



Combining sieving and washing, a way to treat MSWI boiler fly ash



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ABSTRACT

Municipal Solid Waste Incineration (MSWI) fly ashes contain some compounds that could be extracted and valorised. A process based on wet sieving and washing steps has been developed aiming to reach this objective. Such unique combination in MSWI fly ash treatment led to a non-hazardous fraction from incineration fly ashes. More specifically, MSWI Boiler Fly Ash (BFA) was separately sampled and treated. The BFA finer particles (13 wt%) were found to be more contaminated in Pb and Zn than the coarser fractions. After three washing steps, the coarser fractions presented leaching concentrations acceptable to landfill for non-hazardous materials so that an eventual subsequent valorisation may be foreseen. At the contrary, too much Pb leached from the finest particles and this fraction should be further treated. Wet sieving and washing permit thus to reduce the leachability of MSWI BFA and to concentrate the Pb and Zn contamination in a small (in particle size and volume) fraction. Such combination would therefore constitute a straightforward and efficient basis to valorise coarse particles from MSWI fly ashes.

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1. Introduction

In Europe, the 2008/98/EC directive (EC, 2008) dictates the management system to apply to waste, based on Lansink's scale and known as the waste hierarchy. The hierarchy promotes prevention, reuse and material recovery, before energy recovery and elimination processes. Considering the waste hierarchy for waste treatment residues such as Municipal Solid Waste Incineration (MSWI) fly ashes and Air Pollution Control (APC) residues, material recovery could be a promising technique. Indeed, such ashes and residues contain compounds (heavy metal ones for example) that could be valorised if they are extracted and purified. Recent projects over landfill mining aiming to valorise energy and material from landfills (ELFM, 2010; Van Gerven et al., 2010) prove the current need of an intensive and effective waste management to avoid wasting resources. Whenever such a project exists, material recovery, if feasible, should preferably take place before landfilling, to avoid material weathering and excavation process.

In Belgium, waste landfilling is extremely limited (Eurostat, 2012) but concerns the incineration residues. Before being landfilled as hazardous waste MSWI fly ashes and APC residues have to be treated essentially because of their salt and lead content (Van Gerven et al., 2005). Different treatments have been developed to decrease the leachability of the solids; the treatments

are generally classified as separation, stabilisation/solidification and thermal techniques (Chandler et al., 1997; Quina et al., 2008a).

Effectively, MSWI fly ashes and APC residues contain high chloride amounts, too high for landfilling or for any valorisation option. Chlorides are mostly present as NaCl and KCl in MSWI fly ashes (Le Forestier and Libourel, 1998; Mangialardi, 2003), while they are also found as CaCl₂ in APC residues (Le Forestier and Libourel, 1998). Several studies recommend washing (only with water) the residues to remove chlorides before applying another treatment (Chandler et al., 1997; Nagib and Inoue, 2000; Mangialardi, 2003; Piantone et al., 2003; Hyks et al., 2009; Jiang et al., 2009; Liu et al., 2009; Wang et al., 2010). A single washing, followed by displacement washing of the filtration cake, removes from 30% up to 95% of the chlorides, depending on the liquid-to-solid (L/S) ratio (Wang et al., 2001; Jiang et al., 2009). Washing fly ashes produces hydrate phases that form protective layers around the fly ash grains and reduce the inhibition action on cement hydration observed in case of cement stabilisation (Mangialardi, 2003). Used before acid leaching, washing reduces the acid consumption (Nagib and Inoue, 2000; Zhang and Itoh, 2006). When fly ashes are washed before a thermal treatment, the amount of volatilised heavy metal compounds decreases, because the chlorides have been removed and calcium-containing aluminosilicates have formed (Wang et al., 2001; Jiang et al., 2009).

However, other leachable compounds than chlorides dissolve when fly ashes or APC residues are in contact with water. Table 1 presents the extracted amounts of several elements generally found in MSWI fly ashes and APC residues. The extracted amounts

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are firstly expressed as a weight ratio comparing the leached element weight to the total solid weight (the ratio may also represent the concentration of the soluble form of the element) and secondly, as the percentage of the leached element amount compared to its concentration. All washing experiments presented in Table 1 are batch tests, without pH control. L/S ratio and time vary from test to test, from 1 to 100 and from 15 min to 20 h, respectively. Although both parameters may influence the compound extraction, the comparison of the results given in Table 1 brings useful information. From this table, it can be noticed that the electrofilter residues are generally composed of less soluble compounds, compared to scrubber and bag filter ones. This could be due to the fact that electrofilter residues may be composed mainly by fly ashes, while scrubber and bag filter residues also contain reaction products from the APC system (CaCl₂ in case of lime injection, NaCl if soda is used). Table 1 also shows that, while heavy metal compounds may leach during the washing step and achieve too high concentrations in water, the extraction yield from the solid is low and the majority of the element remains in the solid. In case of Pb, maximum 1.1% of the total Pb was extracted while the leached amount may achieve up to 160 mg/kg.

Washing could then be considered as an extraction step for high soluble compounds such as chlorides. However, it implies a pollution transfer to the resulting solution, which has to be treated before discharge. Furthermore, using large amounts of water would raise treatment costs and environmental impacts, because of the necessary wastewater treatment. An optimal washing should thus consume a minimum of water and dissolve a maximum of chlorides.

Mixing time may influence the compound dissolution, for kinetic reasons. The dissolution appears to be rather rapid for chloride salts. 5 min were sufficient to obtain the maximal and steady dissolution of K and Na (Wilewska-Bien et al., 2007). However, a too long mixing time may also reduce the dissolution or extraction rate; during leaching tests performed on APC residues, the maximum chloride extraction was obtained after 2 h mixing and was lower when the time exceeded 4 h (Chimenos et al., 2005). Some other elements, such as Cr, take several days to achieve an equilibrium concentration (Astrup et al., 2005). A mixing time of 2 h was found to be acceptable for washing (Chimenos et al., 2005; Jiang et al., 2009).

To set up an efficient washing treatment, the water consumption should also be minimised. This can be made by reducing the amount of water used per mass of solid (corresponding to the L/S ratio) of each step and of the entire process. The L/S ratio of each step may not be too low to permit to handle the suspension as a

solution and not as sludge, while the L/S ratio of the entire process should be high enough to remove a maximum of soluble compounds. The L/S ratio influences the compound dissolution, due to their solubility but the influence is generally notable only for L/S ratio lower than 10 L/kg in case of high soluble compounds such as chlorides. Cl, K and Na dissolution remains constant for L/S ratios from 10 to 100 L/kg (Nagib and Inoue, 2000; Wang et al., 2001), while it decreases for L/S ratios lower than 10 L/kg (Wang et al., 2001; Jiang et al., 2009). The influence of the L/S ratio on the heavy metal dissolution depends on the metal: Cr, Pb and Zn dissolution increases for L/S ratio going from 2 to 100 L/kg while Cd and Cu dissolution remains constant (Wang et al., 2001; Jiang et al., 2009). A L/S ratio lower than 10 L/kg should thus permit to dissolve a major part of chloride compounds and minimise the heavy metal (Cr, Pb and Zn) dissolution.

However, a L/S ratio of 10 L/kg still represents huge amounts of water to treat MSWI ashes. It is therefore advantageous to use a L/S ratio high enough per washing step and to assure a low L/S ratio for the whole process (global consumed water volume compared to the treated solid mass), by re-using the same solution for several washing steps in a counter-current or in a recirculating process. Chimenos et al. developed a counter-current batch washing process, with two washing steps and one rinse on the final filter (Chimenos et al., 2005). They found acceptable residues, according to the local regulation, after recirculating the solution for 4 cycles, using a L/S ratio of 3 L/kg for each step and a mixing time of 1 h (the real water consumption is not mentioned but the solution is counter-current recirculated and fresh water is only added to keep the same L/S ratio at each stage). Wilewska-Bien et al. investigated a washing treatment of fly ash at a pilot scale and found that the leachate resulting from the water washing step might be recirculated for chloride (NaCl, KCl) extraction; the input of fresh water represented only a L/S ratio of 0.5 L/kg (Wilewska-Bien et al., 2007). A recirculating washing process seems thus efficient to remove chlorides from MSWI fly ashes and APC residues and permits to reduce the water consumption, compared to washing with only fresh water.

Besides the chloride salt removal, some other compounds, such as metal ones, could also be extracted from MSWI fly ashes and APC residues. Physical separation processes, such as magnetic, Eddy current or size-based separation, are usually applied to bottom ash (Chandler et al., 1997; Vandecasteele et al., 2007; Grosso et al., 2011) which globally presents coarser solid fractions than fly ashes and APC residues. Moreover, the processes are rarely developed for these fine residues; no eddy current application for MSWI fly ashes or APC residues has been found. Magnetic

Table 1
Extraction yield ranges of some elements during MSWI fly ashes and APC residues washing (Katsuura et al., 1996; Nagib and Inoue, 2000; Wang et al., 2001; Mangialardi, 2003; Chimenos et al., 2005; Jiang et al., 2009).

		Electrofilter	Scrubber	Bag filter			Electrofilter	Scrubber	Bag filter
Al	g/kg	0.7–0.8	2–7	0.9–1.5	Al	% extracted	1.3–1.5	4.8–17	2.4–4.0
Ca	g/kg	10–34	25–75	21–50	Ca		3.8–8.1	21–63	13–31
Cd	mg/kg	0.7–650	0.7–0.9	–	Cd		3.0–3.3	0.7–0.9	–
Cl	g/kg	22–27	34–56	72–205	Cl		31–40	59–97	37–77
Cr	mg/kg	2.8–4	4.5–44	4.1–28	Cr		1.0–1.4	1.4–13	1.8–12
Cu	mg/kg	2.0–2.3	0.4–0.6	0.3–0.5	Cu		0.16–0.22	0.04–0.06	0.10
Fe	g/kg	0–0.01	1–2	0.3	Fe		0–0.06	5.3–11	0.8–0.9
K	g/kg	15–125	25–28	19–50	K		33–47	63–70	24–63
Mg	g/kg	0.02–2	1–2	–	Mg		0.12–0.20	5.9–12	–
Na	g/kg	13–85	20–24	32–79	Na		24–45	47–56	27–68
Ni	mg/kg	2–5	–	–	Ni		2.2–2.3	–	–
P	g/kg	–	1–5	–	P		–	3.8–19	–
Pb	mg/kg	6.25–160	2.1–19	1.6–5.1	Pb		0.12–0.16	0.1–1.1	0.10–0.20
S	g/kg	13–20	–	1–2	S		30–31	–	3.0–5.0
Si	g/kg	–	1	1.7–3.4	Si		–	0.89	1.6–3.2
Zn	mg/kg	18–22	0.3–4.4	0.2–0.3	Zn		0.12–0.28	0–0.10	–

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