New technical document on BAT and costs for aluminium production
Simon Glöser-Chahoud (TFTEI Technical Secretariat)

Agenda

- New document on BAT for aluminium production
- Production of primary aluminium
  - Alumina production (Bayer Process)
  - Fused-salt electrolysis (Hall-Héroult Process)
- Emission abatement technologies and related costs
- Next steps to further develop the document
BAT reference document for non-ferrous metals

✓ Comprehensive description and specification of emission abatement technologies for major non-ferrous metals:
  ✓ copper and its alloys;
  ✓ aluminium and its alloys;
  ✓ lead and tin;
  ✓ zinc and cadmium;
  ✓ precious metals;
  ✓ ferro-alloys (e.g. FeCr, FeSi, FeMn,);
  ✓ nickel and cobalt;
  ✓ carbon and graphite electrodes.

✓ > 1000 pages of partly site specific data

✓ Skipping between different abatement technologies and sections necessary to extract information

5th TFTEI Annual Meeting - Ottawa, Canada, October, 22-24, 2019

Specific document on aluminium

✓ Development of a short but comprehensive document on BAT for aluminium production

✓ Focus on primary aluminium production in a first step
  ✓ Secondary aluminium processing strongly depends on properties of scrap
  ✓ Higher variation in design of processes and related abatement technologies

First feedback from experts received, additional input very welcome

5th TFTEI Annual Meeting - Ottawa, Canada, October, 22-24, 2019
Global production dominated by China

- Very high energy (electricity) demand → tendency to move production to sites/locations with low cost energy
- Many European countries have shut down their primary aluminium production sites

Sources: USGS (2018), German Environmental Agency UBA (2018)

Basic mass and energy balances

<table>
<thead>
<tr>
<th>Output:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminium</td>
<td>1 kg</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Input:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminiumfluoride (Cryolite)</td>
<td>0.018 kg</td>
</tr>
<tr>
<td>Anodes-C</td>
<td>0.43 kg</td>
</tr>
<tr>
<td>Alumina ($\text{Al}_2\text{O}_3$)</td>
<td>1.9 kg</td>
</tr>
<tr>
<td>Bauxite</td>
<td>4-7 kg</td>
</tr>
<tr>
<td>Electricity</td>
<td>48.2 MJ</td>
</tr>
<tr>
<td>Process heat</td>
<td>3.83 MJ</td>
</tr>
</tbody>
</table>

Basic process steps

1. Calcination of Bauxite to produce Alumina (Bayer Process)
2. Production of electrode materials for fused-salt electrolysis
3. Fused-salt electrolysis (Hall-Héroult Process)
   1. Prebake cell
   2. Soderberg cell
4. Casting, further treatment
Alumina production and related emissions (Bayer Process)

**Emission parameter** | **Emission value**
--- | ---
Dust (kg/kg alumina) | 50-100*10^{-6}
NO\textsubscript{2} (kg/kg alumina) | 100-200*10^{-6}
CO\textsubscript{2} (kg/kg alumina) | not reported

- Dust from milling / crushing and further treatment most relevant air emission
- NO\textsubscript{2}, SO\textsubscript{x} emissions depend on fuel and combustion technologies

Emission ranges for different plants taken from the BAT document

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Emission abatement technologies for alumina production

**Average flue gas flow (Nm\textsuperscript{3}/h)** | **Abatement technology** | **Average emission value of dust**
--- | --- | ---
220 000 | ESP | 68 mg/Nm\textsuperscript{3} 0.1 kg/t alumina
300 000 | ESP | 23 0.01
107 000 | Fabric filter | 23 0.07
93 000 | Fabric filter | 23 0.05

Exemplary values for different plants taken from the BAT document

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Main technologies for aluminium electrolysis

<table>
<thead>
<tr>
<th>Cell technology</th>
<th>Cell type</th>
<th>Anode configuration</th>
<th>Alumina feed configuration</th>
<th>Acronym</th>
<th>Breakdown in Europe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prebake cell</td>
<td>Centre worked</td>
<td>Vertical</td>
<td>Bar broken centre feed</td>
<td>CWPB (*)</td>
<td>None</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Vertical</td>
<td>Point centre feed</td>
<td>PFPB</td>
<td>90 %</td>
</tr>
<tr>
<td></td>
<td>Side-worked</td>
<td>Vertical</td>
<td>Manual side feed</td>
<td>SWPB (*)</td>
<td>None</td>
</tr>
<tr>
<td>Søderberg cell</td>
<td>Vertical stud</td>
<td>Vertical</td>
<td>Manual side feed</td>
<td>SWVSS (*)</td>
<td>None</td>
</tr>
<tr>
<td></td>
<td>Horizontal stud</td>
<td>Horizontal</td>
<td>Manual side feed</td>
<td>PFVSS</td>
<td>10 %</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Bar broken feed</td>
<td>HSS (*)</td>
<td>None</td>
</tr>
<tr>
<td>(*): No longer in operation in Europe.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

 ✓ The Søderberg technology uses a continuous anode, which is introduced into the cell as a paste and then bakes in the cell itself.
 ✓ The Prebake technology, as the name implies, uses multiple anodes in each cell, which are baked in a separate facility.

Source: USGS [2018], German Environmental Agency UBA (2018)

Anode production

<table>
<thead>
<tr>
<th>Emission parameter</th>
<th>Emission value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total fluoride (kg/kg anode)</td>
<td>10-100*10^6</td>
</tr>
<tr>
<td>Dust (kg/kg anode)</td>
<td>10-1000*10^6</td>
</tr>
<tr>
<td>SO₂ (kg/kg anode)</td>
<td>100 - 6000*10^6</td>
</tr>
<tr>
<td>NOₓ (kg/kg anode)</td>
<td>100 - 400*10^6</td>
</tr>
<tr>
<td>BaP (kg/kg anode)</td>
<td>0-3*10^6</td>
</tr>
</tbody>
</table>

Production process:
 ✓ Raw materials: petroleum coke, coal tar bits or recycled anode butts
 ✓ Distinction between Prebake and Soderberg anodes
 ✓ Forming and baking at around 1200°C
 ✓ Graphitization

Proposed abatement technologies
 ✓ Bag filters for dust (alternatively ESP with cyclone)
 ✓ Recuperative incinerators for VOC
 ✓ Coke scrubbers for pitch vapors
 ✓ Treatment of fluorides in case of the use of recycled anode butts

Emission ranges for different plants taken from the BAT document
Fused-salt electrolysis
(Hall-Héroult Process)

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Direct emissions</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO</td>
<td>0.18</td>
<td>kg/kg Al</td>
</tr>
<tr>
<td>CO₂</td>
<td>1.4</td>
<td>kg/kg Al</td>
</tr>
<tr>
<td>HF</td>
<td>40*10⁶</td>
<td>kg/kg Al</td>
</tr>
<tr>
<td>Perfluoroethane</td>
<td>25*10⁶</td>
<td>kg/kg Al</td>
</tr>
<tr>
<td>Perfluormethane</td>
<td>250*10⁻⁶</td>
<td>kg/kg Al</td>
</tr>
<tr>
<td>SO₂</td>
<td>0.007</td>
<td>kg/kg Al</td>
</tr>
<tr>
<td>PM₁₀</td>
<td>706*10⁻⁶</td>
<td>kg/kg Al</td>
</tr>
<tr>
<td>PM₂⁺</td>
<td>581*10⁻⁶</td>
<td>kg/kg Al</td>
</tr>
</tbody>
</table>

**Key abatement technologies**

✓ Avoidance of „anode effect“ in which PFCs are formed
  ✓ Point feeding of anodes and alumina, computer controlled voltage
  ✓ Efficient gas collection from electrolytic cells

✓ Fluoride “scrubbing systems” use alumina to extract gaseous fluoride from pot gases. This “activated” alumina, which contains the residual fluoride, is then used as a feed for the reduction process (alternative scrubbing with crushed limestone or water).

Direct air emissions are average values for Germany reported by the Environmental Agency (UBA)

Conclusions, next steps

- **Conclusions regarding the document**
  ✓ Draft document completed in May 2019
  ✓ First revisions from experts received
  ✓ Revised version prepared

- **Next steps**
  ✓ Dissemination of revised document among aluminium experts in TFTEI
    ✓ Preparation of contact list for further work and communication
  ✓ Enhancement of the document in future work
    ✓ Secondary aluminium production
    ✓ Level of detail (technical/economical)
Thank you very much for your attention!

Questions?

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