Leaching behavior of Antimony in MSWI bottom ash

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Introduction

Bottom ash from municipal solid waste incineration (MSWI BA) contains harmful substances such as heavy metals, chloride and sulfate which are mobilized in contact with water. Standardized leaching tests are used to measure the extent of mobilization. It is known that fresh bottom ash displays elevated concentrations of various heavy metals such as lead or zinc due to the formation of hydroxo-complexes as a result of high pH values of 12 and above. Storage of bottom ash (BA) is accompanied by ageing processes, mainly the reaction of CaO and $Ca(OH)_2$ with CO_2 leading to lower pH values in contact with water around 11.

Knowledge of the long-term leaching behavior of potentially harmful substances is crucial for the assessment of the environmental compatibility of reusing municipal solid-waste incineration bottom ash (MSWI BA) in construction, i.e., as a road base layer. Thus, BA fractions obtained from wet-processing aiming at the improvement of environmental quality were used to investigate the mobility of relevant substances. Therefore, eluates from laboratory-scaled leaching procedures (column percolation and lysimeters (see in Fig. 1)) were analyzed to learn about the long-term behavior of substances.

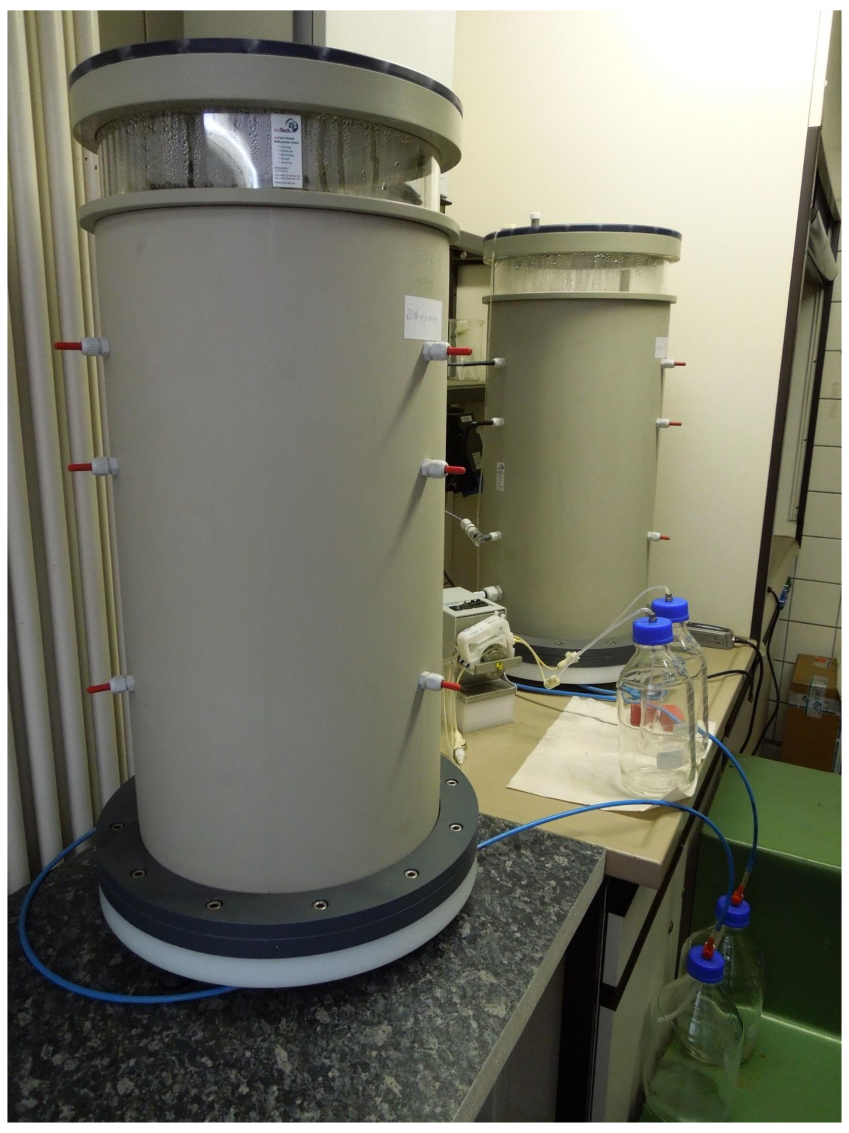

Fig. 1: BAM's lysimeter test rig. The volume of the vessels is 40.6 L.

Material

The MSWI BA used was taken from a bottom ash treatment plant in Germany. Ferrous (Fe) and non-ferrous (NFe) metals were already removed by standard methods (magnets, eddy current separation). A wet-mechanical process step was implemented in the plant to remove the finest fraction below 0.25 mm (see Fig. 2). Two mineral fractions (0.25-4 mm and 4-60 mm) were generated by different sieving steps and used for the lysimeter experiments.

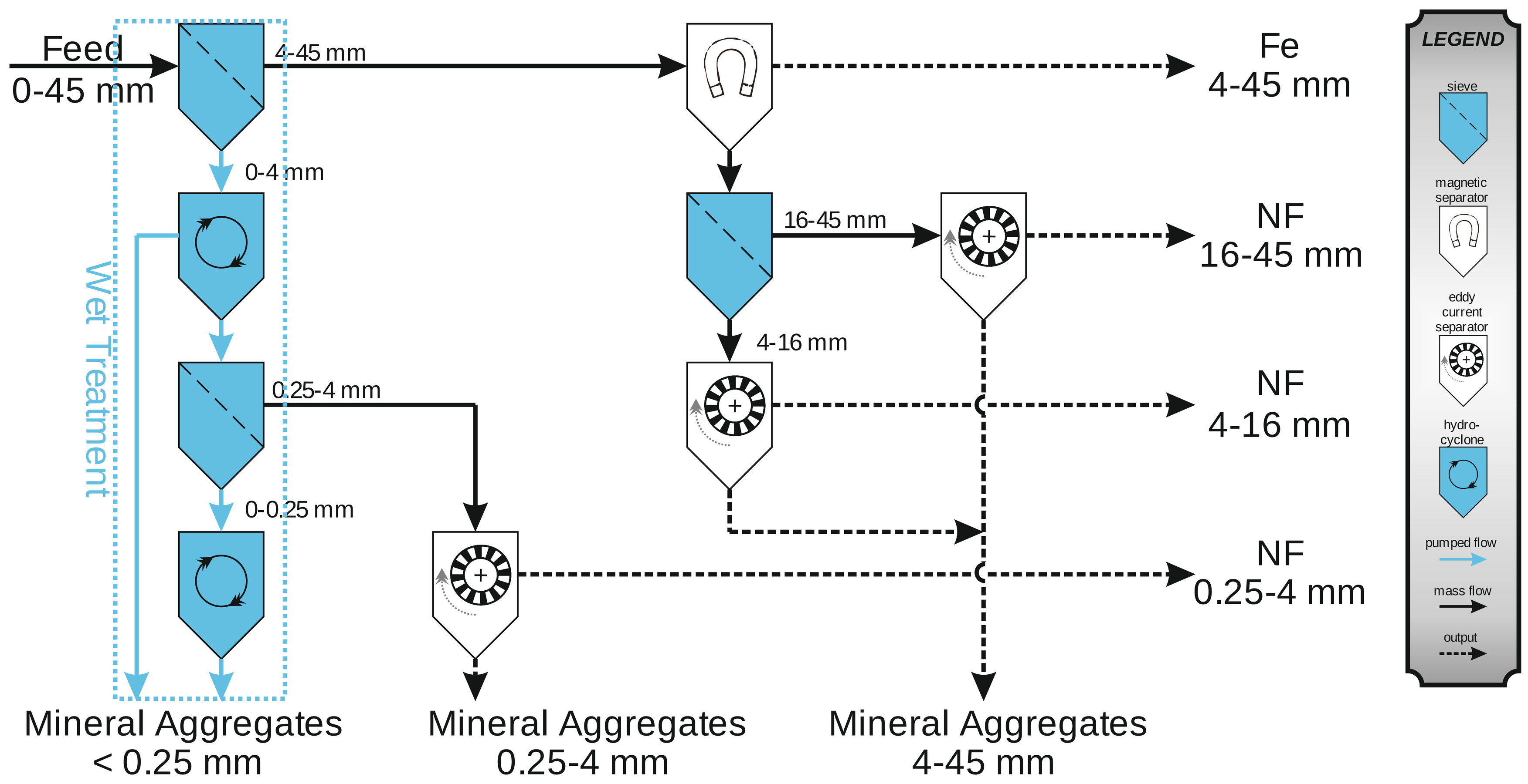

Fig. 2: Flow diagram for wet-mechanical bottom ash treatment

Results

In opposite to batch tests, where no time-dependent release of a certain element can be detected, in column test and lysimeter investigations, leachate rates can be obtained at different liquid/solid (L/S) ratios. Usually, the highest element concentrations in the leachate can be observed in the beginning of the experiment at low L/S ratios. Then the concentrations drop to lower values. This behavior is displayed for the element calcium (Ca) in Fig. 3 (left).

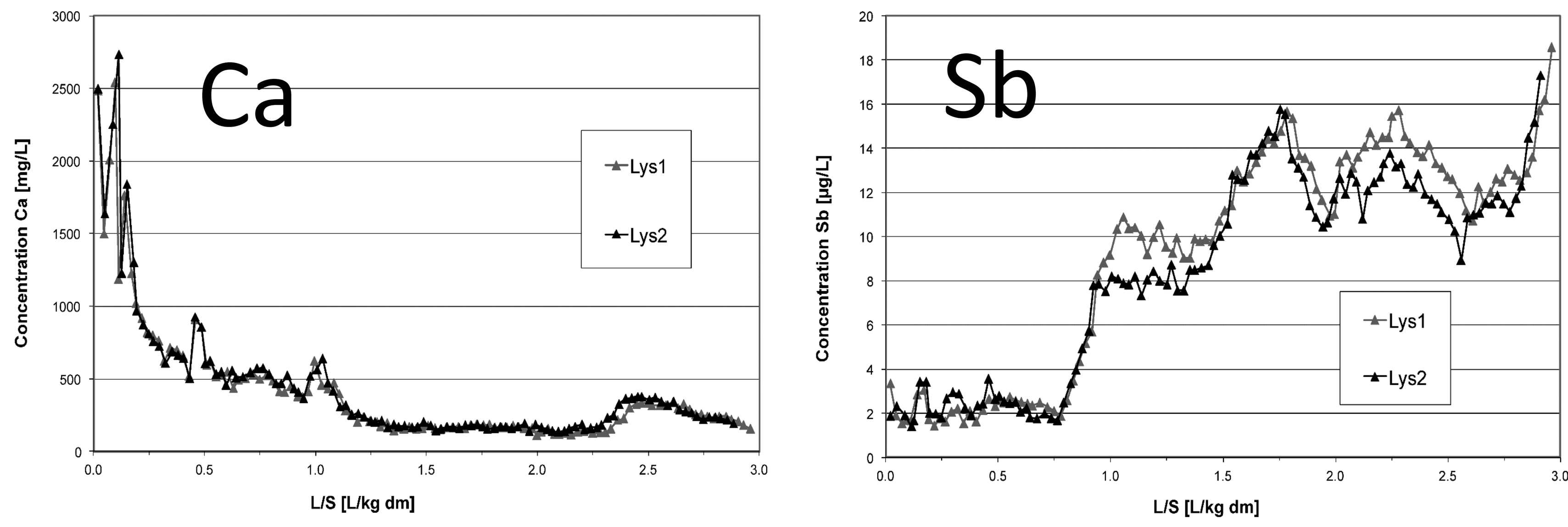

Fig. 3: Concentration of Ca (left) and Sb (right) measured in the lysimeter experiment as function of L/S ratio.

Surprisingly, the observed behavior for antimony (Sb) was different (Fig. 3 right). A low leaching level up to an L/S ratio of 0.75 L/kg followed by an increase by almost a factor of 10. Plotting the Sb concentration versus the Ca concentration (Fig. 4) proves the relationship and can be explained by the formation of sparingly soluble Ca-antimonate ($Ca(Sb(OH)_6)$).

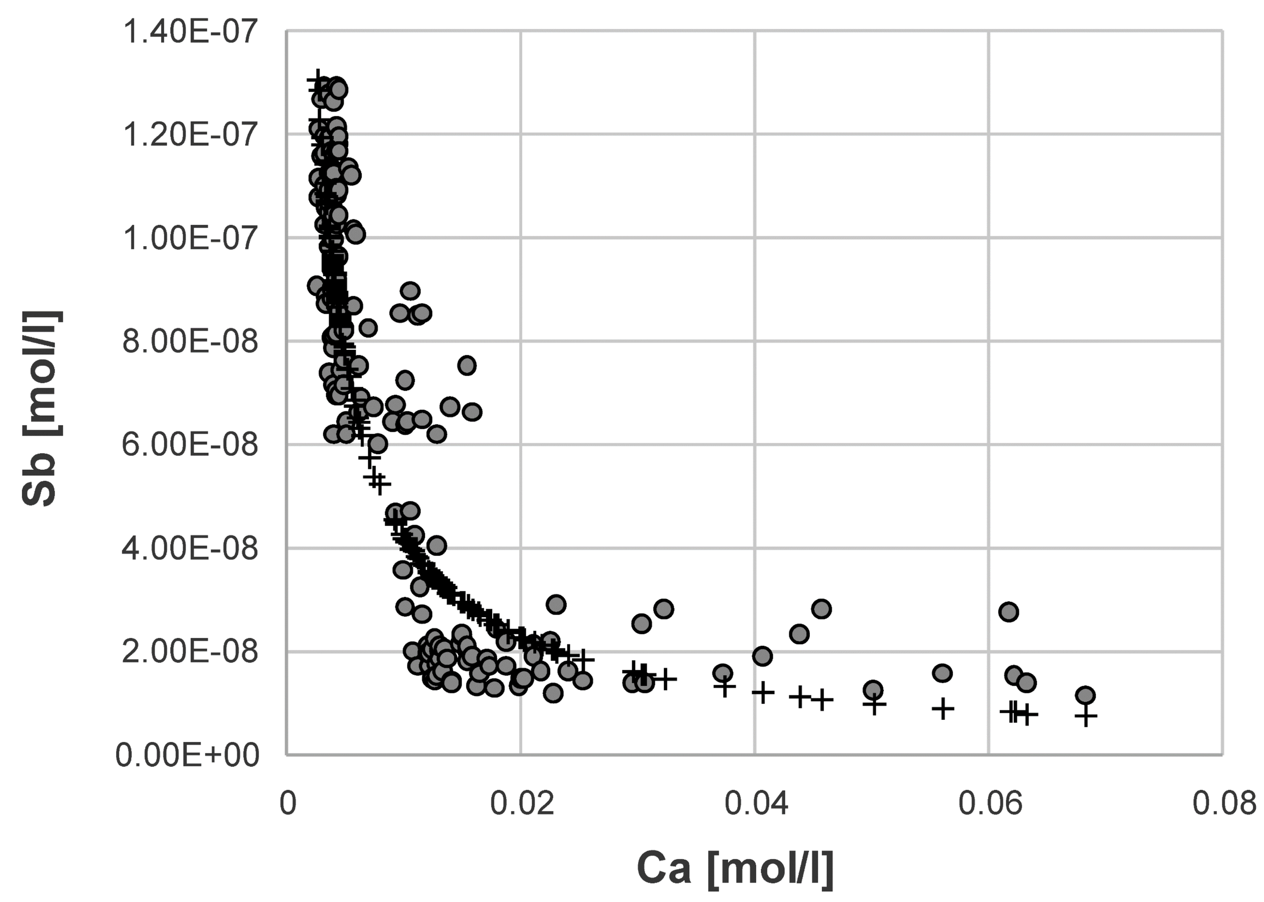

Fig. 4: Sb concentration plotted versus Ca concentration. The crosses are the result of a parameter fit with MS Excel solver.

Using the Solver module in MS Excel, the experimental data for Sb and Ca from the lysimeter experiments describe the solubility of Sb as a function of Ca by the following equation:

$$K_L = [Ca^{2+}]^m [Sb(OH)_6^-]^2$$

with K_L the solubility product of calcium antimonate.

The best fit resulted in a value of 5.0×10^{-19} for K_L and 1.78 for the exponent m, see Figure 4. With these values, the chemical formula to balance positive and negative charges would be $Ca(Sb(OH)_6)_2 x Ca_{0.78}(OH)_{1.56}$.

Conclusion

The leaching behavior of Antimony could be critical in view of the application of MSWI bottom ash as secondary building material for road construction etc. According to the draft of the German Ordinance on Secondary Building Materials (Mantelverordnung) the limit value for Sb is 0.02 mg/kg (at an L/S ratio of 2 L/kg). In opposite to other heavy metals timing of the analysis for Sb could be crucial. In an advanced ageing state of the material Ca concentration could be so low that Sb is already mobilized to levels above the limit value. Thus, a further stabilization of sparingly soluble Sb phases in MSWI BA might be necessary (e.g. by addition of certain iron oxide species).

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