Treatment of Leach Pad Waters at the Landusky Mine

A. Opara, D. Jack Adams*, Mike J. Peoples & William C. Maehl

Landusky Conventional Biotreatment System

Treatment Conditions

- Water temp. <2 - 12° C
- pH~4.0 adjusted to ~6.5
- NO₃-N - ~250 mg/L
- Hardness >2,100 mg/L
- Broad spectrum of metals (Se, Cd, CN, Cu, Fe, Mn, Ni, Zn)

(3) – 250,000 gallon (946 m³) Bioreactors in series
Refurbishing Bioreactors 1 & 2
Electro-Biochemical Reactor Technology (EBR)

(EBR Plot-Testing During Refurbishing)
<table>
<thead>
<tr>
<th></th>
<th>Influent</th>
<th>LBS Effluent</th>
<th>EBR Effluent</th>
<th>Discharge Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CN(^1)</strong></td>
<td>0.084</td>
<td>NA</td>
<td>&lt;0.005</td>
<td>0.005</td>
</tr>
<tr>
<td><strong>CN(^1)</strong></td>
<td>0.012</td>
<td>0.072</td>
<td>&lt;0.005</td>
<td>NA</td>
</tr>
<tr>
<td><strong>Al [mg/L]</strong></td>
<td>0.34</td>
<td>1.99</td>
<td>0.04</td>
<td>NA</td>
</tr>
<tr>
<td><strong>Cd [mg/L]</strong></td>
<td>0.135</td>
<td>0.125</td>
<td>&lt;0.001</td>
<td>0.005</td>
</tr>
<tr>
<td><strong>Cu [mg/L]</strong></td>
<td>0.061</td>
<td>0.122</td>
<td>0.014</td>
<td>0.031</td>
</tr>
<tr>
<td><strong>Mn [mg/L]</strong></td>
<td>57</td>
<td>55</td>
<td>29</td>
<td>NA</td>
</tr>
<tr>
<td><strong>Ni [mg/L]</strong></td>
<td>0.832</td>
<td>0.893</td>
<td>0.007</td>
<td>NA</td>
</tr>
<tr>
<td><strong>Se [mg/L]</strong></td>
<td>0.858</td>
<td>0.417</td>
<td>0.039</td>
<td>0.050</td>
</tr>
<tr>
<td><strong>Zn [mg/L]</strong></td>
<td>2.26</td>
<td>2.94</td>
<td>0.04</td>
<td>0.388</td>
</tr>
<tr>
<td><strong>NO(_3)-N [mg/L]</strong> (2011-2014 Ave)</td>
<td>255</td>
<td>25</td>
<td>&lt;1</td>
<td>10.0</td>
</tr>
</tbody>
</table>

\(^1\)After EBR system aerobic step.
In comparison testing Inotec has demonstrated EBR technologies with precious metals, base metals, coal mining and coal fired power pant waters to be best treatment solution for removing Se, nitrates and other co-contaminants.

Adapted from Mohamed Y. El-Naggar and Steven E. Finkel - May 2013
EBR Technology

- EBR technology utilizes directly supplied electrons to provide energy for cell growth and contaminant conversion

- Low voltage (1-3 Volts potential and low milli-amps) provides:
  1. Electrons and electron acceptor environments for controlled contaminant removal environment
  2. Compensation for inefficient and fluctuating electron availability through nutrient metabolism

- 1 mA provides ~$6.24 \times 10^{15}$ electrons/second to the EBR system.
  - Replaces excess nutrients – Lower OPEX costs
  - Results in a more robust system with better contaminant removal
  - Produces less TSS (bio-solids) – Lower CAPEX Costs
## Conversion to EBR Technology 2014
*(Preliminary Full-Scale EBR Results)*

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<th>Discharge Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Al [mg/L]</td>
<td>0.11</td>
<td>0.19</td>
<td>0.04</td>
<td>NA</td>
</tr>
<tr>
<td>Cd [mg/L]</td>
<td>0.21</td>
<td>0.12</td>
<td>0.009</td>
<td>0.005</td>
</tr>
<tr>
<td>Cu [mg/L]</td>
<td>0.01</td>
<td>0.12</td>
<td>0.003</td>
<td>0.031</td>
</tr>
<tr>
<td>Ni [mg/L]</td>
<td>1.45</td>
<td>0.89</td>
<td>0.55</td>
<td>NA</td>
</tr>
<tr>
<td>Se [mg/L]</td>
<td>0.830</td>
<td>0.417</td>
<td>0.035</td>
<td>0.050</td>
</tr>
<tr>
<td>Zn [mg/L]</td>
<td>2.25</td>
<td>2.94</td>
<td>0.87</td>
<td>0.388</td>
</tr>
<tr>
<td>NO₃-N [mg/L]</td>
<td>220</td>
<td>25</td>
<td>0.03</td>
<td>10</td>
</tr>
</tbody>
</table>
RCTS and In Situ Pump Tank (2015)

RCTS Unit - Aeration of EBR Effluent Prior to Treatment

In situ Treatment Pump Tank

Trickling Filter – Cyanide Polishing
• Reconfiguring the Landusky EBR system 2014 for partial redistribution of the EBR effluent to in situ heap treatment

• Approaches have been proven in full-scale applications at several US hard rock mines at elevations >3,200 meters
Initial In Situ Treatment of L-87 Pad (2014)

- ~220,000 gallons of inoculum
- ~550,000 gallons of rinse water
- Less than 1 treatment volume per 80 volumes of L-87 Pad Water to be treated.
- ~112 Million tons of Pad Materials
- ~150 Million gallons of water per year

L87 in 2014 was 223
L87 in 4/2015 is 221
L91 in 2014 was 218
L91 in 4/2015 is 225
In Situ Control Valves and Distribution System
A lined spent ore depository constructed in 2002/2003

~2,500,000 tons of spent ore

A total nitrate/ nitrite load of ~24.73 tons

Nitrates were from ANFO and cyanide degradation
Active Treatment (2004 - 2006)

- Treated with ~13 million gallons of re-circulated treatment/rinse water solution from a constructed treatment system pond.
- Sampling results and kriging analysis indicated in situ denitrification was highly effective, reducing the estimated nitrate load by approximately 90%.
- Treatment completed by 2007 and site was reclaimed.
In Situ Cyanide Degradation

WAD Cyanide In Situ Biotreatment

<table>
<thead>
<tr>
<th>DATE</th>
<th>3-Dec</th>
<th>31-Dec</th>
<th>28-Jan</th>
<th>25-Nov</th>
</tr>
</thead>
<tbody>
<tr>
<td>WAD CN (mg/L)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>100</td>
<td>200</td>
<td>300</td>
<td>400</td>
</tr>
</tbody>
</table>

[Graph showing the degradation of WAD cyanide over time.]
In situ Arsenic Stabilization

[Graph showing arsenic levels over time with date and arsenic concentration axes]

- GWAC6
- AC@ USGS
- SW Limit
- GW Limit
Refinery Site – In Situ Se Stabilization
Thank You

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