ARD treatment in sequential filter sections – efficiency of different alkaline by-products

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ARD-reactor
Separating wall
Alkaline material
Supportive materials

ARD from reactors
1. Fly ash F
2. Lime mud/fly ash
3. Fly ash E
4. Lime kiln dust
5. Green liquor dreg
6. LD-slag

Type of alkali
OH/CO₂  OH/CO₃  OH/CO₂  OH/CO₃  CO₃  OH
Results

- Total buffering capacity in the filters
- Acidity loadings from reactors

### ARD from Reactors

<table>
<thead>
<tr>
<th></th>
<th>Tot.alk.(meq/kg)</th>
<th>N.cap.(eq)</th>
<th>Ac. Load(eq H+)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008 Fly ash F</td>
<td>3.200</td>
<td>1,024</td>
<td>3.3</td>
</tr>
<tr>
<td>2008 Lime mud/fly ash</td>
<td>6.600</td>
<td>3,762</td>
<td>3.3</td>
</tr>
<tr>
<td>2008 Fly ash E</td>
<td>2.500</td>
<td>775</td>
<td>3.3</td>
</tr>
<tr>
<td>2008 Lime kiln dust</td>
<td>9.000</td>
<td>5,490</td>
<td>2.5</td>
</tr>
<tr>
<td>2008 Green liquor dreg</td>
<td>7.400</td>
<td>2,442</td>
<td>2.5</td>
</tr>
<tr>
<td>2008 LD-slag</td>
<td>1.600</td>
<td>1,536</td>
<td>2.5</td>
</tr>
</tbody>
</table>

### ARD from Reactors (pH 2.8-3.3)

<table>
<thead>
<tr>
<th></th>
<th>pH</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008 Fly ash F</td>
<td>5.7</td>
</tr>
<tr>
<td>2008 Lime mud/fly ash</td>
<td>3.6</td>
</tr>
<tr>
<td>2008 Fly ash E</td>
<td>3.4</td>
</tr>
<tr>
<td>2008 Lime kiln dust</td>
<td>5.8</td>
</tr>
<tr>
<td>2008 Green liquor dreg</td>
<td>3.7</td>
</tr>
<tr>
<td>2008 LD-slag</td>
<td>4.9</td>
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</tbody>
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ARD from reactors (pH 2.8-3.3)

1. Fly ash F
2. Lime mud/fly ash
3. Fly ash E
4. Lime kiln dust
5. Green liquor dreg
6. LD-slag

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<tr>
<th>Year</th>
<th>pH 2008</th>
<th>pH 2009</th>
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<tr>
<td>2008</td>
<td>5.7</td>
<td>3.6</td>
</tr>
<tr>
<td>2009</td>
<td>5.0</td>
<td>3.8</td>
</tr>
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</table>

- pH increase season 2 for all filters except fly ash F
- Net alkalinity
  - Lime kiln dust and LD-slag both seasons
  - Fly ash F both seasons, but low alkalinity (0.1 meq/L)
  - In season 2, also green liquor dreg and fly ash E
- Net acidity
  - Lime mud/fly ash F

Iron and aluminum, % removed from solution
Conc. from reactors: Fe 90 mg/L, Al 25 mg/L

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<th>Fe 2009</th>
<th>Al 2008</th>
<th>Al 2009</th>
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<tbody>
<tr>
<td>F1, fly ash F</td>
<td>88</td>
<td>80</td>
<td>85</td>
<td>80</td>
</tr>
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<td>F2, lime mud/fly ash F</td>
<td>31</td>
<td>14</td>
<td>12</td>
<td>13</td>
</tr>
<tr>
<td>F3, fly ash E</td>
<td>21</td>
<td>30</td>
<td>13</td>
<td>19</td>
</tr>
<tr>
<td>F4, lime kiln dust</td>
<td>24</td>
<td>71</td>
<td>0</td>
<td>64</td>
</tr>
<tr>
<td>F5, green liquor dreg</td>
<td>29</td>
<td>18</td>
<td>0</td>
<td>12</td>
</tr>
<tr>
<td>F6, LD-slag</td>
<td>6</td>
<td>79</td>
<td>0</td>
<td>73</td>
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Iron and aluminum, % removed from solution
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F1, fly ash F 88 80 85 80
F2, lime mud/fly ash F 31 14 12 13
F3, fly ash E 21 30 13 19
F4, lime kiln dust 24 71 0 64
F5, green liquor dreg 29 18 0 12
F6, LD-slag 6 79 0 73

Iron and aluminum, % removed from solution
Conc. from reactors: Fe 90 mg/L, Al 25 mg/L

• F1, fly ash F
• F2, lime mud/fly ash F
• F3, fly ash E
• F4, lime kiln dust
• F5, green liquor dreg
• F6, LD-slag

2008 89 % 46 % 32 % 54 % 25 % 42 %
2009 87 % 17 % 45 % 80 % 20 % 81 %

The main purpose with the first filter section is however to neutralize the acid and increase pH, not necessarily decrease trace elements!

Discussion

• 2008
  – F1: Iron and aluminum prec.
  – F2, F3, F5: Iron and aluminum low degree of prec. (low pH)
  – F4, F6: Iron and aluminum low degree of prec., pH too low for iron(II)hydrolysis
• 2009
  – F1: Iron and aluminum prec.
  – F2, F3, F5: Still low degree of Fe and Al prec.
  – F4, F6: Iron and aluminum prec., pH high enough for Fe(II)hydrolysis (pH>8). Blue-green precipitates (probably FeCO3 (green rust))
Discussion

• Filters 2, 3 and 5 low acid neutralizing effect
• Iron and aluminum precipitates seem to passivate neutralizing surfaces (especially for carbonate materials)
• Horse manure added to filters 2 and 3 in summer 2010
  — pH increased to above 5.5

Conclusions

• Carbonated fly ash and mixture fresh fly ash/lime mud act as carbonate materials
• Hydroxide materials were superior to carbonate materials in the present experimental setup
• As the filters are designed today, only hydroxide materials work sufficiently, some modifications are though suggested

Conclusions, cont.

• Filters with carbonate materials
  — Addition of reducing material, analogous to an ALD
  — Aeration of ARD prior to filter
• Filters with hydroxide materials
  — Mixing of material with e.g. wood chips for better flow
  — Precipitation of aluminum cannot be avoided, iron(II) can however maintain in solution up to pH 8

Thanks for Your Attention!

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