Sustainable Treatment of Acid Mine Drainage

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3/5/2015
Key Facts & Figures

- Corporate head office in **Oftringen**, Switzerland
- **8,000 employees**
- More than **150 plants** in over **50 countries**
- Turnover of **EUR 3.0 billion**
- Ownership of mineral deposits for the next **100 years** of business
- Most plants are **ISO 9001 / ISO 14001** certified
- **Pioneer** in ISO 14001 for quarries
- In business for **over 125 years**
- **Privately-owned** Swiss based Corporation
Objectives

- Continue **worldwide profitable growth** to remain the **leading company** in our business
- Stay **privately-owned** and financially strong
- The above, while respecting all laws, our code of conduct and live the **Omya values**
Omya, a Good Local Citizen

- Legislative and regulatory compliance
- Measures and continually improves environmental performance
- Health and safety as a key factor
- Training and information of customers, staff and suppliers
- Community relations
- Active cooperation worldwide on industrial relations
- Commitment to staff development and career planning at all levels
Omya Vision for Sustainability

- Omya sustainability framework

Each of these pillars holds a number of objectives we are working towards incorporating into our everyday activities.
Corporate pillar: Total Product Life Cycle

- **Sustainable Extraction practices:**
  - High purity deposits
  - Best Available Techniques
  - Optical sorting / magnetic separation
  - Waste prevention / reduction («Zero Waste»)
  - Use of sustainable energy sources
  - Water purification and recycling

**Sustainable Processing practices:**
- Optimization of capacity
- Water optimization
- Recovery of excess heat
- Reduction of energy consumption
- Reduction of process additives
- Water purification and recycling

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Optimizing Resource Efficiency:
Reduce » Reuse » Recycle

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Corporate pillar: Partnership with People and Planet

«Sustainability is the key to future success on our journey to achieving our objectives»

Omya plant and quarry in southern France with ongoing restoration (left side)
Gold occurs in association with pyrite which produces sulphuric acid when exposed to water and oxygen. The acid dissolves the surrounding ore in flooded parts of the mine, slimes dumps and tailings, releasing the heavy metals within.

The ferric hydroxide formed in this reaction is also called "Yellow Boy", a yellowish orange precipitate that covers stream or river beds with a slimy sludge.
Acid Mine Drainage

‘Yellow Boy’ AMD sludge at Tweelopie Spruit in Krugersdorp

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Acid Mine Drainage

Treatment of AMD (Metals build up)

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Acid Mine Drainage

Lime Usage in AMD

- The treatment of AMD will require lime and limestone to precipitate the heavy elements and neutralise acid. Metals precipitate at the approximate pH as per table below:

<table>
<thead>
<tr>
<th>Metal ion</th>
<th>Precipitation pH range</th>
<th>Optimum pH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ferric iron</td>
<td>$\text{Fe}^{3+}$</td>
<td>&gt;4.0</td>
</tr>
<tr>
<td>Aluminium</td>
<td>$\text{Al}$</td>
<td>4.5-10</td>
</tr>
<tr>
<td>Chromium (III)</td>
<td>$\text{Cr}^{3+}$</td>
<td>&gt;5.3</td>
</tr>
<tr>
<td>Copper</td>
<td>$\text{Cu}$</td>
<td>&gt;6</td>
</tr>
<tr>
<td>Ferrous iron</td>
<td>$\text{Fe}^{2+}$</td>
<td>&gt;9</td>
</tr>
<tr>
<td>Lead</td>
<td>$\text{Pb}$</td>
<td>&gt;6.0</td>
</tr>
<tr>
<td>Nickel</td>
<td>$\text{Ni}$</td>
<td>&gt;6.7</td>
</tr>
<tr>
<td>Cadmium</td>
<td>$\text{Cd}$</td>
<td>&gt;6.7</td>
</tr>
<tr>
<td>Zinc</td>
<td>$\text{Zn}$</td>
<td>8.0-11</td>
</tr>
<tr>
<td>Manganese</td>
<td>$\text{Mn}$</td>
<td>&gt;6.5</td>
</tr>
</tbody>
</table>
Acid Mine Drainage – the Process Flow

1. Calcium Carbonate
   CaCO₃

2. Acid Mine Drainage Water at pH 2-3

3. Lime slurry

4. The PCC slurry is used to raise the pH cost effectively (not using lime) and importantly to protect the pipes and etc from corrosion of the acidic water

5. Treated water to pH 9

6. H-H Disposal Site – treated water sludge

The sludge settles at the bottom and is pumped to the disposal site; the clear cleaner water is pumped to the Game Reserve

Krugersdorp Game Reserve
Tweelopie Spruit

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At Risk: Krugersdorp Game Reserve
Industrial Acid Waste Treatment
Acid effluents from the surface treatment industry

- **Printed circuit board (PCB) industry**
  - Volume of waste effluent: ~ 2.3 mio m³/y in Europe

<table>
<thead>
<tr>
<th>Estimated volume of acid waste for the surface treatment industry</th>
<th>PCB produced Surface area</th>
<th>Wastewater volume</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>m²/y</td>
<td>m³/y</td>
</tr>
<tr>
<td># 1 producer in Austria</td>
<td>114'000</td>
<td>153'000</td>
</tr>
<tr>
<td>PCB producers in Austria</td>
<td>342'000</td>
<td>459'000</td>
</tr>
<tr>
<td><strong>PCB producers in Europe</strong></td>
<td><strong>1'710'000</strong></td>
<td><strong>2'295'000</strong></td>
</tr>
<tr>
<td>Galvanic industry in Europe</td>
<td></td>
<td>3'901'500</td>
</tr>
<tr>
<td>Paint / lacquering in Europe</td>
<td></td>
<td>1'303'500</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>7'500’000</strong></td>
</tr>
</tbody>
</table>
Current treatment of the PCB acid waste (1/2)

• Batch process:

1. Neutralization of the acids
   • Calcium hydroxide (lime): Ca(OH)$_2$
   • Sodium hydroxide: NaOH

2. Precipitation of the heavy metals
   • Precipitation agents (Na$_2$S)
   • Complexing agents
   • Flocculants
Current treatment of the PCB acid waste (2/2)

• **Solids removal within one single sludge:**

1. Sludge dewatering
   • Sedimentation
   • Decantation
   • Filter press

2. Sludge disposal
   • According to local regulatory affairs
   • Landfill, incineration
Costs of the current treatment process

• Costs:
  → Chemicals (~ 25% OPEX costs)
    1. Neutralization: NaOH, Ca(OH)$_2$
    2. Removal of heavy metals: complexing agents, flocculants

→ Sludge disposal (up to 75% OPEX costs!)
  • Contaminated sludge
    → with all the precipitated heavy metals
  • Low solid content of the sludge
    → hard to dewater, jelly consistence
Alternative treatment process

• Added values to the sludge
  • Selective precipitation of valuable heavy metals or substances present in the acid waste (e.g. Cu sludge, white gypsum)

• Process advantages
  • Continuous process
  • No flocculants
  • Easy dewatering of high solid sludge cakes
  • Concentrated sludge cakes of selective metals
Step-wise precipitation process

• Continuous process:

1. Step-wise neutralization of the acids
   • Calcium carbonate (limestone): CaCO$_3$
   • Calcium hydroxide: Ca(OH)$_2$

2. Selective precipitation
   • Precipitation of added-value substances
     → e.g. white gypsum, copper
Example of lab scale testing

- Selective precipitation
  - Batch process in a 6 L reactor
    1. Mixing of the industrial acid waste
    2. Dosage of the limestone slurry
    3. Settling
    4. Filtration of white gypsum
Example of pilot scale testing

- **Continuous neutralization process**
  - 8 h continuous process per precipitation step

- **Continuous sludge dewatering**
  - Filter band (smallest available) to dewater the sludges:
    - white gypsum (photos), iron and copper sludge
Added-value sludges

• Three selective precipitations
  • High concentration of selective substances:
    → New added value to the sludge
    e.g. copper sludge with > 25 wt% Cu

Batch pilot testing

<table>
<thead>
<tr>
<th>Precipitated substance</th>
<th>White gypsum</th>
<th>Iron</th>
<th>Copper</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concentration in cake</td>
<td>100 %</td>
<td>&gt; 10 %</td>
<td>&gt; 25 %</td>
</tr>
<tr>
<td>Cake solid content (after filterpress)</td>
<td>60 % TS</td>
<td>55 % TS</td>
<td>70 % TS</td>
</tr>
</tbody>
</table>
Treatment of the PCB acid waste

- Heavy metals removal from treated effluent
  - Improvement by continuous sludge removal
    → e.g. filtrate: Cu < 5ppm, Fe < 0.1ppm

<table>
<thead>
<tr>
<th></th>
<th>Raw acid</th>
<th>After 1(^{st}) precipitation</th>
<th>After 2(^{nd}) precipitation</th>
<th>After 3(^{rd}) precipitation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fe [ppm]</td>
<td>500</td>
<td>480</td>
<td>~ 0</td>
<td>0</td>
</tr>
<tr>
<td>Cu [ppm]</td>
<td>1’200</td>
<td>1’200</td>
<td>1’150</td>
<td>~ 5</td>
</tr>
<tr>
<td>Ni [ppm]</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>0</td>
</tr>
<tr>
<td>SO(_4^{2-}) [ppm]</td>
<td>9’500</td>
<td>2’100</td>
<td>1’800</td>
<td>1’500</td>
</tr>
<tr>
<td>PO(_4^{3-}) [ppm]</td>
<td>30</td>
<td>10</td>
<td>10</td>
<td>0</td>
</tr>
<tr>
<td>NO(_3^{-}) [ppm]</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Cl(^-) [ppm]</td>
<td>3’900</td>
<td>2’800</td>
<td>2’700</td>
<td>2’500</td>
</tr>
</tbody>
</table>
Technical conclusions

• New neutralization process for the industrial acid waste:
  ➢ Stepwise dosing providing selective metal precipitation
  ➢ pH adjustment to neutral range without issue with overdosing
  ➢ Continuous or Batch process

• Applications:
  • No use of additional flocculants
  • Easy dewatering and high solid sludge cakes
  • Sludge cakes with selective metals at high concentration
March 5, 2015

Thank you for your attention!