MSWI Bottom Ash Characterization and Resource Recovery Potential Assessment

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Abstract

Municipal solid waste incineration (MSWI) bottom ash contains valuable components that can be recovered as secondary materials, such as ferrous and non-ferrous metals, some rare earth elements, glass etc. Metal-free mineral fraction can be used in construction industry as a substitute for natural materials. Important benefit of bottom ash recycling for the plant operator is also in reduction of fees for solid residuals landfilling. The composition of bottom ash is highly dependent on the composition of incinerated waste but in average can be around 5–13% ferrous metals, 2–5% non-ferrous metals, 15–30% glass and ceramics, 1–5% unburned organics and 50–70% mineral fraction. Several incineration plants in Europe are equipped with advanced systems for metals recovery, mostly based on magnetic separation of ferrous metals and separation of non-ferrous metals usually by eddy-current separators.
To assess the possibilities of the bottom ash treatment in the Czech Republic it is necessary to obtain data about the bottom ash composition and evaluate its resource recovery potential. This paper summarizes characteristics of bottom ash samples from waste-to-energy plant in Prague. Emphasis of the study was primarily placed on the material composition. Bottom ash samples were dried and sieved into eight size fractions in the first step. It must be said that particle size distribution plays a decisive role for further utilization of bottom ash. In the second step, individual size fractions were sorted, using magnetic separation and the set of grinding, sieving, and manual separation processes, into the following materials: glass, ceramics and porcelain, magnetic particles with ferrous scrap, non-ferrous metals, unburned organic material, and residual fraction.

Keywords: MSWI, bottom ash, metal recovery, non-ferrous metals

Introduction

Municipal solid waste incineration has in recent years become a leading technology for waste treatment in Europe. Modern MSWI plants can not only use the energy content of waste but can also contribute to recovery of valuable components from solid incineration residues.

Nowadays, bottom ash has a high potential for recovery of ferrous and non-ferrous metals. In the future, recovery of selected rare earth elements, glass, and/or other critical components can be expected. Moreover, metal-free mineral fraction has increased potential for advanced utilization in construction industry. Annual production of bottom ash in EU countries is more than 20 million of tons.

The composition of bottom ash corresponds to the composition of incinerated waste which can be significantly variable depending on the locality and season of the year. The average composition reported in literature is around 5–13% ferrous metals, 2–5% non-ferrous metals, 15–30% glass and ceramics, 1–5 % unburnt organics and 50–70% mineral fraction (Muchova, 2010; Chimenos et al., 1999; Berkhout et al., 2011).

Current methods of bottom ash treatment used for material recovery are based mostly on dry-mechanical separation technologies. MSWI plants are often equipped with magnetic separator to recover ferrous scrap. Magnetic separation is usually done just after the bottom ash discharge by means of overhead or drum magnets. The efficiency of such separation without any preparation is limited to large pieces of scrap.

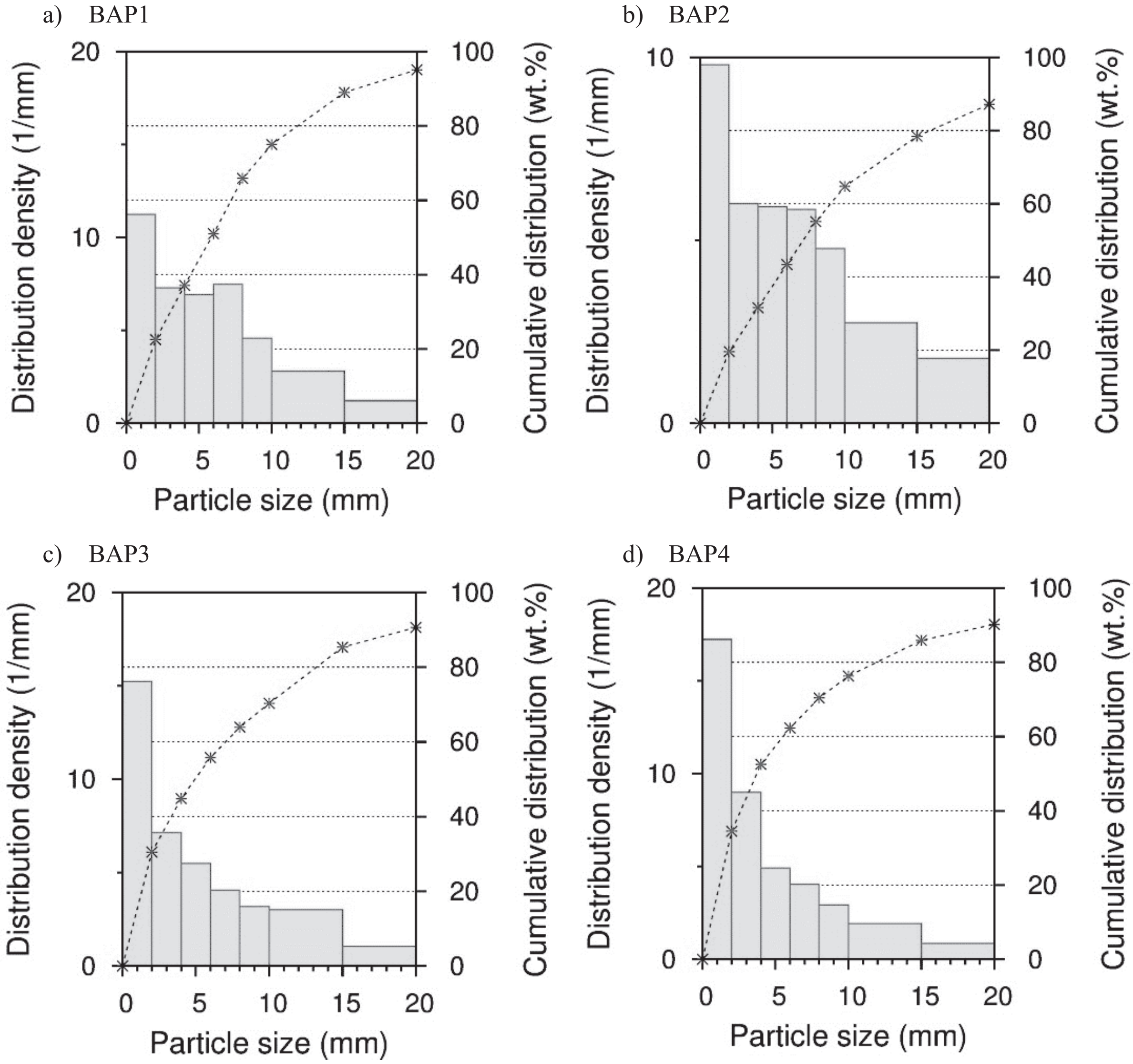

Fig. 1 a–d. Particle size distribution of the bottom ash samples BAP1–4

Rys.1 a–d. Skład ziarnowy popiołu dennego próbek BAP1–4

Separation of non-ferrous metals is performed by eddy currents separators (ECS). To achieve sufficient separation efficiency it is necessary to pre-treat the bottom ash. Pre-treatment can include a period of drying followed by sieving into at least two fractions that are then treated separately. Sometimes the coarse fraction is further crushed to release metals contained in ash agglomerates. The separation efficiency of these conventional technologies for non-ferrous metals is 20–30% of their total content in bottom ash (Koralewska, 2013).

Several technologies were introduced to increase the separation efficiency especially oriented towards non-ferrous metals recovery. These technologies use different methods to solve problems caused by fine particles that in wet bottom ash form sticky aggregates and deposits on sieves and separators. Wet separation (Muchova, 2010) uses a combination of dry separation and wet physical techniques in water stream. Advanced dry recovery method is able to remove fine particles with the highest water content and treat rest of the bottom ash by conventional methods (Rem, 2012). Dry bottom ash discharge was developed to enable dry bottom ash treatment through the whole process (ZAR, 2014; MARTIN, 2014). Separation efficiency can reach over 90% for both ferrous and non-ferrous metals.

Pilot plant for glass recovery was installed in MSWI plant Bratislava (Slovakia) in 2011. Multi-step pre-treatment consisting of sieving, drying, dry-washing and separation of ferrous and non-ferrous metals is required. Cleaned glass particles are separated from bottom ash flow by combination of optical detection method and pneumatic ejection. Glass particles above 7 mm can be separated by this method; efficiency can be up to 75% (Makari, 2014).

Tab. 1. Composition of bottom ash sample BAP1 according to particle size fractions (in wt.%)

Tab. 1. Skład chemiczny próbek popiołu dennego BAP1 w klasach ziarnowych (% mas)

Fraction (mm)	2–4	4–6	6–8	8–10	10–15	15–20	> 20
Glass	16.9	12.1	25.6	35.7	32.6	28.1	9.2
Ceramics	< 0.1	0.3	1.0	1.7	4.7	14.6	15.8
Unburned organics	2.5	2.0	1.5	1.3	1.2	1.0	0.8
Magnetic fraction	45.3	7.0	18.6	12.2	15.2	9.0	15.5
of which Fe scrap	0.3	0.6	0.5	1.3	1.6	0.6	5.4
Non-ferrous metals	2.1	2.7	2.5	2.2	2.7	3.1	1.2
Residual	33.2	76.0	50.7	46.8	43.5	44.3	57.4

Tab. 2. Composition of bottom ash sample BAP2 according to particle size fractions (in wt.%)

Tab. 2. Skład chemiczny próbek popiołu dennego BAP2 w klasach ziarnowych (% mas)

Fraction (mm)	2–4	4–6	6–8	8–10	10–15	15–20	> 20
Glass	15.3	15.3	31.2	39.6	40.7	40.8	10.4
Ceramics	0.1	0.1	0.5	2.5	3.6	8.6	13.7
Unburned organics	2.6	2.0	1.5	0.9	1.1	0.7	0.7
Magnetic fraction	44.2	22.8	17.8	14.0	13.6	15.6	22.9
of which Fe scrap	0.4	1.7	1.5	2.4	2.1	2.7	4.9
Non-ferrous metals	2.1	3.2	2.7	3.1	3.3	3.1	1.1
Residual	35.8	56.5	46.4	39.9	37.7	31.4	51.2

Experimental

Samples of bottom ash for analyses presented in this paper were obtained from MSWI plant in Prague (ZEVO Malešice) during summer 2014. Three samples (BAP1–3) are one-day samples of weight of 15–20 kg. Sample BAP4 is a mixed sample from four days of total weight 115 kg. Bottom ash was sampled from a bottom ash conveyor before magnetic separation. Annual bottom ash production of plant is 74 480 tons (in year 2014), 3 723 tons of iron scrap were obtained by means of magnetic separators in year 2014.

Before the analysis the samples were dried under laboratory conditions for 7 days. Dry samples were sieved into 8 fraction with particle sizes <2 mm, 2–4 mm, 4–6 mm, 6–8 mm, 8–10 mm, 10–15 mm, 15–20 mm a > 20 mm. Each fraction was then manually sorted according to the material character into following fractions: glass, porcelain and ceramics, magnetic particles and iron scrap, non-ferrous metals, unburned organics and residual mineral fraction. Magnetic and residual mineral fractions were further processed in order to release metal particles sintered into ash aggregates by crushing in a ball mill and manual separation of particles retained on 0.5 mm sieve. This procedure was repeated until no aggregates were retained on the sieve.

Results and discussion

Particle size distribution plays a decisive role for further utilization of the bottom ash. Metals are with higher efficiency recovered from fractions of larger particles. State-of-the art techniques can recover metal particles from ca. 2 mm size, in special cases even down to 0.5 mm or smaller but this requires a sophisticated tailor-made technology and high investment costs. Conventional techniques recover metals from particles above 5–10 mm. The particle size distribution of studied samples is shown in Fig. 1. It can be seen that the fraction below 2 mm, which is difficult for treatment, represents about 20–35% of total weight, while the more easily recoverable fractions above 10 mm form only about 20–30 wt.%. It can be also noted that the particle size distribution is greatly heterogeneous even though the samples were collected only several days apart.

Composition of bottom ash in the individual size fractions above 2 mm determined by the

Tab. 3. Composition of bottom ash sample BAP3 according to particle size fractions (in wt.%)
Tab. 3. Skład chemiczny próbek popiołu dennego BAP3 w klasach ziarnowych (% mas)

Fraction (mm)	2–4	4–6	6–8	8–10	10–15	15–20	> 20
Glass	14.3	25.4	36.4	41.3	42.5	37.3	9.5
Ceramics	< 0.1	0.3	1.2	1.9	4.1	18.1	16.7
Unburned organics	2.8	1.4	1.0	0.7	1.3	0.8	0.9
Magnetic fraction	52.0	22.0	14.5	14.0	18.8	18.2	39.8
of which Fe scrap	1.0	1.6	2.1	1.2	4.6	6.8	24.0
Non-ferrous metals	2.8	2.9	3.0	3.6	2.5	1.5	2.6
Residual	28.1	47.8	43.8	38.5	30.8	24.1	30.5

Tab. 4. Composition of bottom ash sample BAP4 according to particle size fractions (in wt.%)
Tab. 4. Skład chemiczny próbek popiołu dennego BAP4 w klasach ziarnowych (% mas)

Fraction (mm)	2–4	4–6	6–8	8–10	10–15	15–20	> 20
Glass	16.7	21.6	32.5	33.9	33.7	28.1	3.7
Ceramics	0.2	0.1	0.6	1.5	3.6	10.0	10.7
Unburned organics	2.6	1.5	1.5	1.6	1.2	1.4	1.0
Magnetic fraction	45.2	25.5	23.0	19.3	22.7	24.2	24.1
of which Fe scrap	0.8	1.3	2.3	2.8	6.2	4.4	1.0
Non-ferrous metals	2.2	2.9	2.9	3.2	3.2	1.6	3.4
Residual	33.1	48.3	39.5	40.6	35.5	34.7	57.1

Tab. 5. Total composition of bottom ash samples (in wt.%)
Tab. 5. Skład chemiczny popiołu dennego (% mas)

	BAP1	BAP2	BAP3	BAP4
Glass	18	22	20	15
Ceramics	2.7	3.3	3.4	2.0
Unburned organics	1.3	1.1	1.0	1.1
Magnetic fraction	15	18	19	19
of which Fe scrap	0.8	1.8	3.9	1.5
Non-ferrous metals	1.9	2.1	1.9	1.8
Fraction < 2 mm	22	20	30	34
Residue	39	35	24	27

manual separation is given in Tab. 1–4. The overall composition of the samples is summarized in Tab. 5.

In average the samples contain 18–22 wt. % of glass, 2.0–3.4 wt. % of ceramics, around 2 wt. % of non-ferrous metals and 15–20 wt. % of magnetic particles. Only a small part of magnetic fraction can be characterized as ferrous scrap. The most of the magnetic fraction is comprised by alloys and/or iron oxides particles with low Fe grade.

The composition of individual particle size fractions shows some trends that are similar for all of the samples, although in general there is a significant variability. Glass prevails in the fractions 6–20 mm with the share mostly between 30 and 40%. Ceramics is in significant amounts present only in fractions above 15 mm but can form up to 20% of these fractions. The content of magnetic particles is very variable with a significant amount found in the fraction 2–4 mm where most of the particles are mix of ferrous alloys and oxides. Ferrous scrap is in higher amounts present in fractions above 10 mm. Non-ferrous metals are in most cases evenly distributed between the fractions with the share between 2–3%. Most of these metals are represented by aluminium (70–90%), followed by copper and different types of alloys.

Conclusion

Pilot analysis of four bottom ash samples from MSWI plant in Prague showed that the average composition of bottom ash is 18–22 wt.% of glass, 2.0–3.4 wt.% of ceramics, around 2 wt.% of non-ferrous metals, 15–20 wt.% of magnetic particles and 30–50 wt.% of the residual fraction formed by ash and minerals. This composition is within the range reported from various MSWI plants in Europe; thus, it is believed that the separation technologies used in some European countries to recover valuable components from bottom ash can be applicable and profitable also in the conditions of the Czech Republic. In the next phase of the project more samples will be analysed to study the seasonal variability of the bottom ash composition and also the variability between different MSWI plants in the Czech Republic. Detailed composition of the fractions of ferrous and non-ferrous metals will be further studied with the prospect of possible recovery techniques.

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Charakterystyka popiołu dennego z MSWI oraz ocena odzysku

Miejskie spalarnie odpadów stałych (ang. skrót MSWI) wytwarzają popiół, który zawiera cenne składniki, które można odzyskać w postaci materiałów wtórnych, tj. metali żelaznych i nieżelaznych, niektórych metali ziem rzadkich, szkła itd. Pozbawiona metalu frakcja mineralna może być użyta w przemyśle budowlanym jako zamiennik dla materiałów naturalnych. Ważną korzyścią płynącą z recyklingu popiołu dennego dla zarządzających spalarnią jest obniżenie kosztów składowania stałych pozostałości pospalaniu. Skład popiołu dennego w dużej mierze zależy od składu odpadów i średnio zawiera około 5-13% metali żelaznych, 2-5% metali nieżelaznych, 15-30% szkła i ceramiki, 1–5% niespalonych składników organicznych i 50-70% frakcji mineralnej. Kilka spalarni w Europie jest wyposażonych w zaawansowane systemy odzysku metali, głównie oparte o separacje magnetyczną.

Aby ocenić możliwości odzysku popiołu dennego w Republice Czeskiej, zebrano dane na temat składu popiołu dennego i określono potencjał odzysku. Niniejsza praca podsumowuje charakterystykę próbek popiołu dennego pobranych ze spalarni generującej energię z odpadów znajdującej się w Pradze. Nacisk był przede wszystkim położony na skład materiału. W pierwszym etapie próbki popiołu dennego zostały osuszone i przesiane na 8 różnych frakcji. Warto uwzględnić, że rozkład wielkości ziaren ma decydujący wpływ na dalszą utylizację popiołu dennego. W drugim kroku, poszczególne frakcje zostały poddane separacji magnetycznej oraz innym procesom tj. rozdrabnianie, przesiewanie oraz separacja ręczna, na poszczególne frakcje: szkło, ceramika i porcelana, cząsteczki magnetyczne ze skrawkami żelaza, metale nieżelazne, niespalone materiały organiczne i pozostałe frakcje.

Słowa kluczowe: MSWI, miejskie spalarnie odpadów stałych, odzysk metalu, metale nieżelazne