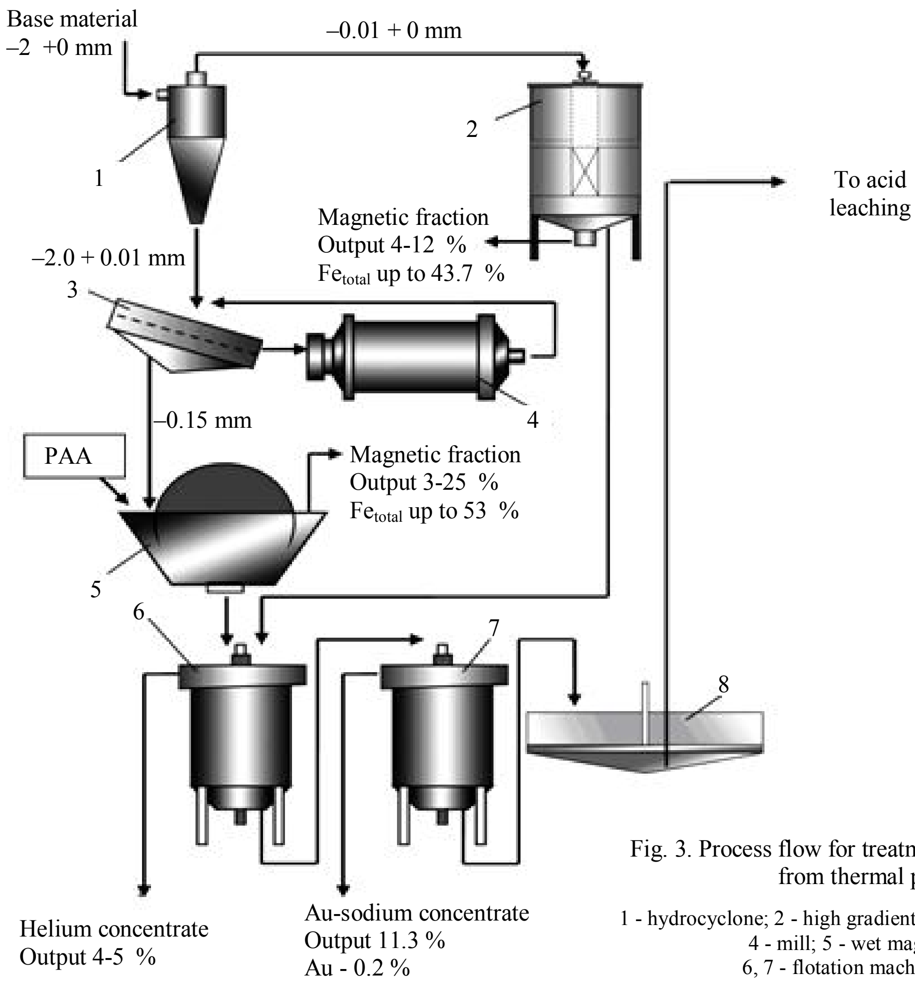

Fig. 3. Process flow for treatment of ash and slag wastes from thermal power plant

1 - hydrocyclone; 2 - high gradient magnetic separator; 3 - screen; 4 - mill; 5 - wet magnetic separator; 6, 7 - flotation machine; 8 - thickener

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Results of pursued researches became a basis for development of an industrial process flow for processing of ash and slag materials [9-13]. Process flow of complex ASW processing is shown in Fig.3.

The coal concentrate can be further used as a blending component for production of coal briquettes. Ferrum concentrate also containing chromium, nickel, molybdenum, vanadium, can be used as a feedstock for the metallurgical industry to obtain alloys with specific properties. Significant quantities of magnetic microspheres are used in the cement industry to adjust the clinker module. The resultant aluminum-bearing product can be used as a coagulant for water purification.

A part of ASW complex treatment it is recommended to recover trace elements from aluminum-bearing components using selective solvents (macromolecular acids: stearic, oleic, naphthenic, along with primary and tertiary amines). Division of magnetic separation tails into heavy and light fractions in the course of rare earth elements' extraction is not practicable, as they are distributed across both fractions. Complicated ASW composition makes it difficult to determine formation and mineral forms of trace elements. Mineral forms of substances are lost and physical properties are changed due to heat treatment in the course of ASW formation.

Residue remaining after complex ASW treatment is an inert silicon-containing mass, which can be used in construction.

Conclusion. Based on experimental and theoretic researches a principal process flow for carbon-containing technogenic materials processing has been proposed, which includes crushing, magnetic separation, including high-gradient magnetic separation, flotation and acidic extraction of trace elements. In order to assess efficiency of ASW processing using a proposed process sequence a complex utilization ratio has been determined which is equal to 62.4 %.

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