Biosolids and Crocodile Manure For Treating Acidic Metalliferous Mine Drainage

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The Problem

- Number of mine sites in Darwin area with legacy issues.
- Metal mines with acidic drainage.
- Not allowed to discharge in dry season.
- Wet season are storms and flash floods.
# Typical Chemistry

<table>
<thead>
<tr>
<th>Dissolved Metals</th>
<th>Al</th>
<th>As</th>
<th>Cd</th>
<th>Co</th>
<th>Cr</th>
<th>Cu</th>
<th>Fe</th>
<th>Pb</th>
<th>Mn</th>
<th>Ni</th>
<th>U</th>
<th>Zn</th>
<th>SO4</th>
<th>pH</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>µg/L</td>
<td>µg/L</td>
<td>µg/L</td>
<td>µg/L</td>
<td>µg/L</td>
<td>µg/L</td>
<td>µg/L</td>
<td>µg/L</td>
<td>µg/L</td>
<td>µg/L</td>
<td>µg/L</td>
<td>µg/L</td>
<td>mg/L</td>
<td>pH Units</td>
</tr>
<tr>
<td>LOR</td>
<td>10</td>
<td>1</td>
<td>0.1</td>
<td>1</td>
<td>1</td>
<td>10</td>
<td>1</td>
<td>5</td>
<td>1</td>
<td>1</td>
<td>0.5</td>
<td>1</td>
<td>-</td>
<td>6-8</td>
</tr>
<tr>
<td>ANZECC/ARMCANZ Guidelines¹</td>
<td>55</td>
<td>24²</td>
<td>0.2</td>
<td>ID</td>
<td>1.0</td>
<td>1.4</td>
<td>ID</td>
<td>3.4</td>
<td>1900</td>
<td>11</td>
<td>ID</td>
<td>8.0</td>
<td>-</td>
<td>6.8</td>
</tr>
<tr>
<td>Mine water</td>
<td>950000</td>
<td>25</td>
<td>130</td>
<td>25000</td>
<td>1100</td>
<td>7900</td>
<td>140000</td>
<td>29</td>
<td>260000</td>
<td>27000</td>
<td>1100</td>
<td>13000</td>
<td>35000</td>
<td>2.7</td>
</tr>
</tbody>
</table>
Possible Solution

• Had to consider climate, site available material and proximity:
  – Onsite dolomite, mountain of old waste tyres
  – Local farms (cow and crocodile)
  – Local sewage works with stockpiled biosolids (relatively new and 1-2 years old) as expensive to dispose in landfills
  – Local oyster farm with spent oyster shells
  – Green waste (mulch aged and fresh)
Historic Use

• Not new idea to use biosolids in US.
  – Studies have e.g. McCullough et al, 2008
  – Using sewage in acid pit lake and SRB column work (Eger et al, 2003)
  – Also taconite mine remediation in Minnesota mine reclamation (Eger et al 2013)
  – But new in Australia

• Water quality implications of using shredded tyres as an inert drainage layer in a wetland system (by Fannin et al, 2009).
Biosolids

- Non-industrial source
- Chlorinated and non-chlorinated
- Fresh and aged (1-2 years)
- The older and more established stockpiles more likely to contain sulphate reducing bacteria
- Both tested
The Study

• Examines use of biosolids and other organic/neutralising materials as providing organic matter/cellulose and SRBs

• First stage of tiered assessment:
  – **Proof of Principle testing – static test**
  – Bench scale testing: dynamic test
  – Pilot scale testing: dynamic test

• Leads to development of sizing and design criteria for full scale system
The Study

- Assessed biosolids (older, chlorinated and younger un-chlorinated) from sites in Darwin
- Manures from local farms, including crocodile
- Carbonate source – crushed oyster shells and local dolomite
- Mulch and shredded tyre from the site
- Vegetative organic carbon – mulch to sustain SRB
- Rubber tyres – suggested drainage layer
The Study

• Static proof of principle test
• Mixture of substrates with mine water in various proportions
• pH, conductivity and redox recorded weekly
• 30 samples (including duplicates, controls)
Results

• Most successful substrates, in terms of pH increasing from 2.5 – 7.1 included:
  • Bio solids, chlorine dosed
    - older/lime present?
  • Crocodile manure
    - diet relevant
  • Waste oyster shells
    - calcium carbonate
# Results

<table>
<thead>
<tr>
<th>mg/l</th>
<th>Al</th>
<th>As</th>
<th>Cd</th>
<th>Co</th>
<th>Cr</th>
<th>Cu</th>
<th>Fe</th>
<th>Pb</th>
<th>Mn</th>
<th>Ni</th>
<th>U</th>
<th>Zn</th>
<th>SO4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mine water</td>
<td>95</td>
<td>0.025</td>
<td>0.13</td>
<td>25</td>
<td>1.1</td>
<td>7.9</td>
<td>1400</td>
<td>0.029</td>
<td>260</td>
<td>27</td>
<td>1.1</td>
<td>13</td>
<td>35000</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Substrate</th>
<th>Al</th>
<th>As</th>
<th>Cd</th>
<th>Co</th>
<th>Cr</th>
<th>Cu</th>
<th>Fe</th>
<th>Pb</th>
<th>Mn</th>
<th>Ni</th>
<th>U</th>
<th>Zn</th>
<th>SO4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biosolid (Cl-dosed)</td>
<td>99.96</td>
<td>96.00</td>
<td>100.00</td>
<td>98.48</td>
<td>100.00</td>
<td>99.96</td>
<td>65.71</td>
<td>100.00</td>
<td>26.92</td>
<td>99.48</td>
<td>99.61</td>
<td>99.85</td>
<td>40.00</td>
</tr>
<tr>
<td>Oyster Shell</td>
<td>99.94</td>
<td>84.00</td>
<td>100.00</td>
<td>32.00</td>
<td>98.82</td>
<td>99.97</td>
<td>64.29</td>
<td>100.00</td>
<td>30.77</td>
<td>40.74</td>
<td>93.18</td>
<td>97.15</td>
<td>31.43</td>
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<tr>
<td>Shell, biosolid (Cl-dosed)</td>
<td>99.99</td>
<td>99.99</td>
<td>100.00</td>
<td>90.40</td>
<td>100.00</td>
<td>100.00</td>
<td>62.14</td>
<td>100.00</td>
<td>26.92</td>
<td>99.37</td>
<td>99.46</td>
<td>99.93</td>
<td>37.14</td>
</tr>
<tr>
<td>Biosolid(Cl), mulch</td>
<td>99.96</td>
<td>84.00</td>
<td>100.00</td>
<td>94.40</td>
<td>98.73</td>
<td>100.00</td>
<td>45.00</td>
<td>100.00</td>
<td>11.54</td>
<td>98.81</td>
<td>98.64</td>
<td>99.87</td>
<td>37.14</td>
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<tr>
<td>Mulch croc manure</td>
<td>100.00</td>
<td>99.99</td>
<td>100.00</td>
<td>98.76</td>
<td>100.00</td>
<td>100.00</td>
<td>99.74</td>
<td>100.00</td>
<td>82.69</td>
<td>98.37</td>
<td>99.38</td>
<td>99.96</td>
<td>51.43</td>
</tr>
</tbody>
</table>
Summary

– Croc manure, biosolid (Cl dosed) show potential.
– Up 100% reduction in metals (Al, Pb, Cu, Zn, As, Cd, Fe, U).
– Mn and Fe not removed fully in anaerobic systems.
– Oyster shell most effective alkalinity supplier.
– Sulfate reduced (40 - 50%) showing SRB?.
– Mulch potential cellulose source.
– Shredded tyre, inert.
Oz and US Differences

• The Australia Department of Industry, Tourism and Resources (2007) drainage >800 mg/L CaCO$_3$ acidity and a loading of >150 kg CaCO$_3$/d not suitable.

• Developed by examining systems which failed and did not take into account area.

• In US, 3.5g acidity/m$^2$/d (Hedin, 1994) and rule of thumb (Wildeman, pers com.):
  – pH3 : 20 m$^2$/l/min
  – pH4 : 15 m$^2$/l/min
Ongoing Tiered Assessment

Bench Scale Testing
(thanks Jim Gusek)

Pilot Scale Testing (Louisville, Kentucky)
Layout Options

- Flow control, balancing ponds etc.
- Flash floods in Darwin
- Usually two cells to cope with down time (maintenance)
- Aerobic polishing to remove Fe, Mn and BOD

Thanks again Jim G!
Thank You

Larson’s Frog Pioneers

• Still an innovative (pioneering) technology
• Systems can be built in nearly any climate – including NT!
• They can attract – roos and echidna!