Investigating the Mineralogy of MSWI Bottom Ash using XRD and PARC

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Municipal waste

Municipal waste treatment in 2012
EU 28 + Switzerland, Norway and Iceland

Graph by CEWEP, Source: EUROSTAT 2012
MSW Incineration/ Waste to Energy plant

Bottom Ash (80%)

~90% Volume reduction

Fly Ash (20%)
BA Processing

Plant

- 0-32 mm
- 4-32 mm
- 0-4 mm
- <0.25 mm
- 0.25-1 mm
- 1-4 mm
- clean 4-32 mm
- filter cake <0.25 mm

Lab

- recycled
- not recycled/too contaminated

0-4 mm dry sieving

4-32 mm washing

TU/e Technische Universiteit Eindhoven University of Technology
**BA Processing**

**Plant**
- 0-32 mm
  - dry sieving

**4-32 mm**
- washing

**FBA**
- 0-4 mm

**Lab**
- investigated
  - dry sieving

**BA-S**
- <0.25 mm
- 0.25-1 mm
- 1-4 mm

**clean**
- 4-32 mm
- FC <0.25 mm
BA fines (<4mm)

Problems:

- by 2020 all BA has to be recycled in NL/ no landfilling
- highly contaminated: Cl\textsuperscript{-}, SO\textsubscript{4}\textsuperscript{2-}, Cu, Sb…
- very high porosity

Positives:

- very low/no metallic aluminum content
- potential pozzolanic reactivity
Goal of using XRD/PARC

- What phases (crystalline and amorphous) are present in BA?
- How much of each phase is present?
- What is the composition of each phase?

- Are contaminants located in specific phases?
- Can modeling of leaching/treatments be improved based on this information?
- Can the pozzolanic reactivity be predicted based on this?
# Leaching behaviour

<table>
<thead>
<tr>
<th>Element</th>
<th>SQD Limits</th>
<th>FBA (&lt;4mm)</th>
<th>BA-S (&lt;0.25mm)</th>
<th>FC (&lt;0.25mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sb</td>
<td>0.32</td>
<td>0.22</td>
<td>0.82</td>
<td>2.4</td>
</tr>
<tr>
<td>As</td>
<td>0.9</td>
<td>&lt; 0.0</td>
<td>0.06</td>
<td>&lt; 0.3</td>
</tr>
<tr>
<td>Ba</td>
<td>22</td>
<td>0.7</td>
<td>0.82</td>
<td>0.4</td>
</tr>
<tr>
<td>Cd</td>
<td>0.04</td>
<td>&lt; 0.001</td>
<td>-</td>
<td>&lt; 0.02</td>
</tr>
<tr>
<td>Cr</td>
<td>0.63</td>
<td>0.12</td>
<td>1.79</td>
<td>0.2</td>
</tr>
<tr>
<td>Co</td>
<td>0.54</td>
<td>&lt; 0.03</td>
<td>0.036</td>
<td>&lt; 0.02</td>
</tr>
<tr>
<td>Cu</td>
<td>0.9</td>
<td>14</td>
<td>9.64</td>
<td>1.3</td>
</tr>
<tr>
<td>Pb</td>
<td>2.3</td>
<td>&lt; 0.1</td>
<td>0.12</td>
<td>0.1</td>
</tr>
<tr>
<td>Mo</td>
<td>1</td>
<td>1.1</td>
<td>2.02</td>
<td>0.7</td>
</tr>
<tr>
<td>Ni</td>
<td>0.44</td>
<td>0.24</td>
<td>0.077</td>
<td>0.07</td>
</tr>
<tr>
<td>Se</td>
<td>0.15</td>
<td>&lt; 0.007</td>
<td>-</td>
<td>&lt; 0.2</td>
</tr>
<tr>
<td>Sn</td>
<td>0.4</td>
<td>&lt; 0.02</td>
<td>-</td>
<td>&lt; 0.1</td>
</tr>
<tr>
<td>V</td>
<td>1.8</td>
<td>&lt; 0.1</td>
<td>-</td>
<td>&lt; 0.1</td>
</tr>
<tr>
<td>Zn</td>
<td>4.5</td>
<td>0.48</td>
<td>-</td>
<td>0.4</td>
</tr>
<tr>
<td>Cl⁻</td>
<td>616</td>
<td>6200</td>
<td>11013</td>
<td>2966</td>
</tr>
<tr>
<td>SO₄²⁻</td>
<td>1730</td>
<td>1700</td>
<td>2558</td>
<td>21179</td>
</tr>
</tbody>
</table>

- mg/kg<sub>ds</sub>
- One batch shaking test:
  72h, L/S=12
## Mineral Phases

<table>
<thead>
<tr>
<th>Mineral</th>
<th>Formula</th>
<th>FBA 0-4mm % wt.</th>
<th>BA-S &lt;0.25 % wt.</th>
<th>FC &lt;0.25 % wt.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Melilite</td>
<td>(Ca,Na)$_2$(Al,Mg,Fe)(Al,Si)$_2$O$_7$</td>
<td>4.7</td>
<td>3</td>
<td>0.7</td>
</tr>
<tr>
<td>Feldspar</td>
<td>CaAl$_2$Si$_2$O$_8$</td>
<td>5.7</td>
<td>3.9</td>
<td>1.4</td>
</tr>
<tr>
<td>Calcite</td>
<td>CaCO$_3$</td>
<td>13.5</td>
<td>25.6</td>
<td>17.4</td>
</tr>
<tr>
<td>Ettringite</td>
<td>Ca$_6$Al$_2$(SO$_4$)$<em>3$(OH)$</em>{12}$·26H$_2$O</td>
<td>0.2</td>
<td>4.1</td>
<td>10.4</td>
</tr>
<tr>
<td>Gypsum</td>
<td>CaSO$_4$·2H$_2$O</td>
<td>0.2</td>
<td>5.4</td>
<td>2.6</td>
</tr>
<tr>
<td>Halite</td>
<td>NaCl</td>
<td>0.8</td>
<td>0.7</td>
<td>0.4</td>
</tr>
<tr>
<td>Apatite</td>
<td>Ca$_5$(OH)(PO$_4$)$_3$</td>
<td>6.5</td>
<td>5.2</td>
<td>-</td>
</tr>
<tr>
<td>Quartz</td>
<td>SiO$_2$</td>
<td>12.5</td>
<td>7</td>
<td>2.1</td>
</tr>
<tr>
<td>Hematite</td>
<td>Fe$_2$O$_3$</td>
<td>3.8</td>
<td>2.2</td>
<td>1.2</td>
</tr>
<tr>
<td>Magnetite/Spinel</td>
<td>Fe$_3$O$_4$</td>
<td>8.9</td>
<td>3.8</td>
<td>0.5</td>
</tr>
<tr>
<td>Other</td>
<td>-</td>
<td>7.1</td>
<td>4.2</td>
<td>0.4</td>
</tr>
<tr>
<td>Amorphous</td>
<td>-</td>
<td>36.1</td>
<td>34.9</td>
<td>63</td>
</tr>
</tbody>
</table>
SEM – Single point EDX
SEM – Elemental mapping

- Mg
- Si
- Al
PARC - Phase Recognition and Characterization

- Software compares spectral image from each pixel and groups them into phases according to composition
- no information about crystallinity
FBA (0-4mm)
BA-S (>0.25mm)
FC (<0.25mm)
Outlook - Contaminants

• Result: amorphous and crystalline phases present composition and amount of each phase

• determination of trace element/contaminant content with PARC difficult → Microprobes
Outlook - Reactivity

FC after digestion in NaOH

larger area analyzed

512μm

8x8 fields
Thank you for your attention