Features of material composition of slag incineration plants

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Abstract. The most part of the municipal solid waste which is formed in the world is utilized by burning. The slags which are formed in the course of burning of garbage contain heavy metals from which the main ones are aluminum, copper, zinc and lead. Waste from garbage burning can be buried in special grounds or be applied as grounds at construction of waste landfill, that can significantly reduce space reserved for warehousing of waste. The analysis of material composition is carried out for definition of possible areas and ways of utilization slags of refuse incinerators. Distribution of chemical elements on fineness classes in the initial material is studied. As a result of microprobe research, the authors establish the forms of finding of ecologically controlled elements in slag. Recommendations about the choice of ways of enrichment are made.

1. Introduction

Consumption and storage and processing of industrial waste are closely connected with the solution of questions of environmental protection. Now the problem of utilization domestic solid waste (DSW) gained global character [1-3]. Almost universal export of DSW on landfills is only temporary solution of a problem as at the same time not only environmental pollution (processes of evaporation, decomposition, penetrations of harmful substances into the soil) continues and also the huge areas of land fund are withdrawn [4-7].

The most widespread in the world way of processing of DSW is their burning on a grid-iron lattice of furnace devices of special package boilers which design considers the specific properties of DSW. Burning is conducted at rather low temperatures (up to 900 °C) without additional input of fuel. At the same time about 70 - 75% of the DSW components burn down. Unburned firm remains most of which (20 – 30% of the waste which arrived on burning) is presented by slags contain compounds of heavy metals from which the main are aluminum, copper, zinc and lead [8]. Therefore slags of incineration plants need to be directed for additional processing for additional recovery of valuable components and decrease in degree of negative impact of this material on the environment at storage.

In world practice of utilization of this material, slags split up to fineness less 40 (50) mm and disperse on fraction 0 – 2 (3) mm, 2 – 6 mm and 6 – 40 (50) mm. Coarse fractions, as a rule, contain bigger amount of metals and them direct to the following repartition for additional recovery of metals. Small fraction 0 – 2 (3) mm and tails of large fractions processing direct to landfills for burial [9-14]. However this material still contains zinc, copper, lead, aluminum and iron, in the quantities many times exceeding the established maximum concentration limits (MCL) [15]. Decreasing a mass
fraction of these metals in fine fractional tails of slag processing will allow to reduce negative impact of this material on the environment at its burial and to consider the possibility of their utilization as construction sands.

For the solution of objectives the material structure of test tails of slag processing from combustion of DSW is studied in detail. The grain-size, existence of magnetic inclusions, the chemical and phase composition, the structure of material and forms in which Cu, Zn, Pb and Al are present in slag are defined.

2. Object and Research Methods
Material represents loose powder of fineness less than 0.5 mm. The particle size distribution of slag defined on the laser analyzer is presented in table 1.

Table 1. Particle size distribution of an input material.

| Size (mm) | Vol Under (%) |
|----------|---------------|
| 0,02     | 0,0           |
| 0,04     | 0,0           |
| 0,06     | 0,0           |
| 0,08     | 1,08          |
| 0,1      | 4,57          |
| 0,2      | 42,58         |
| 0,3      | 74,28         |
| 0,4      | 90,46         |
| 0,5      | 97,58         |
| 0,6      | 100,0         |

Results of the analysis showed that in material there are no particles less than 0.065 mm in size. The humidity of initial material was 0.2%, bulk density – 920 kg/m³.

In the magnetic analysis of material the mass of magnetic fraction was 16.7%.

The element composition of material is determined by a X-ray fluorescent method on a x-ray power dispersive spectrometer of ARL QUANT’X of the Thermo Scientific company.

The phase composition of material is defined on the x-ray PRO MPD X Pert diffractometer according to methodical instructions NSOMMI No. 191 "The Radiographic Quantitative Phase Analysis (RQPA) with use of a method of the internal standard".

The X-ray spectral microanalysis with the electron probe (XSMA) was carried out on the electron probe JXA-8100 microanalyzer of Jeol equipped with wave spectrometers and the power dispersive Link Pentafel attachment.

3. Results and Discussion
Full, objective and reliable mineralogical information about real composition, structure, morph structural characteristics, technological properties of technogenic raw materials is now one of the main tools for justification while choosing technological processes of its recycling and forecasting of qualitative quantitative indices [16-18].

Priority task at adaptation of traditional methods of enrichment to slag processing of incineration plants is establishment of influence pattern in its structure, phase composition, physical and physicochemical properties on efficiency of separation processes [19-22].

The results of the chemical analysis of the studied test are presented in table 2. On the chemical composition tails of slag processing are 95% of the following elements: Al, Si, Zn, Ca, Cu and Fe.
Table 2. The chemical composition of an input material.

| Chemical element | Mass concentration (%) |
|------------------|------------------------|
| Si               | 11.17                  |
| Ca               | 5.09                   |
| Fe               | 3.09                   |
| S                | 0.49                   |
| Al               | 45.63                  |
| Ti               | 0.33                   |
| Mg               | 2.06                   |
| Cl               | 0.24                   |
| K                | 0.26                   |
| P                | 0.39                   |
| Zn               | 5.75                   |
| Cu               | 4.82                   |
| Mn               | 0.18                   |
| Cr               | 0.18                   |
| Pb               | 0.57                   |
| Sn               | 0.12                   |
| Ni               | 0.06                   |

Specific features of slag formation of incineration plants cause structure of their silicate phases, forms of present and distribution of metals in slags.

X-ray phase studying of samples showed that initial material for 58% is presented by metal phases: Al – 44%, Zn – 7%, Cu – 5%, Pb and Si – 1%. Ferriferous phases are presented by wustite (9%) and magnetite (4%). Nonmetallic phases are presented by silicates of calcium and alumina.

Photo mineralogical studying of samples showed that material mainly consists of the isolated grains of the main phases having complex structure. Cluster or multiple grains are not established (figure 1).

Figure 1. Optical-mineralogical study of the material. a) S1, S2, S3, S6, S7 – silicates of variable composition, S4, S5 – metal part Cu-Zn; b) S1, S3 – metal Al, S2 – metal part Al-Cu, S4 – alumina, S5 – metal part Al-Zn, S6 – metal part Cu-Zn, S7 – metal Pb, S8 – metal Zn.

Grains of the metal phases Cu, Zn and Pb have fineness from 60 to 500 microns. A form of grains mainly wrong, extended. Grains of a needle form are found. Texture of grains is uniform. Grains of metal Al have more regular shape in comparison with other metal phases. Grain boundaries are irregular.

Grains of silicates have fineness from 60 to 500 microns. Structure of grains is very non-uniform, dendritic. Practically all grains of silicates have inclusions of various form, size and the chemical composition.
Grains of ferriferous phase have fineness from 150 to 500 microns. Structure of grains is non-uniform, with multiple inclusions of rounded shape. Inclusions in comparison with the bulk of grain have the bigger content of iron that predetermines the chemical composition of a particle in general (figure 2).

![Figure 2. Iron oxide particles. a) S1, S2 - silicates of iron, 1 – oxide of iron; b) S1 - silicates of iron, 1-7 – aluminosilicates of iron variable composition](image)

Further studying of material was carried out by the X-ray spectral microanalysis with the electron probe (XSMA) that allowed to determine distribution of Cu, Zn, Pb and Al by the main phases of material.

Metal particles represent copper-zinc alloy (mass fractions of Cu and Zn are approximately equal) with fine inclusions of lead (a mass fraction of Pb of 75 - 79%). The amount of inclusions does not exceed 10 – 15 microns. At particles of zinc there are inclusions of metal aluminum located in the form of a streak no more than 1 - 2 micron thick. Particles of metal aluminum have dendritic impregnations of two types: Cu-Al compound (in the ratio 1:1) and Su-Al-Fe compound (in the ratio 1:6:3).

Grains of ferriferous phase have variable chemical composition and different structure. These grains represent silicate and ferrous substance with inclusions of ferric oxides and metal iron. This type of grains contains Cu of 0.1 - 1%, Zn of 0.1 - 0.5%, Ni of 0.1 - 0.2% and Pb of 0.2 - 1%. Grains of a silicate phase have simpler and homogeneous structure.

Distribution of Cu, Ni, Zn and Pb on the main phases of material was estimated when element mapping of a sample was carrying out. It is established that Pb and Sn have uniform distribution on material phases, Cu, Zn and Ni are concentrated in grains of metals.

### 4. Conclusion

The conducted researches showed that in the material Cu, Zn and Pb form independent metal phases and alloys, as well as enter into the composition of ferric oxides and silicates. As a result of element mapping it is established that Pb and Sn have almost uniform distribution on material phases.

Reduction of Cu, Zn and Pb in initial material can be reached at enrichment by gravitational methods in air or water environments. Separation of metals in a specific product will be caused by the high density of copper-zinc alloys and lead. Allocation of ferriferous phases from tails of gravity enrichment or from initial material is probable by the method of magnetic separation. The absence in initial material of particles less than 0.08 mm in size will promote increasing in efficiency of material division.

Ferriferous and silicate phases contain Cu of 0.1 - 1%, Zn of 0.1 - 0.5%, Ni of 0.1 - 0.2% and Pb of 0.2 - 1% in the form of inclusions and their size is in range from 2 micron to 100 microns. Reduction of Cu, Zn and Pb in a nonmetallic part of material will require thin crushing of material before enrichment by a hydrometallurgical method.
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