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Resource Recovery Potential of MSWI Bottom Ash in the Czech Republic

Šyc M.[1,*], Samusevich O.[1], Veselý V., Václavková Š.[1], Zach B.[1], Svoboda K.[1], Pohořelý M.[1], Punčochář M.[1]

[1]Institute of Chemical Process Fundamentals of the CAS, Rozvojová 135/1, Prague 6, Czech Republic

*corresponding author: Michal Šyc

e-mail: syc@icpf.cas.cz

Abstract Bottom ash (BA) from waste-to-energy (WtE) plants contains valuable components, especially Fe and NFe metals, which can be recovered. Metal-free mineral fractions can be used in the construction industry. To assess the resource recovery potential of BA, it was necessary to obtain the information about its material composition. We analyzed six samples from all three WtE plants in the Czech Republic. It was found that the raw BA contained 10–23 % of glass, 2–5 % of ceramics, 10–16 % of magnetic fraction, 6–11 % of ferrous scrap, and around 1.3–2.8 % of non-ferrous metals (NFe). The contents of individual components were also studied with respect to the granulometry. This paper summarizes the results and outlines the bottom ash potential as well as the economic aspects of bottom ash treatment and material recovery.

Keywords: bottom ash, urban mining, waste-to-energy, metal recovery

1. Introduction

Waste-to-energy is a leading technology for municipal solid waste (MSW) treatment in Europe with an annual capacity of approximately 80 million tons. European bottom ash production is approximately 20 million tons per year. Bottom ash is a very heterogeneous material and its composition varies with MSW composition. Hence, strong effect of the spreading of separate collection system for plastics, glass, metals, etc. on bottom ash material composition can be expected. The following bottom ash compositions have been reported in literature: 5–13 % ferrous metals, 2–5 % non-ferrous metals, 15–30 % glass and ceramics, 1–5 % unburned organics, and 50–70 % mineral or residual fraction (Muchová, 2010; Chimenos *et al.*, 1999; del Valle-Zermeno *et al.*, 2017).

Recovery of ferrous scrap by magnetic separation is a common practice all over Europe and a recovery efficiency up to 90 % can be achieved. Recovery of non-ferrous metals is increasing among WtE plants across Europe due to recent developments in new technologies with high recovery efficiency. Conventional technologies can recover NFe metals from particles larger than 10 mm with an overall efficiency of approximately 30–40 %. Several ways for increasing the efficiency of recovery have been developed in the last few years. The removal of fine particles, which form a sticky mass and deteriorate separation, by ballistic separator prior to NFe metal separation on an eddy current separator can increase the recovery efficiency up to 85 %. Dry bottom ash discharge can aid in avoiding problems with wet sticky particles and can also inhibit the oxidation of metal particles during the rapid cooldown in a wet discharge system. The recovery of glass is rare mainly because of economic constraints; however, a pilot plant for the recovery of transparent glass shards from bottom ash particles larger than 7 mm is installed in a WtE plant in Bratislava (Makari, 2014).

Bottom ash analyses and characterizations based on acid digestion or leachability tests have been often published in literature up to now with an aim to evaluate environmental issues. However, in order to determine resource recovery potential, scarcely presented material composition of bottom ash is necessary. In this paper, we present a comprehensive study on the material composition of bottom ash from Czech waste-to-energy plants.

2. Material and Methods

Six samples in total were analyzed. The details about samples are summarized in Table 1.

The particle size distribution of dry bottom ash was determined by sieving an entire sample through screens with mesh sizes 20, 15, 10, 8, 6, 4, and 2 mm on a high-capacity automatic sieving device.

Each fraction of the bottom ash samples were sorted into the following categories:

- glass,
- ceramics and porcelain,
- magnetic fraction,
- ferrous scrap,
- NFe metals,
- unburned organic material,
- and residual fraction.

The first step of the analysis was the removal of magnetic particles by a magnetic grate separator. These particles were further subdivided into ferrous scrap and magnetic fraction. Non-magnetic particles were manually sorted into glass, ceramics and porcelain, NFe metals, unburned organic material, and residual fraction. More details about the procedure can be found in our previous paper (Šyc *et al*., 2016).

3. Results

3.1. Results of material composition analyses

The results of material composition analyses are shown in Table 2.

The major component of bottom ash was glass with 9.2–22.7 %. Glass was dominantly concentrated in particles 6–20 mm. Around 2/3 of the glass was transparent glass shards that could be potentially recovered.

Ferrous scrap content was 6–11 %. The majority of ferrous scrap (usually more than 80 %) was in particles over 20 mm, than can be recovered by magnetic separators.

The magnetic fraction was 10–16 %. This fraction had mineral rather than metallic character and its magnetic properties were caused by iron oxides (e.g. magnetite). XRF analysis showed an elemental composition of the magnetic fraction: 15–25 % Fe, around 4 % Al, almost 10 % Ca, and other metals, like Cu, Zn, and Mn, in minor concentrations.

Non-ferrous metals content ranged from 1.3 to 2.8 % and was nearly equally distributed among all analyzed size fractions. Hence, for the achievement of efficient recovery, techniques that separate NFe metals from fine particles have to be applied.

The cumulative distribution of recoverable components (NFe metals, ferrous scrap, and glass) for sample P3 is in Figure 3. It is suggested that the efficiency of recovery is most influenced by particle size.

Ferrous scrap was concentrated in larger particles, i.e. nearly 90 % of its total content in dry ash was in particles over 20 mm. Therefore, a high efficiency of recovery can be achieved even with overband magnets.

In particles over 20 mm, there was approximately 20 % of NFe metals. Conventional techniques for NFe metals recovery usually separate NFe metals from particles larger than 10 mm. In these particles, there are ca. 30-40 % of NFe metals. Therefore, to achieve a high recovery efficiency, advanced technologies that are able to recover NFe metals from smaller particles have to be employed. Current technologies can separate NFe metals from particles over 2 mm, which could result in a recovery efficiency over 90 %.

Glass recovery itself is rare nowadays. It is, however, possible to recover transparent glass shards from particles over 7 mm, which could result in an overall recovery efficiency of 60–80 %.

Table 1. Analyzed samples overview

WtE plant	Sample	Date of sampling
Prague	P1	07/2014
	P2	10/2014
	P3	05/2015
Liberec	L1	06/2014
	L2	10/2014
Brno	B1	07/2015

Table 2. Material composition of bottom ash (in wt. %)

Sample	**P1**	**P2**	**P3**	**L1**	**L2**	**B1**
Glass	13.6	22.7	17.2	9.2	12.2	14.8
Porcelain and ceramics	1.8	3.3	5.1	2.2	2.6	3.6
Unburnt organics	0.2	0.3	0.6	1.0	0.6	0.2
Magnetic fraction	16.3	11.1	11.4	15.8	15.6	10.2
Ferrous scrap	8.9	10.3	8.5	7.0	6.1	11.0
NFe metals	1.6	1.9	2.2	1.3	1.3	2.8
Residual fraction	25.4	19.7	25.4	29.0	25.9	20.5
Fraction below 2 mm	32.2	30.7	29.6	34.4	35.7	36.8

3.2. Economical potential of recovery

The majority of revenues can be expected from the recovery of metals. The price of metals varies in time and with respect to specific countries, it is 80-160 EUR/t for ferrous scrap, 700-1000 EUR/t for aluminum, and 3000-4000 EUR/t for copper (Lamers, 2015; London Metal Exchange, 2015). To maximize revenues, it is desirable to maximize the efficiency of separation even at the expense of produced fraction grade (Berkhout *et al*., 2011). Of course, with decreasing grade, the price will be affected by lower metal content. In addition, costs in the form of fees for smelters can arise because of more demanding metal refining.

For our calculations we, therefore, decreased the prices of metals found in databases and set the price for ferrous scrap to 80 EUR per ton and for NFe metals to 500 EUR per ton.

We evaluated two scenarios with different recovery efficiency based on technologies efficiency – overall efficiencies of NFe metals recovery of 30 and 85 % and efficiency of ferrous scrap recovery of 85 %. Revenues related to one ton of bottom ash are shown in Table 3. Ferrous scrap recovery is widely spread and common practice. In the case of NFe metals recovery by eddy current separator, a very low content of magnetic particles in the material is required. Therefore, multi-step recovery of ferrous scrap and other magnetic particles often has to be employed prior to the eddy current separator. It is obvious that non-ferrous metals recovery is economically feasible. In case of the employment of an advanced technology with high efficiency, revenues can be more than doubled as compared to Fe scrap recovery only.

4. Conclusion

The analyzed BA samples contained 9.2–22.7 % of glass, 1.8–5.1 % of ceramics and porcelain, 0.2–1.0 % of unburnt organic matter, 10.2–16.3 % of magnetic fraction, 6.1–11.0 % of Fe scrap, and 1.3–2.8 % of NFe metals (in dry matter). Ferrous scrap was concentrated in particles larger than 20 mm, which contained more than 80 % of the total ferrous scrap amount. The content of non-ferrous metals was nearly equally distributed among all size fractions.

Metal recovery from BA is increasing nowadays and several technologies with high efficiency are under development or have been recently installed. Metal recovery is desirable not only with respect to environmental issues, but, because of revenues from metals, it is also profitable. NFe metal recovery can double the revenues compared to Fe scrap recovery only, it is, however, technologically more complicated and challenging.

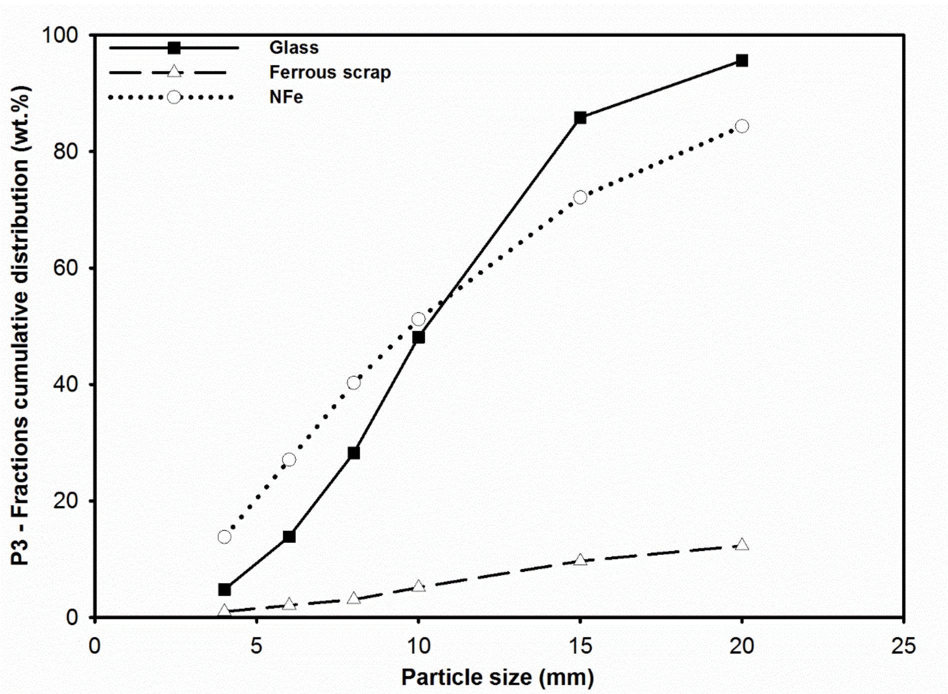

Figure 1. Cumulative distribution of ferrous scrap, NFe metals, and glass in sample P3

Table 3. Metals value in bottom ash

	Content in BA (wt. %)	**Efficiency of recovery**	**Value** (EUR per tonne BA)
Ferrous scrap	10	85%	6.8
Non-ferrous metals	2	85%	8.5
		30%	3.0

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