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Abstract. One of the methods for processing ash from waste incineration can be plasma treatment. In most cases, studies are carried out with inert gas systems. The size of the processed pieces of sintered ash is 10-50 mm. The power of the plasma torch is 75 kW at an air flow rate of 8.8 g/s. Temperature control on the ash surface is carried out using a two-beam pyrometer. The total melting time is 7 hours. The temperature of the least heated part of the melt is 1300°C. Liquid slag is cooled in a large number of cold water. Upon contact of the hot molten slag with water, glass-like pieces 2-3 mm in size are formed. The composition and properties of the slag are studied using a scanning electron microscope with an attachment for elemental analysis and an X-ray diffractometer.

1. Introduction

The accumulation of solid waste is a major environmental problem for humanity. There are several methods to process them: burning, gasification, melting. The burning is the most common method [1]. There are a lot of advantage including reducing the volume of waste generated by 10 times, the absence of biological pollutants and unpleasant odors at the ash, the ability to use the resulting heat and electricity[2].

Nowadays the issue of the ash processing, which is formed as a result of combustion, is the most important, due to the fact that its accumulation and storage occupies a fairly large area.Moreover, ash increases the level of environmental pollution under the influence of rain. This leads to a negative impact at human health, worsens the condition of the soil and the degree of cleanliness of reservoirs [3, 4]. This is due to the presence of metals in the ash, which are quickly removed by rain and groundwater when the ash is buried. This can significantly complicate the environmental situation in the area.

Plasma treatment is one of the most promising methods for processing ash generated as a result of waste incineration [5]. Basically, systems that operate on inert gases are used for the research [6]. As a result of this plasma action a vitrified slag is formed which has a high resistance to leaching [7].

For example, at the research [8] the analysis of glass transition of mixed medical waste showed that thermal plasma is a promising technology for the treatment of dangerous waste. The thermal energy of plasma at thermal plasma vitrification, is used for processing hazardous waste containing metals, inorganic oxides and organic substances at temperatures above 1200 K. Metal-containing waste is melted, and organic pollutants are thermally destroyed. Plasma glazing results to the formation of a glass-like, leach-resistant monolithic slag that is environmentally safe for landfill disposal or can be reused as glass ceramics for building materials such as interior and exterior wall cladding or conventional floor tiles [9,10].

Also at [11], during tests, fly ash was melted in a laboratory installation containing a DC plasma torch in an inert atmosphere. The temperature of the melt bath reached 1300 K. Vitrification resulted in a significant reduction in the volume to 60%.

Currently, the use of plasma technology to ensure high-quality ash processing involves overcoming the temperature of complete melting of the ash and its consistent rapid cooling. As a result, we can expect the formation of a vitrified state that encloses heavy metals at the matrix, preventing them from passing into the aquatic environment. Since the ash contains a sufficiently large amount of silicon in every cases practically, its oxide will form a water-impermeable film that prevents its penetration into the internal volume of the vitrified mass.

The purpose of this research is getting an inert vitrified material from wood ash using a high-voltage AC plasma torch.

2. The experimental part

The high-voltage three-phase AC plasma torch was used for the experiment [12, 13]. The plasma torch is presented at Figure1.

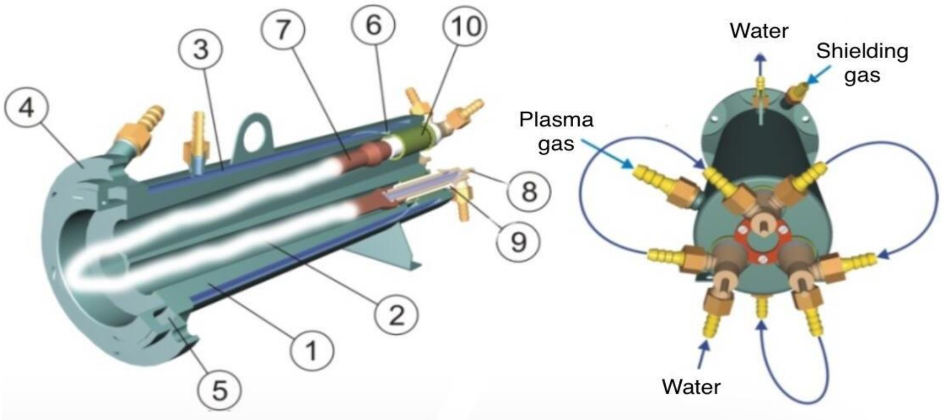

Figure 1. Three-phase high-voltage electric arc AC plasma torch with rod electrodes working on air (1- housing; 2- discharge channel and electric arc; 3- cooling jacket; 4- connecting flange; 5- shielding gas distribution collector; 6- plasma gas distribution collector; 7- electrode; 8- water-cooled electrode holder; 9- insulator; 10- bushing).

The housing (1), equipped with a cooling jacket (3), has 3 converging channels (2) for installing the electrodes. The water-cooled electrodes (7) assembled with the electrode holders (8) are inserted into the channels and secured with screws through a special washer. The electrode holder (8) is equipped with channels and fittings for the supply and discharge of coolant, an insulator (9), a bushing (10) with a rubber o-ring and a rod for connecting a high-voltage cable (collet connector). The plasma-forming gas is fed into the channels tangentially from the distribution collector (6). The plasma generator is provided with a flange (4) for connection to the response devices. Also, this model of plasma torch has the ability to organize a protective layer of cold gas around the plasma torch to reduce the thermal load on adjacent structures. A collector (5) with tangential holes located evenly around the circumference outside the output nozzle of the plasma torch, is served to this purpose. This collector was not used at this work. A copper insert was placed inside each channel, reducing the diameter of the channel, to increase the power of the plasma torch.

The investigation was conducted on a lined plasma-chemical reactor. The plasma torch was located at the top cover of the reactor. A water-cooled metal tube was used to maintain the plasma flow. Pieces of sintered ash with a total weight of 10 kg were placed in the lower part of the reactor. The temperature on the melt surface was measured using a two-beam pyrometer. The circuitry of the plasma chemical reactor and its photo are presented at Figure 2.

The total heating time was 7 hours. The power of the plasma torch was 75 kW. Initially, the temperature measured by the pyrometer, quickly increased to 1250° C. However, within 1 hour, the temperature slowly decreased to 1200 ° C, and after that reached 1300 ° C. This is probably due to the phase transition of the ash (melt formation), which requires a lot of energy.

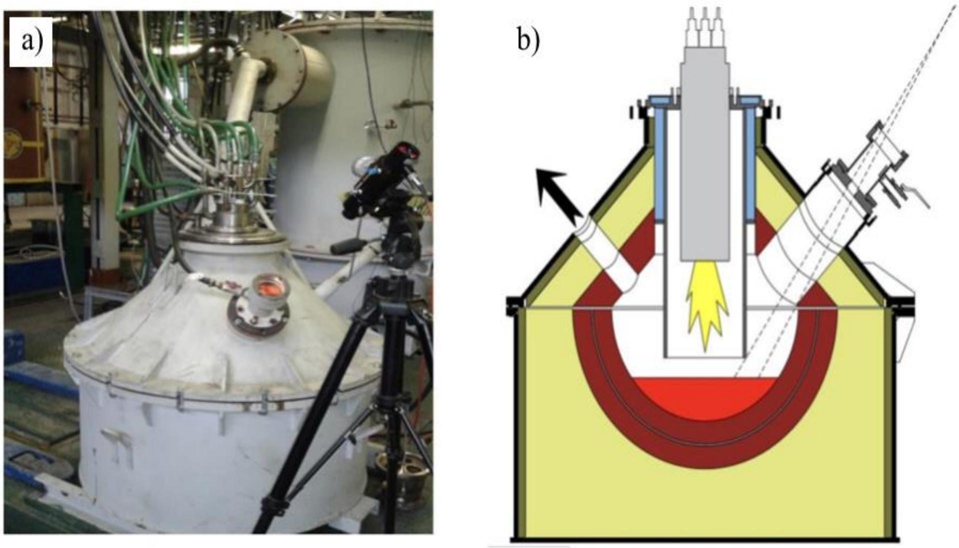

Figure 2: a)Photograph of a plasma chemical reactor, b)Scheme of a plasma chemical reactor

The slag obtained from wood ash was studied using the following methods: x-ray fluorescence analysis, electron scanning microscopy and x-ray phase analysis.

A powder diffractometer RigakuSmartLab 3 of the Saint Petersburg State Institute of Technology (Technical University) used at this investigation. The main technological characteristics of the diffractometer are presented at the Table 1.

Table 1. Specifications of RigakuSmartLab 3.

Parameter	Value
X-ray tube	Cu, power 3 kW,9 kW (with rotating anode)
Generator power	9 kW
Goniometer radius	300 mm
Minimum step 2 Theta	0,0001°

Scanning electron microscopy is one of the most widely used methods for studying nanostructures and nanomaterials.

At a typical scanning electron microscope scanning is performed by a beam of electrons with energies ranging from a few hundred eV to 50 Kev, which is focused on the surface of the sample into a very small spot with a diameter of approximately 5 nm. Research of samples was performed on SEM TESCAN VEGA3 SBH. The main technical characteristics of the SEM are presented at the Table 2.

Table 2. Specifications of SEM TESCAN VEGA3 SBH.

Parameter	Value
Resolution, nm	3 at 30 kV 8 at 3 kV
Increase	from 4,5 before 1 000 000
Electron gun	tungsten heated cathode with thermionic emission
The working value of the vacuum in the chamber, Pa	$< 9 \cdot 10^{-3}$
Image size, pixels	from 512 x 512 before 8192 x 8192

Elemental analysis was performed at an energy-dispersive x-ray fluorescence spectrometer Shimadzu EDX-8000. The technical characteristics of the device are presented at the Table 3.

Table 3. Specifications of Shimadzu EDX-8000.

Parameter	Value
Range of defined elements	6C-92U
Range of detectable concentrations	from parts ppm before 100%
Types of analyzed samples	solids, liquids, powders, pastes, granules, filters, thin films, coatings, etc.
X-ray tube	Rh-anode
Image size, pixels	from 512 x 512 before 8192 x 8192
Voltage, kV	4-50
Amperage, μA	1-1000
Detector type	silicon drift detector (SDD)
Atmosphere of analysis	vacuum, helium

3. Results and discussion section

The research of ash formed as a result of wood burning was carried out using x-ray fluorescence analysis. The results are presented at the Figure 3.

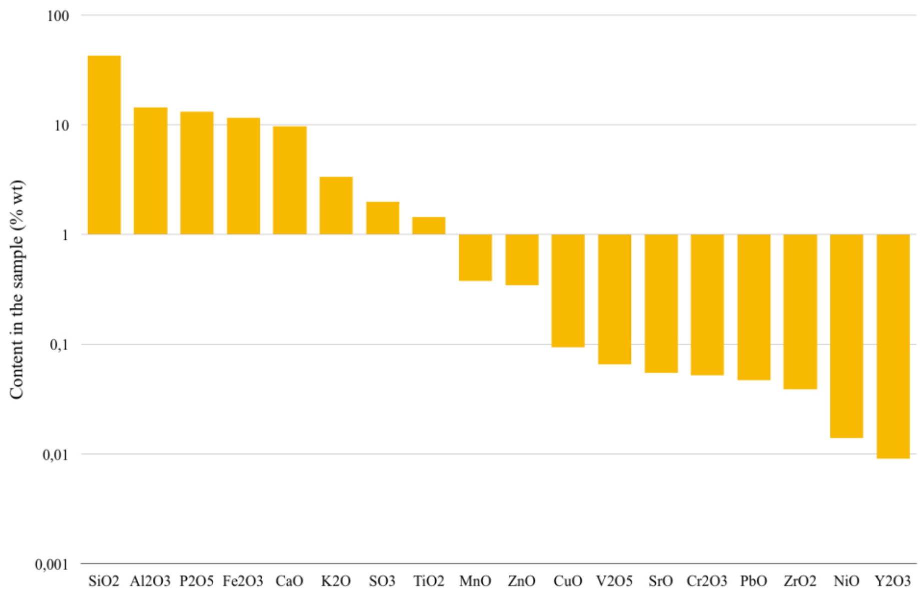

Figure 3. The elemental composition of ash.

As a result of plasma treatment of wood ash and subsequent cooling the glazed slag was obtained. The sample is presented at the Figure 4.

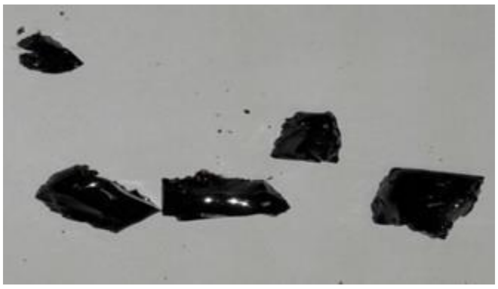

Figure 4. Slag formed after treatment followed by cooling.

The produced slag was analyzed using a powder X-ray diffractometer RigakuSmartLab. There are a diffractogram of a slag sample determined under the following conditions: wavelength-1.5406 (Ang.), number of points for smoothing is 23, degree of background polynomial is 3, piecewise approximation of the background, sensitivity threshold is 3.0 sigma, width of the base of peaks is 3.0 of full width at half maximum, asymmetry is 1.00; shape factor is 0.60. The diffractogram is shown in the Figure 5.

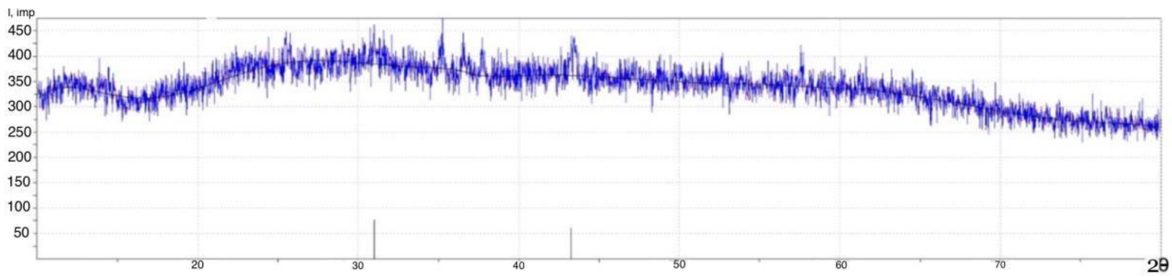

Figure 5. Slag diffractogram.

As can be seen, the entire sample is almost x-ray amorphous. Thus, most of it is glass-like. Individual peaks correspond to crystalline forms of silicon oxide and aluminosilicates.

4. Conclusion

The plasma processing of wood ash with its subsequent cooling gives a glassy product that has a smaller volume and high resistance to leaching. This will reduce the volume of storage, as well as reduce the negative impact on the environment.

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