Heavy metals stabilization in MSWI bottom ash during natural weathering

Vasarevičius, S., Seniūnaitė, J.
Vilnius Gediminas Technical University

COST is supported by the EU Framework Programme Horizon 2020

Introduction:

Incineration is one of effective technology for the treatment of municipal solid wastes (MSW) in many industrialized countries. After MSW incineration several type solid residues, such as bottom ash (BA), fly ash (FA) and boiler ash (BA), are formed [1-3]. As the circular economy strengthens, the use of BA in civil engineering is also increasing, most BA are disposed in landfills because some elements, such as soluble salts (sulfates, chlorides) or heavy metals (Cu, Zn, Pb, Ba) often present in high concentrations in untreated (fresh) bottom ashes [4-5].

Natural weathering is most popular and cost-effective treatment method of BA. During natural or accelerated weathering processes, some characteristics (chemical and mineralogical) of BA particles undergo changes. BA is not an inert material, but a complex of interaction with the ambient atmosphere and further chemical and mineralogical transformations [6]. In the presence of additional contact with atmospheric air (atmospheric CO2), various chemical reactions begin, which results in solidification, volume stability and reactivity of bottom ash [7].

Aim of research:

This research investigated the influence of natural weathering on heavy metals (Cu, Zn, Pb) stabilization of different particle sizes of MSWI bottom ash.

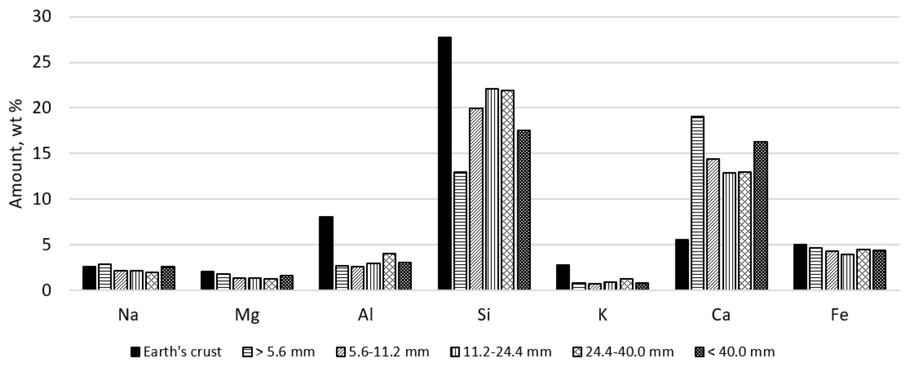

Figure 1. Major chemical elements of MSWI BA in comparison to the element abundances in the Earth's crust, based on [7].

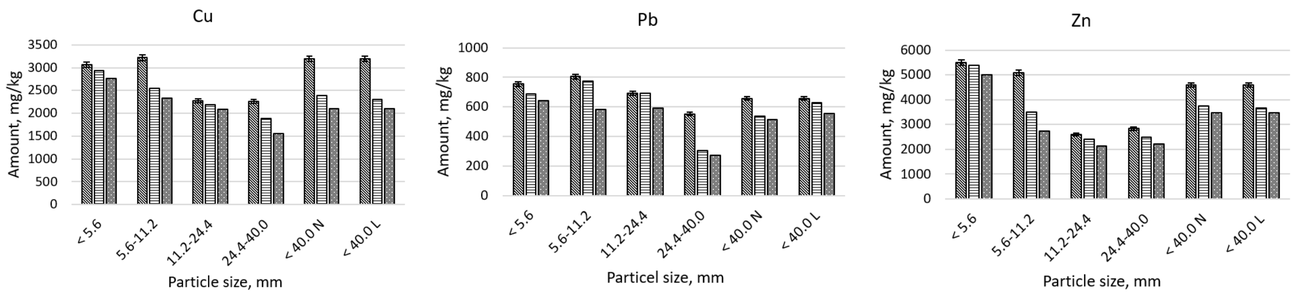

Figure 2. Amount of heavy metals in different bottom ash fractions during natural weathering, mg/kg: a) Cu; b) Pb; c) Zn;

Results and discussion:

Calcite content increased by 3.2 %. Ca(OH)2 in the fractions < 5.6 mm and < 40.0 mm was hydrolyzed to CaCO3 during the stabilization process. These mineralogical changes in BA during the stabilization process can be explained carbonization and sulphates formation reactions.

Cu concentration was lower Cu – 1096 ± 125 mg kg¹ and 1088 ± 122 mg kg¹. The decrease of Zn amount in both < 40.0 mm fractions was very similar and the average was 1120 ± 111 mg kg¹. Pb concentrations in these fractions after 6 months weathering (aging) decreased relatively low – from 104 ± 12 mg kg¹ till 142 ± 15 mg kg¹. The highest decrease of Zn amount (2359 ± 140 mg kg¹) was found in 5.6–11.2 mm fraction after 6 months natural weathering process.

The concentration of copper (Cu) in the < 40.0 mm fraction eluates exceeded the leaching limit value (150 µg L¹), respectively 257.12 ± 5.14 µg L¹ and 178.60 ± 3.57 µg L¹ at the beginning weathering (aging) process. Experimental studies show that Cu concentrations decrease rapidly (19.5-72.0 %) during the first four weeks of the process. After 4 weeks lead (Pb) concentrations was higher than leaching limit value (50 µg L¹) in tree fractions (< 5.6 mm; < 40.0 mm naturally weathering and laboratory aging) BA. The concentration of zinc (Zn) in the BA eluate and filtrate of the different fractions not once exceed the limit value (300 µg L¹), during stabilization process.

Conclusions:

1. All elements (major, minor and trace) concentrations in BA decreases during natural weathering (laboratory) aging. The highest decrease of Cu was found in < 40.0 mm fraction both types stabilized (natural weathering and laboratory aging) BA.
2. After experimental analysis was found, that heavy metals concentrations in BA decreased more rapidly during laboratory aging (then temperature and precipitation amount are constant) the first three months, than in natural weathering BA.
3. Can be conducted, that metal concentrations (Cu, Pb) exceed limit values in untreated MSWI bottom ash eluate, therefore cannot be used in civil engineering. After three months stabilization (weathering or aging) heavy metals concentrations was smaller than limit values.
4. Experimental research also showed that the change of MSWI BA quality parameters during natural weathering (temperature and precipitation amount are not constant) and laboratory aging (temperature and precipitation amount are constant) is similar. From this it can be concluded that natural aging is a more cost-effective way of treating bottom ash, which does not require constant temperature retention and additional water resources.

Materials and Methods:

BA samples were collected from MSW incinerator located in Klaipėda, Lithuania. The main stream is composed of household waste with smaller proportion of commercial waste. The grate furnace incinerator operates at temperatures between 850 °C and 1100 °C with a capacity of 255.000 tons waste per year. The BA samples were collected from the different parts of the BA stockpiles in storage room.

Heavy metals stabilization in five different fractions (< 5.6 mm; 5.6–11.2 mm; 11.2–24.4 mm; 24.4–40.0 mm; < 40.0 mm) MSWI BA, during natural weathering were performed in outside (temperature and amount of precipitation are not constant). Five laboratory stands were filled 200 ± 5 kg different fractions fresh (untreated) BA. For comparison one more stand (< 40.0 mm) was placed in laboratory (temperature and amount of precipitation (60 mm per month) are constant).

The experiment was carried out in 6 months. Samples of weathered BA (form outside and laboratory stands) and leachate (from laboratory stand) for analysis were taken 12 times (every 2 weeks.).

The following methods were used in the analysis: fractionation of BA, XRF, XRD, AAS and extraction (leaching) tests (LST EN ISO 15586:2004).

Table 3. The mineral composition of untreated, 3 months and 6 months laboratory aging BA

Bottom ash type	Mineral									
	Carbonates	Oxide			Silicates				Phosphates	Sulfates
	Calcite	Quartz	Hematite	Magnetite	Diopside	Gehlenite	Akermanite	Microcline	Hydroxylapatite	Anhydrite
	$CaCO_3$	SiO_2	Fe_2O_3	$Fe+2Fe+3O_4$	$CaMgSi_2O_6$	$Ca_2Al_2SiO_7$	$Ca_2Mg(Si_2O_7)$	$K(AlSi_3)O_8$	$Ca_5(PO_4)3(OH)$	$Ca(SO_4)$
Untreated sample	XXXX	XXXX	X	XX	X	XX	X	X	X	X
3 months laboratory aging	XXXX	XXXX	X	XX	XX	XX	X	X	X	X
6 months laboratory aging	XXXX	XXXX	X	XX	XX	XX	X	X	XX	X

Note: XXXX - Very high amount (> 20%); XXX - High amount (10-20%), XX - Medium amount (5-10%), X - small amount (trace) (<5%).

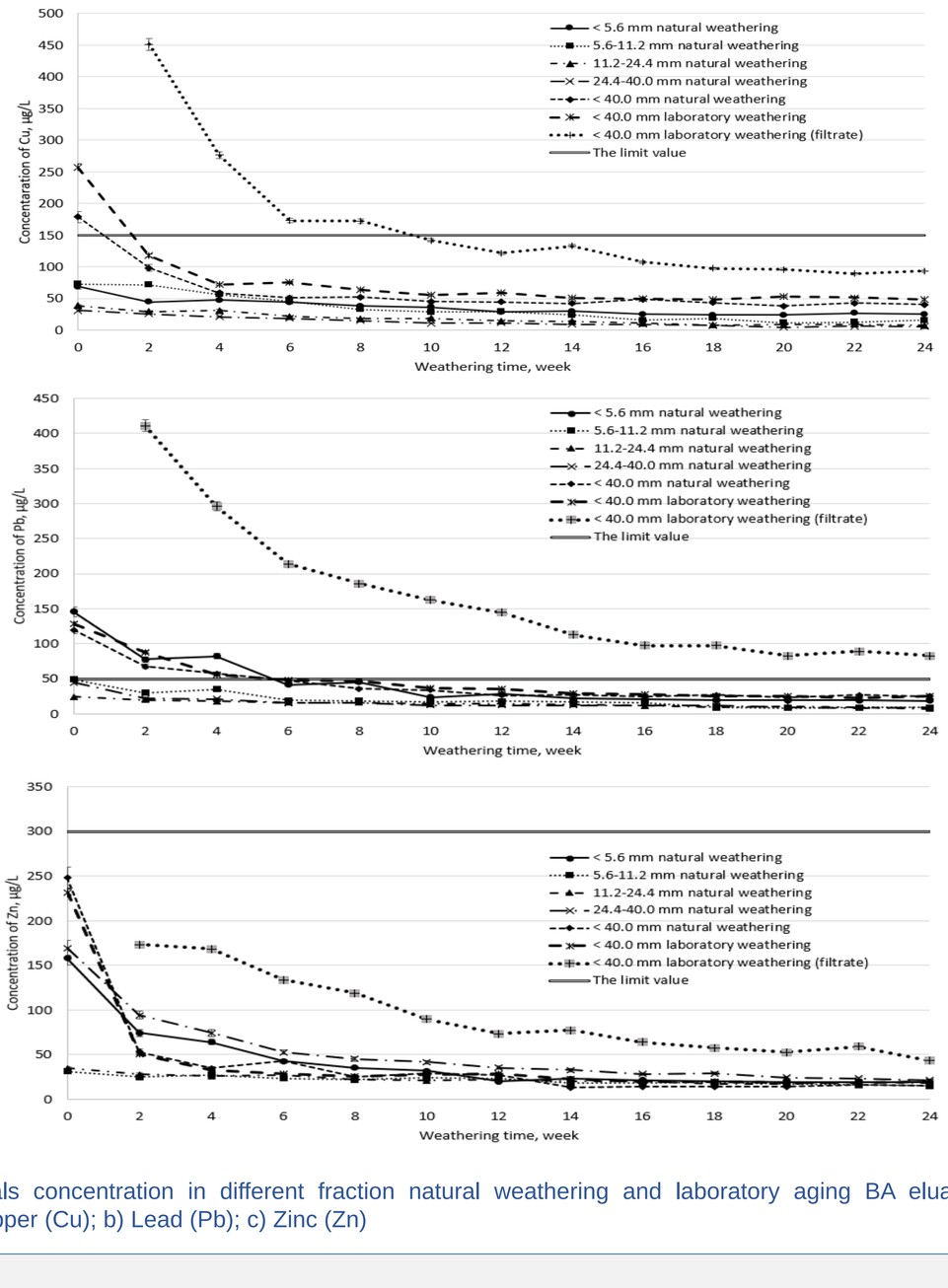

Figure 4. Metals concentration in different fraction natural weathering and laboratory aging BA eluate and leachate: a) Copper (Cu); b) Lead (Pb); c) Zinc (Zn)

Reference:

1. Inkaew. K.; Saffarzadeh. A.; Shimaoka. T. Modeling the formation of the quench product in municipal solid waste incineration (MSWI) bottom ash. Waste Manage. 2016. 52. 159-168.
2. Tang. P. Florea. M.V.A.; Spiesz. P.; Brouwers. H.J.H. Characteristics and application potential of municipal solid waste incineration (MSWI) bottom ashes from two waste-to-energy plants. Constr. Build. Mater. 2015. 83. 77–94.
3. Holm. O.; Simon. F. G. Innovative treatment trains of bottom ash (BA) from municipal solid waste incineration (MSWI) in Germany. Waste Manage. 2017. 59. 229–236.
4. Santos. R. M.; Mertens. G.; Salman. M.; Cizer. Ö.; Gerven. T. Comparative study of ageing. heat treatment and accelerated carbonation for stabilization of municipal solid waste incineration bottom ash in view of reducing regulated heavy metal/metalloid leaching. J. Environ Manage. 2013. 128. 807–821.
5. Tang. J.; Steenari. B. M. Leaching optimization of municipal solid waste incineration ash for resource recovery: A case study of Cu. Zn. Pb and Cd. Waste Manage. 2016. 48. 315–322.
6. Hyks. J; Astrup. T. Influence of operational conditions. waste input and ageing on contaminant leaching from waste incinerator bottom ash: A full-scale study. Chemosphere. 2009. 76(9). 1178–1184.
7. Bayuseno. A.P.; Schmahl. W.W. Understanding the chemical and mineralogical properties of the inorganic portion of MSWI bottom ash. Waste Manage. 2010. 30. 1509–1520.