

Weathering processes in municipal solid waste incinerator bottom ash deposits

C. A. Johnson
C. Schweizer

Swiss Federal Institute for Environmental Science and Technology
(EAWAG), CH-8600 Dübendorf, Switzerland

Municipal solid waste incineration (MSWI) is becoming increasingly popular worldwide. One of the main environmental concerns with regard to the utilisation or the landfilling of MSWI residues is the long-term leaching and transport of heavy metals into the environment. The concentrations of potential contaminants in MSWI bottom ash such as Cu, Pb and Zn are in the range of g/kg. The mobility of these components depends both on their geochemical properties and on the composition and reactivity of the matrix components.

The matrix components of municipal solid waste incinerator (MSWI) bottom ash are Si, Ca, Al and Fe. Estimated as oxides they account for approximately 80% of the dry mass of bottom ash. Other major components are Mg, CO₃, Na, K, S (as SO₄ and S(-II)), Cl in order of abundance. Organic components make up a further 1–2% of the MSWI bottom ash material. Mineralogical studies have determined that MSWI bottom ash is composed of equal amounts of fine ash material and melted components of which half have crystallised and small quantities of metallic components, ceramics and stones.

The key parameter with regard to the long-term mobility of heavy metal cations is the acid neutralising capacity ANC of MSWI bottom ash. Leaching experiments in the laboratory have indicated that Ca minerals constitute the ANC equivalent to the titration end point at pH 7.5 (Johnson *et al.*, 1995). Leachate pH initially ranges between pH 11 and 12, due to the leaching of portlandite (Ca(OH)₂). In the initial stages Ca solubility appears to be controlled by portlandite and gypsum. However, the leachate of aged deposits (>10 a) is generally buffered by CaCO₃. Furthermore the buffer capacity of fresh MSWI bottom ashes (approx. 1.5 meq/g) is significantly higher than that of aged samples (0.6–1.0 meq/g). Since the initially mobile Ca cannot be washed out of bottom ash deposits within a few years and because of the apparent reduction in ANC, Ca is probably incorporated into less soluble secondary minerals.

Evidence of the secondary Ca-mineral formation has been obtained by field sampling from a landfill

deposit in Switzerland (Landfill Lostorf). A bulk sample (3 months old) was taken of the freshly deposited MSWI ash and 60–70 further samples were taken of a whitish deposits within the landfill (see Fig. 1). These deposits ranged from a few millimeters to centimeters in diameter. The latter samples were taken from a depth of 0.5 m and were approximately a year old at the time of sampling. Secondary mineral formation was also investigated in the laboratory. In order to avoid problems arising due to the heterogeneity of the MSWI ash, ground glass (synthesized from oxides at 1400°C, shock-cooled in a water bath) and oxides of the same composition as MSWI bottom ash (Si:Ca:Al:Mg:Fe = 8:4:2:1:1) were aged at 25, 55 and 80°C (liquid:solid = 2:1) for up to a year. In the glass ageing experiments, half of the Ca was added as portlandite to the suspension. X-ray diffraction (XRD) measurements were made of all samples.

XRD measurements of bulk MSWI bottom ash samples from the landfill deposit identified the presence of calcite (CaCO₃), anhydrite (CaSO₄) and ettringite (3 CaO·Al₂O₃·CaSO₄·32H₂O). The same minerals, with the exception of anhydrite, were detected in selected secondary mineral formations from the landfill, identified as whitish encrustations. Gypsum (CaSO₄·2H₂O) was found in these samples. Other identifiable minerals were Mg/K aluminosulphates and a Mg Al hydroxide hydrate and gibbsite (Al(OH)₃). A Ca silicate hydrate, riversideite (5CaO·6SiO₂·H₂O) was identified in the bulk sample.

Ca silicate hydrates were observed in the aged oxide mixtures. Ca silicate hydrates such as CaO·SiO₂·H₂O and tobermorite (5CaO·6SiO₂·5H₂O) were identified as was a Ca aluminosilicate, katoite (3CaO·Al₂O₃·SiO₂·4H₂O). Ca aluminosulphate hydroxides, such as ettringite, were detected. Mg Al hydroxide hydrate was observed in these samples as well. The same Ca silicate hydrates, ettringite, gypsum, portlandite and Mg Al hydroxide hydrate were observed in the aged glasses, though Ca silicate hydrates were only formed at elevated temperatures.



FIG. 1. Photograph of a typical encrustation (diameter approximately 5 mm) on a MSWI bottom ash sample. Ettringite, gypsum and gibbsite were identified in this sample.

These results indicate that the minerals which are most readily formed and identifiable with XRD appear to be soluble and crystalline sulphates and hydroxides. They are observed in the field and laboratory model systems. Furthermore the solubility of Ca, Al and SO_4 in landfill leachates appears to be controlled by gypsum and/or ettringite (Johnson *et al.*, 1998). The formation of such minerals is, however, unlikely to affect ANC, since they are in the most cases quite soluble at pH values below 11. The Ca silicate hydrates which can be observed in field and laboratory samples are also known to be soluble in the basic to neutral pH range and are unlikely to be the cause of a reduction in ANC. There is, instead, recent evidence to suggest that clay precursors could play an important role in secondary mineral formation. Zevenbergen *et al.* (1992) have observed the formation of clay precursors as weathered rims on glasses in aged MSWI bottom ash deposits. The results of these authors suggests that silicon availability may kinetically limit the formation of

secondary silicates and may thereby lead to the formation of clays instead of cement-type minerals such as Ca silicate hydrates. Such weathering products may significantly contribute to the reduction in ANC. Evidence for the formation of such minerals in artificially weathered field samples and synthetic glasses and the effect on ANC are currently being studied.

References

- Johnson, C.A., Brandenberger S. and Baccini, P. (1995) *Environ. Sci. Technol.*, **29**, 142–7.
- Johnson, C.A., Kaeppli, M., Brandenberger, S., Ulrich, A. and Baumann, W. (1998) Submitted to *J. Contam. Hydrol.*
- Schweizer, C. and Johnson, C.A. (1998) *In preparation.*
- Zevenberg, C., van Reeuwik, P., Bradley, J.P., Bloemen, P. and Comans, R.N.J. (1996) *Clays Clay Miner.*, **44**, 546–52.