SELENIUM, URANIUM, AND NITRATE: TREATMENT OF TROUBLESOME CONTAMINANTS IN MINING WASTEWATERS – EBR CASE STUDIES

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Jack Adams, Jane Fudyma, John Bowden
PROBLEM STATEMENT

• Selenium, uranium, and nitrate are common in many North American mining environments

• Often difficult to remove using conventional methods
  • Complex treatment trains with multiple unit processes
  • High capital and operating expenses
  • Disposal of sludge or brine stream
BIOLOGICAL TREATMENT

• Microbes mediate the removal of metal and inorganic contaminants through redox reactions

\[ \text{UO}_4^{2+} + 2e^- + 4H^+ \rightarrow \text{U}^+_4 + 2H_2O \]

\[ \text{NO}_3^- + 5e^- + 6H^+ \rightarrow \frac{1}{2}\text{N}_2 + 3H_2O \]

\[ \text{SeO}_4^{2-} + 6e^- + 8H^+ \rightarrow \text{Se}_{(s)} + 4H_2O \]

Decreasing DO and ORP

Increasing electron requirement
CONVENTIONAL BIOREACTORS

• Organic electron donors (nutrients) provide electrons under oxidation/metabolism
  • One molecule of glucose = 24 electrons under full metabolism
  • Excess nutrients to control ORP

• Excess biomass production
  • High TSS leads to post-treatment solids management
  • Biomass carries metals → post-treatment management
  • High CAPEX /OPEX costs

\[
\begin{align*}
\text{UO}_4^{2+} + 2e^- + 4H^+ & \rightarrow U_4^+ + 2H_2O \\
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ELECTRO-BIOCHEMICAL REACTOR

• Low voltage (1-3 Volts potential) supplied directly
• 1 mA provides $6.24 \times 10^{15}$ electrons/second
  • Electrons and electron acceptor environments for controlled contaminant removal environment
  • Compensation for inefficient and fluctuating electron availability through nutrient metabolism
ELECTRO-BIOCHEMICAL REACTOR

- Low voltage (1-3 Volts potential) supplied directly
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  - Electrons and electron acceptor environments for controlled contaminant removal environment
  - Compensation for inefficient and fluctuating electron availability through nutrient metabolism
  - Replaces up to 2/3 of the nutrients/electron donors required, while producing lower contaminant concentrations
  - Produces much less TSS (bio-solids)

From onsite EBR effluent, no filtration or post-treatment
### EBR CASE STUDIES

<table>
<thead>
<tr>
<th>Source</th>
<th>Ave. total Se [µg/L]</th>
<th>Ave. total U [µg/L]</th>
<th>Ave. NO$_3$-N [mg/L]</th>
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</thead>
<tbody>
<tr>
<td><strong>Water A</strong> Underground metals mine, flotation-influenced process waters</td>
<td>2,712</td>
<td>1.99</td>
<td>0.8</td>
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<tr>
<td><strong>Water B</strong> Open pit coal mine, seepage waters</td>
<td>105</td>
<td>18.4</td>
<td>49.8</td>
</tr>
<tr>
<td><strong>Water C</strong> Prospect gold mine, leach solutions</td>
<td>3.17</td>
<td>92.5</td>
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# EBR Case Study A (Flotation)

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EBR CASE STUDY A (FLOTATION)

Influent Se [mg/L] vs. Effluent Se [mg/L]

- Influent
- EBR Effluent
- Limit

Ave = 2,712 µg/L
Ave = 5.44 µg/L
EBR CASE STUDY A (FLOTATION)

Uranium [mg/L]

Test Day

Ave = 1.99 µg/L
Ave = <0.1 µg/L

Influent
EBR Effluent
EBR CASE STUDY A (FLOTATION)

NO₃-N [mg/L]

NO₂⁻-N [mg/L]

Test Day

- **Influent**
- **EBR Effluent**
- **Limit**
# EBR CASE STUDY B (COAL MINE)

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EBR CASE STUDY B (COAL MINE)

Selenium [mg/L]

Test Day

Ave = 105 µg/L

Ave = 0.52 µg/L

Influent  EBR Effluent  Limit
EBR CASE STUDY B (COAL MINE)

Test Day

Influent

EBR Effluent

Ave = 18.4 µg/L

Ave = 0.07 µg/L
# EBR CASE STUDY C (GOLD MINE)

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EBR CASE STUDY C (GOLD MINE)

Ave = 3.17 µg/L
Ave = 1.25 µg/L
EBR CASE STUDY C (GOLD MINE)

![Graph showing NO$_3^-$ and NO$_2^-$ levels over test days.]

- **NO$_3^-$ (mg/L):**
  - Influent values fluctuate from 0 to 300 mg/L.
  - EBR Effluent values remain consistently near 0 mg/L.

- **NO$_2^-$ (mg/L):**
  - Influent values range from 0 to 10 mg/L.
  - EBR Effluent values show a slight increase from 0 to 70 mg/L.

Test Day ranges from 0 to 70 with markers at intervals of 10 days.
The successful EBR trials have positive implications for mine sites facing challenges of simultaneous treatment of multiple contaminants to low discharge levels, in a simplified and more affordable manner.
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