A case for elimination of tailings ponds through in-line treatment using a low cost, flocculent free approach: results from two on-site trials

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Introduction

• In-line treatment – why do it
  • Heat
  • Liability
  • Resource Recovery (bitumen, water)
  • Social License

• How we approached it
  • Oil removal-because it is hard on treatment processes and it has value
  • Heavy solids – remove settleable solids (clarifier, centrifuge, cyclone)
  • Ultrafiltration – remove enough to facilitate (passive) treatment and release to the environment possible (because reuse is already easy).
First a comment on effort

- When we initiated the centrifuge project it was with a research budget discretionary fund (Do they exist anymore?).
- The cost of the project was 3x higher than originally expected. Welcome to the oil sands but this was largely a data issue.
- We learned a great deal, NOTHING beats on site pilot work.
- Most of the participants have since moved on, the learnings are poorly documented history, perhaps lost history in the tailings world.
  - The centripetal components of this presentation are reconstructed from a fraction of the total data that was collected.
- The water treatment piece had much wider participation but it too appears to have been forgotten.
Fresh Tailings

- Combination of:
  - Froth flotation tails – primary target fines dominated.
  - Secondary extraction tails – sand contribution.
  - Water cap recycle water – movement due to storage balancing.
Oil Removal

- We deployed a standard horizontal mechanically induced flotation system (Wemco).
- Foaming was an issue. Gaskets had to be managed and ports locked down.
- Solids accumulation in cells was problematic – large efficiency losses and clean-out downtime.
- Surprising oil recovery possible (OK nothing for a mine but BIG for an ESC).
Heavy Solids

- Mud tank used as buffer tank with two mud guns.
  - Solids accumulation in mud tank was horrendous.
    - Required confined space entry and steam service for maintenance.
- Hydrocyclone shaker skid (desilter)
  - Never achieved the theoretical cut
  - Screens blinded immediately. Cold weather a big issue.
  - Still believe this is a technology worth investigating.
Centrifuge – Brute force has its benefits

Table 3: Trial conditions.

<table>
<thead>
<tr>
<th>Centrifuge Parameters</th>
<th>900</th>
<th>1200</th>
<th>1400</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pump Speed (rpm)</td>
<td>900</td>
<td>1200</td>
<td>1400</td>
</tr>
<tr>
<td>Back Drive %</td>
<td>15</td>
<td>25</td>
<td>38</td>
</tr>
<tr>
<td>Bowl Speed (rpm)</td>
<td>2200</td>
<td>2400</td>
<td>2800</td>
</tr>
</tbody>
</table>

- Coagulants alum and gypsum used
- Flocculant A3338 used
- Measurement challenges
  - CST, % solids, vane shear
- Most important performance parameters were:
  - Solids content of feed
  - Coarse content of feed
  - Gypsum over flocculant
    - Gypsum solids that developed better strength and released water but lower capture
    - Flocculant – better solids capture but marshmallows with wetter solids.

- Chemisty Trials
  - No chemistry
  - Polymer (g/t) 500 750 1000
  - Alum (g/t) 500 750 1000
  - Polymer & Alum (g/t) 500 750 1000
  - Gypsum (g/t) 500 750 1000
  - Polymer & Gypsum (g/t) 500 750 1000
Water Cap – Processing stable ultrafine solids

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Units</th>
<th>Average</th>
<th>Max</th>
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<tbody>
<tr>
<td>pH</td>
<td>SU</td>
<td>8.29</td>
<td>8.39</td>
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<tr>
<td>Total Alkalinity</td>
<td>mg/L as CaCO3</td>
<td>725</td>
<td>780</td>
</tr>
<tr>
<td>TSS</td>
<td>mg/L</td>
<td>359</td>
<td>880</td>
</tr>
<tr>
<td>Turbidity</td>
<td>NTU</td>
<td>489</td>
<td>1000</td>
</tr>
<tr>
<td>Conductivity</td>
<td>μS/cm</td>
<td>2988</td>
<td>3200</td>
</tr>
<tr>
<td>TDS</td>
<td>mg/L</td>
<td>2094</td>
<td>2500</td>
</tr>
<tr>
<td>Total Sodium</td>
<td>mg/L</td>
<td>631</td>
<td>700</td>
</tr>
<tr>
<td>Chloride</td>
<td>mg/L</td>
<td>450</td>
<td>520</td>
</tr>
<tr>
<td>Bicarbonate</td>
<td>mg/L</td>
<td>876</td>
<td>930</td>
</tr>
<tr>
<td>Total Hardness</td>
<td>mg/L as CaCO3</td>
<td>47</td>
<td>56</td>
</tr>
<tr>
<td>TOC</td>
<td>mg/L</td>
<td>47</td>
<td>69</td>
</tr>
<tr>
<td>Oil &amp; Grease</td>
<td>mg/L</td>
<td>25</td>
<td>32</td>
</tr>
<tr>
<td>Naphthenic Acids</td>
<td>mg/L</td>
<td>54</td>
<td>68</td>
</tr>
<tr>
<td>COD</td>
<td>mg/L</td>
<td>425</td>
<td>530</td>
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• CNRL initiated a technology search for pre-treatment to a potential RO water treatment plant.

• Global search, reduced to 12 technologies, 3 selected for piloting

• 2 eventually trialed on site.

• Our pilot system consisted of flotation and ultrafiltration.
Froth Flotation

• High Intensity Froth Flotation (HiFF).
  • Uses a highly charged (anionic) surfactant and air to generate froth.
  • The charged bubble surface causes EDL collapse and attachment.
  • Larger bubble sizes to increase rise rate.
  • Can work with any flotation system.

• 98.6% turbidity removal in a simple step
  • Very low cost
  • Simple implementation
Ultrafiltration

• Uses same principle of EDL collapse using a highly charged replaceable skin layer.
  • Overcomes the issue of membrane fouling
  • >10x the efficiency of standard ultrafiltration.
  • Dead-end, no crossflow required.

• Reduced turbidity to 0.2 NTU

• Subsequent trials with higher concentration brines

• Reduction in Si by 99%
Table 5: Ultrafiltration of 3 high mineral content brines from the Ft McMurray area. Raw is the feed water and Perm is the permeate after ultrafiltration.

<table>
<thead>
<tr>
<th>Scale Parameter</th>
<th>EBD1 Raw</th>
<th>EBD1 Perm</th>
<th>EBD2 Raw</th>
<th>EBD2 Perm</th>
<th>OTSG Raw</th>
<th>OTSG Perm</th>
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</thead>
<tbody>
<tr>
<td>Total Silicon (mg/L)</td>
<td>1641</td>
<td>33</td>
<td>9200</td>
<td>71</td>
<td>120</td>
<td>22</td>
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<tr>
<td>Total Barium (mg/L)</td>
<td>14</td>
<td>4.9</td>
<td>5.5</td>
<td>0.6</td>
<td>32</td>
<td>&lt;0.1</td>
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<tr>
<td>Total Strontium (mg/L)</td>
<td>67</td>
<td>34</td>
<td>13</td>
<td>5</td>
<td>0.21</td>
<td>&lt;0.2</td>
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<tr>
<td>Fe-Dis (mg/L)</td>
<td>10</td>
<td>ND</td>
<td>&lt;6</td>
<td>&lt;0.6</td>
<td>&lt;0.6</td>
<td>&lt;0.6</td>
</tr>
<tr>
<td>Ca-Dis (mg/L)</td>
<td>1387</td>
<td>637</td>
<td>180</td>
<td>150</td>
<td>100</td>
<td>46</td>
</tr>
<tr>
<td>Mg-Dis (mg/L)</td>
<td>115</td>
<td>33</td>
<td>20</td>
<td>4.1</td>
<td>20</td>
<td>2</td>
</tr>
<tr>
<td>TOC (mg/L)</td>
<td>4800</td>
<td>3550</td>
<td>660</td>
<td>180</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Turbidity (NTU)</td>
<td>8.5</td>
<td>2.2</td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
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