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Leaching of copper, lead and zinc from municipal solid waste incineration bottom ash

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Abstract

Municipal solid wastes incineration (MSWI) in modern waste-to-energy plants reduces the volume of MSW by up to 90 %. Incineration process also produces two types of by-products – bottom ash (BA) and fly ash (FA). Municipal solid wastes incineration BA is rich in heavy metals and salts. The disposal of MSWI BA may cause serious environmental problems. The objective of this study is to assess fresh bottom ash chemical composition and heavy metals such as copper (Cu), lead (Pb) and zinc (Zn) leaching values. The chemical composition determination indicates that Cu (400–800 mg kg⁻¹), Pb (680–1760 mg kg⁻¹) and Zn (1330–2010 mg kg⁻¹) are major heavy elements in MSWI bottom ash. The results showed that the concentrations of Cu were 0.1–2 mg kg⁻¹, Pb – 0.2–12.2 mg kg⁻¹, Zn – 0.4–5 mg kg⁻¹. In order to reduce the leaching of heavy metals from bottom ash, they should be pre-treated. The most commonly used technologies are weathering, washing and metals separation.

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Keywords: municipal solid waste incineration; bottom ash; copper; lead; zinc; leaching; chemical composition

1. Introduction

With increasing consumption of goods and rapid urbanization, the generation of municipal solid waste (MSW) has increased drastically [1]. Municipal solid waste incineration is one of many waste management technologies, which

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is important for sustainable economic and environmental development [2] Incineration reduces waste mass by 70 % and volume by up to 90 %. Moreover, it produces energy in the form of heat and electricity [3, 4].

According to the International Solid Waste Association (ISWA) there were 459 waste incineration plants in 28 European Union (EU) countries in 2013 as well as 86 waste incineration plants in the United States (excluding hazardous waste incineration plants) [5, 6]. Compared to with 2001, number of waste incineration plants in EU increased by 14.18 %. Waste incineration technology is widely applied in other regions of the world: 74 waste incineration plants operate in China, 19 in Taiwan, 7 in Australia, 5 in Canada and Singapore.

Municipal solid waste incineration (MSWI) produces two main types of combustion ash: bottom ash (BA) and fly ash (FA) [7, 8]. Accounting for nearly 80–85 % (16–35 % of the input waste mass) MSWI bottom ash is the most significant by-product [9–14]. In 2014, according to Eurostat data, it was burnt 64.377 mln. T. municipal waste and generated about 55 mln. T. bottom ash in the European Union [15].

Bottom ash (BA) is a highly heterogeneous mixture of slag, non-ferrous and ferrous metals, glass and ceramics, other non-combustible and residual organic matters [16]. Unlike FA, bottom ash is classified as non-hazardous waste by the European Waste Catalogue. MSWI bottom ash is mainly composed of silica (31.93–59.59 %), alumina (5.80–18.61 %), calcium (7.58–35.00 %) and iron (5.50–17.05 %) oxide (Table 1), which are natural aggregate compounds [10]. Table 1 gives chemical compositions of bottom ash, which were generated in MSWI plants in various countries.

Table 1. Amount of main chemical elements in MSWI bottom ash.

Oxide	Amount, % wt							
	Spain [8]	Italy [13]	Germany [17]	Netherlands [4]	Japan [11]	China [10]	Taiwan [18]	USA [19]
SiO ₂	43.3	33.70	55.70	54.23	31.93	59.59	50.30	23.64
CaO	16.9	35.00	11.9	13.45	33.40	7.58	15.27	23.82
Fe ₂ O ₃	14.1	5.37	8.80	13.83	5.97	5.50	7.72	17.05
Na ₂ O	7.58	2.27	1.40	2.81	2.53	1.32	1.30	1.70
Al ₂ O ₃	5.80	13.31	14.1	7.86	16.65	18.61	16.43	14.25
MgO	2.22	4.62	2.70	1.81	3.33	1.32	n. d.	1.85
K ₂ O	1.11	1.66	1.2	0.88	2.22	2.29	2.14	0.42

Note: n. d. – no data.

However, chlorides, sulphates and heavy metals, such as copper (Cu), zinc (Zn), lead (Pb) often present in high concentrations in BA [16]. Table 2 gives amount of heavy metals in bottom ash.

The research conducted in different countries showed (Table 2) that bottom ash contains of large quantities of zinc (903–7732 mg kg⁻¹), copper (1041–7743 mg kg⁻¹), lead (687–4552 mg kg⁻¹) and barium (1126–3920 mg kg⁻¹). Also, there were detected chromium, nickel, arsenic. Concentrations of cadmium and cobalt in the bottom ash were small (1–92 mg kg⁻¹).

Table 2. Amount of heavy metals in MSWI bottom ash.

Metal	Amount, mg kg ⁻¹				
	Japan [11]	Italy [13]	Sweden [7]	Germany [20]	Denmark [21]
Zinc (Zn)	3193	903	3800	7732	2600
Copper (Cu)	2321	1041	2700	7743	2060
Lead (Pb)	687	4552	1400	1022	1100
Chrome (Cr)	393	119	490	1158	449
Nickel (Ni)	105	45	240	356	356
Barium (Ba)	1126	n. d.	1300	3920	1600
Arsenic (As)	< 1	16	240	21	27
Cadmium (Cd)	1	92	4	14	3
Cobalt (Co)	5	14	33	67	20

Note: n. d. – no data

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