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Metal distribution characteristic of MSWI bottom ash in view of metal recovery

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A B S T R A C T

Bottom ash is the major by-product of municipal solid waste incineration (MSWI), and is often reused as an engineering material, such as road-base aggregate. However, some metals (especially aluminum) in bottom ash can react with water and generate gas that could cause expansion and failure of products containing the ash; these metals must be removed before the ash is utilized. The size distribution and the chemical speciation of metals in the bottom ash from two Chinese MSWI plants were examined in this study, and the recovery potential of metals from the ash was evaluated. The metal concentrations in these bottom ashes were lower than that generated in other developed countries. Specifically, the contents of Al, Fe, Cu and Zn were 18.9–29.2, 25.5–32.3, 0.7–1.0 and 1.6–2.5 g/kg, respectively. Moreover, 44.9–57.0 wt.% of Al and 55.6–75.4 wt.% of Fe were distributed in bottom ash particles smaller than 5 mm. Similarly, 46.6–79.7 wt.% of Cu and 42.9–74.2 wt.% of Zn were concentrated in particles smaller than 3 mm. The Fe in the bottom ash mainly existed as hematite, and its chemical speciation was considered to limit the recovery efficiency of magnetic separation.

Introduction

Incineration is an important treatment technology in the sustainable management of municipal solid waste (MSW) and its use for this purpose is increasing. During the past 10 years in China, incineration technology has been developing rapidly. The China Statistical Yearbook showed that in 2014 there were 188 municipal solid waste incineration (MSWI) plants with a combined capacity of approximately 0.186 million tons/day, which means that about 30% of the collected MSW was incinerated (National Bureau of Statistics of China, 2015). Therefore, the annual production of MSWI bottom ash is estimated to reach more than 11 million metric tons in the next few years, from which large profits could result from responsible reutilization of this material. The physical and chemical properties of bottom ash, especially its high proportion of calcium and silicon, make the use of bottom ash feasible as an engineering construction material. For example, bottom ash is mainly used for road construction in countries such as France, The Netherlands and Spain, while in Sweden and Norway landfill construction is the primary route for bottom ash utilization (ISWA-WGTT, 2006). Moreover, metal recovery from bottom ash was deemed to be a necessary process for increasing the stability of bottom ash and thereby improving its suitability as a construction material. The metals found in bottom ash, especially the aluminum, can generate hydrogen when they react with water, causing swelling and expansion of the bottom ash material and posing a safety problem in service

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Table 1 – Municipal solid waste composition in different countries and regions (wet mass%).

Region	Organic waste	Paper	Plastic	Glass	Metal	Textile	Others	Reference
USA	21.1	12.4	17.6	5.1	8.9	7.5	27.4	OECD (2007)
France	29.4	23.3	14.8	4.2	5.4	n.m.	22.9	Bayard et al. (2010)
Germany	30.0	24.0	13.0	10.0	1.0	n.m.	22.0	Muhle et al. (2010)
Italy	29.0	28.0	5.0	13.0	2.0	n.m.	23.0	OECD (2007)
UK	36.5	24.0	9.0	6.5	4.0	n.m.	20.0	Burnley (2007)
Japan	34.0	33.0	13.0	5.0	3.0	n.m.	12.0	OECD (2007)
Beijing City	66.2	10.9	13.1	1.0	0.4	1.2	7.2	Wang and Wang (2013)
Shanghai City	72.5	6.0	13.8	3.1	0.2	2.1	2.3	Zhang et al. (2010)
Shenzhen City	47.8	13.7	13.9	1.7	0.7	10.3	11.9	Luo (2006)

n.m.: not mentioned.

(Pecqueur et al., 2001). Economically, scrap metal recovery from MSWI bottom ash also makes sense owing to the cost and availability of raw materials.

The percentage of metal in MSW shows significant differences across different regions and countries (Table 1). Generally, metal consumption has been strongly correlated to economic development, and has affected the quantity of metals discarded in MSW. Yet, in the MSW from most developed cities of China, such as Shanghai, Beijing and Shenzhen, the metal composition is several times less than that found in MSW from many developed countries. The quantity and diversity of metal species found in MSWI bottom ash reflects the complex composition of MSW itself. In addition, the morphology of metals in MSW governs their conversion into different chemical forms, such as elemental or oxidized states, in the bottom ash after thermal treatment. Table 2 lists the contents of both commonly found and scarce metals in bottom ash from different countries.

Considering metals to be a valuable resource, European countries have taken efforts to separate metals from bottom ash for several years. Among all metals, aluminum and iron are the major targets in recovery processes that use physical and mechanical methods. Based on the electrical and magnetic property of different materials, it is feasible to recover the ferrous and non-ferrous metal through magnetic and eddy current separators (ECS), respectively. Schmelzer (1995) designed a set of processes to recover metals from MSWI bottom ash using magnets and achieved a 35.5% recovery rate for ferrous metal from input MSW. Muchová and Rem (2006) reported an advanced metal recovery process capable of recovery rates from MSWI bottom ash for ferrous and non-ferrous particles as high as 83% and 73%, respectively. Generally, the recovery efficiency of ferrous metal by magnetic separation has been significantly higher than that of non-ferrous metal by ECS. About 57%–83% of ferrous scraps can be recovered through magnetic separation while only about 30% of aluminum can be separated from bottom ash using commonly available technology (Grosso et al., 2011).

Due to limitations of technology and cost, most bottom ash currently generated in China is directly disposed of without pretreatment in landfills, in accord with Chinese Standard GB 16889–2008. Most studies in China that concern MSWI bottom ash have researched the use of this material; few have focused on metal recovery. Hu et al. (2011) investigated the distribution of different types of aluminum packaging waste through the thermal process and corresponded influence on the recovery rate by ECS. Huang (2013) used jigging and gravity separation to treat MSWI bottom ash. However, neither the accessibility of metal recovery through magnetic separation and ECS, nor the characteristic metal distribution in MSWI bottom ash from China, is clear.

Table 2 – Chemical composition of bottom ash from different countries (mass%).

Element	Netherlands [a]	Italy [b]	France [c]	Japan [d]	Korea [e]	China [f]
Na	1.14–2.05	1.87–2.27	2.69–4.70	1.71–1.88	2.30–2.70	4.00–7.60
Mg	0.90–1.74	1.73–4.34	1.27–2.02	1.31–2.00	n.m.	1.10–2.87
Al	3.35–4.05	4.01–4.76	3.37–6.92	7.42–8.81	3.00–4.10	n.m.
K	0.82–1.20	0.90–1.23	n.m.	0.71–1.24	1.50–1.90	1.40
Ca	7.17–10.49	16.7–23.8	11.42–16.58	17.62–23.86	18.00–21.00	1.50–8.60
Fe	3.87–11.97	7.19–7.21	3.37–6.91	3.61–5.52	1.50–3.00	2.24–2.90
Ti	n.m.	0.68–0.72	n.m.	0.87–0.98	n.m.	n.m.
Cu	0.17–0.74	0.19–0.36	0.12–0.17	0,17–0.25	0.25–0.53	0.03–0.12
Zn	0.32–0.56	0.22–0.37	0.21–0.43	0.31–0.33	0.31–0.38	0.03–0.33

n.m.: not mentioned.
[a] Meima and Comans (1997).
[b] Funari et al. (2015); Funari et al. (2016).
[c] Dabo et al. (2009); Francois and Pierson (2009).
[d] Shim et al. (2005); Wei et al. (2011).
[e] Shim et al. (2005).
[f] He et al. (2005); Yao et al. (2010).