BIOLOGICAL TREATMENT OF METALS AND INORGANICS IN MINING WATERS

JACK ADAMS
METAL AND INORGANIC BIOTREATMENT

• Cost effective technology to transform and remove metals and inorganics from large water volumes

• Biological metal and inorganic transformation/removal methods, in general, produce 1,000’s to 10,000 times less sludge than conventional chemical precipitation technologies
BIOTREATMENT APPROACH

- Site evaluation - understand site chemistry and environmental parameter interactions
- Select appropriate microorganisms for optimal performance in site waters and site conditions and conduct biotreatability testing in site waters
- Design / Engineer a bioreactor system to provide desired contaminant removals and conduct on-site pilot-scale testing
SITE EVALUATION

- Seasonal or year round treatment
  - Volume to be treated & treatment system size
- Current and seasonal water chemistry
  - pH, temperature, suspended solids, etc.
  - Contaminants
  - Co-contaminants
- Expected changes in water chemistry
BIOTREATABILITY TESTING

ARSENIC REDUCTION SCREEN

DAYS
0 1 2 3 4 5
RELATIVE As REDUCTION

MICROORGANISM
AS-A S-34B AS-B-UT S-34A PST-A PR-3B PR-5A S-280 PR-2A
PR-2B PR-28 PST-3A PR-360 PP

NUTRIENT/AERATION SCREEN

1 - PGY
2 - PEPTONE
3 - DEXTROSE/AMMONIUM SULFATE

Se (mg/l)
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7
NUTRIENT SUPPLEMENT
UNTREATED
AERATED
NON-AERATED

1 2 3
EPA MINE WASTE TECHNOLOGY PROGRAM VALIDATION

- Se ~2.0 mg/L with low levels of Cu and As
- pH ~7.0
- Flow Rate - 2 gpm
- Retention Time 5.5 hr to 11 hr
- Over 9 months testing
TEST SUMMARY*

• Applied Biosciences’ Biological Selenium Removal process was the only technology, including ferrihydrite adsorption, to remove selenium to below discharge criteria (50 ppb) under site testing
  – The Applied Biosciences’ metal removal bioprocess removed selenate and selenite to below detection
  – During the nine months of testing, the bioprocess also consistently removed low levels of copper and arsenic to below detection
### EPA Economic Analysis (Metal Removal)

<table>
<thead>
<tr>
<th>Cost</th>
<th>Ferrihydrite Adsorption</th>
<th>Catalyzed Cementation</th>
<th>Bioprocess</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capital</td>
<td>$1,026,835</td>
<td>$1,083,285</td>
<td>$603,999</td>
</tr>
<tr>
<td>Annual O&amp;M</td>
<td>$2,084,559</td>
<td>$1,165,358</td>
<td>$135,029</td>
</tr>
<tr>
<td>Capital and Operational Costs</td>
<td>$18,017,962</td>
<td>$10,582,608</td>
<td>$1,704,681</td>
</tr>
<tr>
<td>Costs over 10 years</td>
<td>$13.90</td>
<td>$8.17</td>
<td>$1.32</td>
</tr>
</tbody>
</table>

Total treatment costs per (1,000 gal)

*EPA Mine Waste Technology Program Final Report - Selenium (Based on 2mg/L selenium @ 300 gpm – over 10 yrs)
• Nitrate ~240 mg/L
• Selenium ~0.8 mg/L
• Cyanide ~0.7 mg/L
• 108 Millions tons spent ore
• 150 Million gallons require treatment annually
• Geochemistry – changing
• pH ~5.0 => ~7.0
• Other contaminants
  AI, Mg, Mn, Zn, SO4-2, Na, Ni, Cu, As
PILOT-SCALE BIOTREATMENT SYSTEM

Treatment Criteria
- Ambient water temp. ~8° C
- NO₃-N ~240mg/L to <10 mg/L
- Se ~ 0.8 mg/L to <50 ppb
- WAD CN ~0.7 mg/L to <20 ppb
- Treatment costs under $1.00/1,000 gal treated
CURRENT PAD WATER MANAGEMENT

Precipitation
(~150 Million gal annually)

Recirculated

Barren Pond

Biotreatment System

Infiltration

Leach Pad H₂O

Surface
An integrated process system using biological denitrification, biological selenium removal and biological cyanide biooxidation has been constructed to remove these contaminants at ~8°C.
LANDUSKY OPERATION

• System inoculated and on line in August 2002
  – Operational checkout September / October 2002
  – Currently finalizing system optimization
    • Removing nitrate and selenium to below discharge criteria – since August 2002
      – NO$_3$ – from $\sim$ 240 mg/L to <5 mg/L
      – Se – from $\sim$ 0.8 mg/L to <0.002 mg/L
      – CN – from $\sim$0.3 mg/L to 0.03 mg/L
    • Currently balancing the nutrient feed - more complete CN removal and lower costs
  – System inoculated to remove other metals – As, Zn, Cu, Ni, Mn, Al, Au
WASTEWATER POND
(~10 M gal - Full-scale)

<table>
<thead>
<tr>
<th>Initial Values (mg/L)</th>
<th>Chemical/Biological Treatment - Pond (mg/L)</th>
<th>Post Bioreactor (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.11 As</td>
<td>0.16</td>
<td>Below detection (5 ppb)</td>
</tr>
<tr>
<td>11.7 Cu</td>
<td>0.204</td>
<td>0.05</td>
</tr>
<tr>
<td>1.7 Se</td>
<td>Below (50 ppb)</td>
<td>Below detection (2 ppb)</td>
</tr>
</tbody>
</table>
PILOT-SCALE TESTING

Arsenic – 0.6 mg/L
Nitrate – 70 to 120 mg/L
pH ~ 7.0
Flow Rate ~1.0 gpm
Temperature ~8º C to 16º C

ARSENIC / NITRATE REMOVAL

[As] mg/L
[NO3] mg/L

SAMPLE POINTS
FULL-SCALE TREATMENT

- Treatment costs < $0.25/1,000 gallons
- Retention time ~ 7 hr
- pH ~ 7.0
- Flow Rate - 70 to 150 gpm
- Temp. ~ 8º C to 16º C

**SELENIUM / NITRATE REMOVAL**

![Graph showing nitrate and selenium levels over time with various data points and labels for NO3-N and Se in the effluent.](image-url)
SUMMARY

The Applied Biosciences metal and inorganic removal process technology has been validated through the EPA’s Mine Waste Technology Program and various full-scale implementations.

– Simple “pump & treat” bioreactor design
– Low nutrient costs - $0.19 to $0.45 / 1,000 gallons
– Metal removal to below detection
– Can be configured to simultaneously remove various metal and inorganic contaminants, e.g., Se, NO₃, Cu, CN, NH₃, Ni, As, Te, Cd, Zn
ACKNOWLEDGEMENTS

• Shannon Shaw (Robertson GeoConsultants Inc.)
• Tina Maniatis (Applied Biosciences)
• Nick Heiner (Applied Biosciences)
• Anna DeBeer (Applied Biosciences)
• Tim Pickett (Applied Biosciences)