Decommissioned BCR Organic Media Characterization
Standard Mine Superfund Site, Crested Butte, CO

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Presented by: Neal Gallagher
Overview

- Project Overview and Site Background
- Pilot BCR Operations Performance Summary
- Pilot BCR Decommissioning
  - Substrate metals removal data
  - TCLP & Paint Filter
  - Substrate longevity estimates
- Discussion and Conclusions
Overview and Site Background

- **Standard Mine Superfund Site**
  - Approximately 3 miles west of Crested Butte, Colorado (8,900 ft)
  - Site elevation of 3,350 m (11,000 ft)
  - Annual snowfall 10.2 – 17.8 m (400 – 700 in)

- **Inactive hard rock mine**
  - Lead, zinc, silver, gold mined 1874 – 1966

- **Adit level 1 discharges to Elk Creek**
  - Influences Coal Creek, Crested Butte water supply
  - COC’s: cadmium, copper, iron, lead, manganese, and zinc
Overview and Site Background
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- Passive treatment pilot study (1 gpm):
  - Pilot Biochemical Reactor (BCR) constructed in 2007
  - Substrate composed of straw, woodchips, limestone
  - Operational for approximately 5 years

- Project Goals:
  - Test passive treatment performance at a high alpine, remote site
  - Design and construct pilot system to treat the COCs
  - Monitor the system year-round with remote monitoring equipment
Overview and Site Background

- APC
- BCR
- Sampling shed
- Level 1 adit
### Water Chemistry:

<table>
<thead>
<tr>
<th></th>
<th>BCR</th>
<th>Influent</th>
<th>Effluent</th>
<th>Chronic Stream Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temp</td>
<td>°C (°F)</td>
<td>3.4 (38)</td>
<td>3.2 (38)</td>
<td>--</td>
</tr>
<tr>
<td>pH</td>
<td>su</td>
<td>6.2</td>
<td>6.7</td>
<td>--</td>
</tr>
<tr>
<td>Cd</td>
<td>mg/L</td>
<td>0.13</td>
<td>0.00019</td>
<td>0.00031</td>
</tr>
<tr>
<td>Cu</td>
<td>mg/L</td>
<td>0.21</td>
<td>0.0014</td>
<td>0.0062</td>
</tr>
<tr>
<td>Fe</td>
<td>mg/L</td>
<td>9.1</td>
<td>0.56</td>
<td>1.0</td>
</tr>
<tr>
<td>Pb</td>
<td>mg/L</td>
<td>0.31</td>
<td>0.0013</td>
<td>0.0016</td>
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<tr>
<td>Mn</td>
<td>mg/L</td>
<td>10.9</td>
<td>9.3</td>
<td>1.43</td>
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<td>Zn</td>
<td>mg/L</td>
<td>24.7</td>
<td>0.073</td>
<td>0.086</td>
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<tr>
<td>SO4</td>
<td>mg/L</td>
<td>281</td>
<td>119</td>
<td>--</td>
</tr>
</tbody>
</table>
Performance Summary

- 5 year operation

- Low detection limits allowed comparison to strict stream standards

- BCR performance:
  - Consistently meeting acute stream standards:
    - Cadmium, copper, iron, lead, zinc
  - Consistently meeting chronic stream standards:
    - Copper, lead, zinc
  - Demonstrated removal of dissolved metals below 5 µg/L
    - Cadmium, copper, and lead
Pilot BCR Decommissioning
Pilot BCR Decommissioning

Decommissioning Objectives:

- Identify metal precipitation zones in substrate
- Determine substrate disposal requirements (TCLP, Paint Filter)
- Estimate substrate longevity for full scale design
Pilot BCR Decommissioning

Column 1 (C1)  Column 2 (C2)  Column 3 (C3)

Substrate

Drainage Gravel

- 0''
- 4''
- 8''
- 11''
- 14''
- 19''
- 24''
- 27''
Pilot BCR Decommissioning

Expected Metals Precipitation Zones:

0”–1” below surface (BS)
Orange iron hydroxide layer – oxide zone (Thomas 2002)

1”–8” BS
Black sulfide zone – sulfate reduction unlikely here due to depressed pH.

8”–14” BS
Gray aluminum zone – aluminum hydroxysulfates (Thomas 2002)

14”–30” BS
Black sulfide zone

### Metal Precipitation Results:

Columns 1-3 Average Total Metals Analysis, selected results:

<table>
<thead>
<tr>
<th>Average depth from top of substrate</th>
<th>Cadmium, total (mg/kg)</th>
<th>Lead, total (mg/kg)</th>
<th>Copper, total (mg/kg)</th>
<th>Iron, total (mg/kg)</th>
<th>Manganese, total (mg/kg)</th>
<th>Zinc, total (mg/kg)</th>
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</thead>
<tbody>
<tr>
<td>0&quot;</td>
<td>11.1</td>
<td>66.5</td>
<td>21.3</td>
<td>4,510</td>
<td>527</td>
<td>9,260</td>
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<td>8&quot;</td>
<td>2.2</td>
<td>46.4</td>
<td>11.1</td>
<td>5,323</td>
<td>547</td>
<td>5,133</td>
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<td>19&quot;</td>
<td>0.86</td>
<td>46.9</td>
<td>10.1</td>
<td>2,287</td>
<td>434</td>
<td>645</td>
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<td>27&quot;</td>
<td>0.77</td>
<td>44.3</td>
<td>9.6</td>
<td>1,603</td>
<td>418</td>
<td>288</td>
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</table>

- Initial (top) lift expected to contain metal hydroxides, and metal sulfides
- Decommissioning tests were not designed to determine metals removal processes
Metal Precipitation Results:

Column 1 - 3 Total Alkalinity Content of Organic Substrate

Concentration, mg/kg

Depth from Top of Substrate, inches

Column 1
Column 2
Column 3
Average C1/C2/C3
Metal Precipitation Results:

Total Cadmium Content of Organic Substrate

Concentration, mg/kg

Depth from Top of Substrate, inches

Column 1 Total Cd
Column 2 Total Cd
Column 3 Total Cd
Average Total Cadmium
Pilot BCR Decommissioning

Metal Precipitation Results:

![Graph showing total lead content of organic substrate vs. concentration, mg/kg, and depth from top of substrate in inches. The graph includes a line for average total lead.](image-url)
Pilot BCR Decommissioning

Metal Precipitation Results:

Total Copper Content of Organic Substrate

Concentration, mg/kg

Depth from Top of Substrate, inches

Average Total Cu
Metal Precipitation Results:

Total Iron Content of Organic Substrate

Concentration, mg/kg

Depth from Top of Substrate, inches

Average Total Fe
Metal Precipitation Results:

Total Manganese Content of Organic Substrate

Concentration, mg/kg

Depth from Top of Substrate, inches

Average Total Mn
Pilot BCR Decommissioning

Metal Precipitation Results:

Total Zinc Content of Organic Substrate

Concentration, mg/kg

Depth from Top of Substrate, inches

Average Total Zn
Pilot BCR Decommissioning

Metal Precipitation Results:

Columns 1-3 Average Total Metals Content of Organic Substrate

- Total Cd
- Total Cu
- Total Fe
- Total Mn
- Total Pb
- Total Zn

Concentration, mg/kg

Depth from Top of Substrate, inches
## Pilot BCR Decommissioning

### Columns 1-3 Average TCLP Results:

<table>
<thead>
<tr>
<th>Sample ID</th>
<th>Average depth from top of substrate</th>
<th>Arsenic, total (mg/L)</th>
<th>Barium, total (mg/L)</th>
<th>Cadmium, total (mg/L)</th>
<th>Chromium, total (mg/L)</th>
<th>Lead, total (mg/L)</th>
<th>Mercury, total (mg/L)</th>
<th>Selenium, total (mg/L)</th>
<th>Silver, total (mg/L)</th>
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</thead>
<tbody>
<tr>
<td>RCRA Standard¹</td>
<td></td>
<td>5.0</td>
<td>100.0</td>
<td>1.0</td>
<td>5.0</td>
<td>5.0</td>
<td>0.2</td>
<td>1.0</td>
<td>5.0</td>
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<tr>
<td>C1 27&quot;</td>
<td>0&quot;</td>
<td>0.015</td>
<td>0.16</td>
<td>&lt; 0.002</td>
<td>&lt; 0.013</td>
<td>&lt; 0.00003</td>
<td>0.028</td>
<td>0.0065</td>
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<tr>
<td>C1 23&quot;</td>
<td>4&quot;</td>
<td>0.017</td>
<td>0.13</td>
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<td>&lt; 0.002</td>
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<tr>
<td>C1 19&quot;</td>
<td>8&quot;</td>
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<td>C1 16&quot;</td>
<td>11&quot;</td>
<td>&lt; 0.22</td>
<td>0.20</td>
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<td>0.061</td>
<td>&lt; 0.00003</td>
<td>0.017</td>
<td>0.0057</td>
</tr>
</tbody>
</table>


- Paint Filter test results
BCR Substrate Longevity

Two Methods for determining substrate longevity:
- Acidity buffering capacity (limestone longevity)
- Remaining carbon longevity

3 Methods for determining limestone dissolution:
- Performance data - Ca in vs Ca out
- Field measurement of substrate (mass CaCO$_3$ / mass dry substrate)
- Neutralization Potential as CaCO$_3$

2 Methods for carbon longevity:
- Sulfate reduction – 2 mol C per mol SO$_4$
- Field measurement of substrate TOC
BCR Substrate Longevity

- Limestone dissolution (Calcium in vs Calcium out):
  - 8.5 – 14 years of remaining life

- Carbon longevity (sulfide reduction):
  - 8.0 – 18 years of remaining life

- Estimated BCR lifespan:
  - 5 years operation = 13 – 19 years of operation
Conclusions

- **Substrate metals precipitation:**
  - No defined reaction front observed
  - Increased precipitation observed at initial substrate-water interface

- **TCLP & Paint filter:**
  - Substrate is expected to be non-hazardous

- **Substrate longevity:**
  - 13 – 19 year design life, aligns with typical 10 – 20 year life estimate

- **BCR performance:**
  - Effluent Cd, Cu, Pb consistently below 5 µg/L
  - Met acute/chronic stream standards for majority of COCs