In-Situ Nitrate and Selenium Reduction/Stabilization within Waste Rock

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Problem Statement

- Metal and coal mine waste rock releases Se and other co-contaminants (As, Cd, Fe, CN, NO$_3$, SO$_4$, etc.).

- Nitrates are released into these waters from residual blasting compounds.
  - NO$_3$ is the preferred electron acceptor;
  - NO$_3$ needs to be removed prior to Se removal;
  - In situ denitrification decreases the size of the required active water treatment facility and helps stabilize metals.
The Electro-Biochemical Reactor

- Low voltage (1-3 Volts potential) provides:
  - Electrons and electron acceptor environments for controlled contaminant removal environment
  - Compensation for inefficient and fluctuating electron availability through nutrient metabolism
- 1 mA provides $6.24 \times 10^{15}$ electrons/second
  - Replaces excess nutrients
  - Produces much less TSS (bio-solids)
- As a comparison, other electrons donors (nutrients) provide electrons only under metabolism

**Selenium Reduction**

$$\text{SeO}_4^{2-} + 3\text{H}^+ + 2\text{e}^- \leftrightarrow \text{HSeO}_3^- + \text{H}_2\text{O}$$

$$\text{HSeO}_3^- + 5\text{H}^+ + 4\text{e}^- \leftrightarrow \text{Se}_{(s)} + 3\text{H}_2\text{O}$$
<table>
<thead>
<tr>
<th>Water</th>
<th>Parameter</th>
<th>Ave. Influent</th>
<th>Ave. Effluent</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>NO$_3$-N [mg/L]</td>
<td>11.0</td>
<td>&lt;0.1</td>
</tr>
<tr>
<td></td>
<td>Se [μg/L]</td>
<td>355</td>
<td>1.2</td>
</tr>
<tr>
<td>B</td>
<td>NO$_3$-N [mg/L]</td>
<td>16.4</td>
<td>&lt;0.1</td>
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<tr>
<td></td>
<td>Se [μg/L]</td>
<td>35.0</td>
<td>1.4</td>
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<tr>
<td>C</td>
<td>NO$_3$-N [mg/L]</td>
<td>37.0</td>
<td>1.0</td>
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<tr>
<td></td>
<td>Se [μg/L]</td>
<td>531</td>
<td>1.4</td>
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<tr>
<td>D</td>
<td>NO$_3$-N [mg/L]</td>
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<tr>
<td></td>
<td>Se [μg/L]</td>
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<td>0.5</td>
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<td>E</td>
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<tr>
<td></td>
<td>Se [μg/L]</td>
<td>186</td>
<td>1.2</td>
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</table>
Concept: EBR + In Situ
Results: EBR + In Situ

- Three bench-scale columns:
  - EBR, treating mine waters, was used to produce an amended microbial inoculum for the in-situ column nitrate/selenium reduction tests;
  - A control, down-flow column filled with coal waste rock source materials was used to determine baseline selenium and nitrate elution rates; and
  - A down-flow column filled with coal waste rock source materials was inoculated periodically with EBR amended effluents to evaluate in-situ denitrification and selenium reduction/stabilization.
Results: EBR + In Situ

![Graph showing NO₃ concentrations over time with dates 1/21, 2/10, 3/2, 3/22, 4/11. The graph displays two lines: one for Control and another for Inoculated column. There is a significant spike in NO₃ concentration on 3/2 due to the addition of Nitrate Spike.]

- **NO₃ [mg/L]**
- **Date:** 1/21, 2/10, 3/2, 3/22, 4/11

Addition of Nitrate Spike
Results: EBR + In Situ

Se [μg/L]

Date

1/21 2/10 3/2 3/22 4/11

Control

Inoculated column
In Situ: Hardrock Mining

Example successful implementation:

- Wharf gold mine
- Located in the Black Hills, SD
- Open pit, heap leach operation
In Situ: Hardrock Mining

Nitrate [mg/L]

Date

- MW-2A  - MW-45  - Ground Water Limit
In Situ: Hardrock Mining

Arsenic Levels in Receiving Creek and Monitor Well GWAC6

[Graph showing arsenic levels over time with data points for GWAC6, AC@ USGS, SW Limit, and GW Limit]
EBR + In Situ: Hardrock Mining

- Current full-scale implementation:
  - Landusky Mine
  - Located in the Little Rocky Mountains, MT
  - Closed mine
  - Open pit, heap leaching operation
Conclusions: Coal Mines

- Effective management approaches for water treatment should include in situ denitrification treatments to reduce nitrate loads;
  - Significantly reduce active treatment CAPEX and OPEX costs;
  - Demonstrated complete nitrate removal from waste rock at bench-scale;
  - Significant Se reduction and stabilization within the source materials (from 27 ppb to below 4 ppb).
Conclusions: Hardrock Mines

- Treatment of nitrate-N at ranges from 60 to 320 mg/L
  - All sites treated to near or below discharge criteria
  - Sites within two properties have been removed from company inventory - treated to below State closure criteria
- Treatment and stabilization of As
  - Treated to below discharge criteria - <10 μg/L
- Treatment and stabilization of Se
  - Plume treated from ~16 mg/L to <1 mg/L
- Treatment times ranged from 1 to 4 years
Thank You

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