Electro-Biochemical Reactor (EBR) Technology Demonstrates Low Selenium Effluents in Hardrock Mining Wastewaters

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Problem Statement

- Underground mine in the Yukon, Canada, producing:
  - Zn, Cu, Pb, Ag, Au

- Comminution liberates the desired metals as well as contaminants, e.g., Se (typically at 2,000-6,000 µg/L in tailings waters).

- Recovery - floatation.

- Discharged to a tailings impoundment where tails are settled and water is recycled to the mill.
Problem Statement

✧ Positive water balance:
  ✧ Excess water accumulates in the tailings impoundment
  ✧ Needs to be treated and discharged according to the discharge standards

✧ Chemical precipitation methods and biological treatment approaches were examined:
  ✧ Chemical methods ineffective at removing selenium to the required effluent discharge limit of 20 µg/L
  ✧ A newly developed Electro-Biochemical Reactor (EBR) treatment system was evaluated starting in 2010
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 up to 2/3 of the nutrients/electron donors required, while producing lower contaminant concentrations
  - Produces much less TSS (bio-solids)
- As a comparison, other electrons donors (nutrients) provide electrons only under metabolism

**Selenium Reduction**

\[
\text{SeO}_4^{2-} + 3H^+ + 2e^- \leftrightarrow \text{HSeO}_3^- + H_2O \\
\text{HSeO}_3^- + 5H^+ + 4e^- \leftrightarrow \text{Se}(s) + 3H_2O
\]
Electromicrobiology: Emerging field in microbiology which recognizes that microbes can utilize directly provided electrons.

Adapted from Mohamed Y. El-Naggar and Steven E. Finkel, May 2013.
The Electro-Biochemical Reactor

Providing electrons directly has numerous benefits including better ORP control and stability.
Results: Comparative Study

- Comparative study:
  - Between the EBR and a competing bioreactor technology.
  - A split water sample obtained from the Yukon Mine.
  - Testing was performed at the two respective labs.
  - Using the same hydraulic retention times.
  - Analysis done by the same analytical lab in Salt Lake City, UT.
Results: Comparative Study

Graph showing Total Se (μg/L) over time from 10-Mar to 29-May, with data points for Influent, Discharge-EBR, and Discharge-CBR.
Results: Pilot Studies
Results: EBR Pilot Studies

![Graph showing Influent Total Se [mg/L] and EBR Effluent Total Se [mg/L] over Treatment Day. The graph includes data points for both Influent and Effluent, with a limit indicated by a dashed line. The x-axis represents Treatment Day, ranging from 0 to 60, while the y-axes represent Total Se concentrations in mg/L. The Influent data is represented by filled squares, the Effluent data by open circles, and the limit by a dashed line.](image-url)
## Results: EBR Pilot Studies

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Average Influent [mg/L]</th>
<th>Average Discharge [mg/L]</th>
<th>% Removal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Antimony</td>
<td>0.15</td>
<td>&lt;0.001</td>
<td>&gt;99.3%</td>
</tr>
<tr>
<td>Cadmium</td>
<td>0.014</td>
<td>&lt;0.0002</td>
<td>&gt;98.0%</td>
</tr>
<tr>
<td>Copper</td>
<td>0.41</td>
<td>&lt;0.005</td>
<td>&gt;98.7%</td>
</tr>
<tr>
<td>Lead</td>
<td>0.30</td>
<td>0.0008</td>
<td>99.7%</td>
</tr>
<tr>
<td>Molybdenum</td>
<td>0.10</td>
<td>&lt;0.0005</td>
<td>&gt;99.5%</td>
</tr>
<tr>
<td>Selenium</td>
<td>2.73</td>
<td>0.002</td>
<td>99.9%</td>
</tr>
<tr>
<td>Silver</td>
<td>0.041</td>
<td>&lt;0.0001</td>
<td>&gt;99.8%</td>
</tr>
</tbody>
</table>
Results: EBR Sulfate Removal

SO4 [mg/L]

Date


Influent  Effluent  Limit
Full-Scale Design

✧ Design criteria:
  O Six months operation during the year;
  O Treatment flow of 10 L/s;
  O Meeting discharge criteria with a 25% safety factor.

✧ Process design:
  O An anaerobic pre-treatment system with an 8-hour HRT for removal of residual mill organics;
  O A two-stage EBR system each with a 6-hour HRT to remove the total selenium and other metals;
  O An anaerobic post-treatment system with a 6-hour HRT to polish the EBR system effluents and remove the residual nutrients prior to discharge; and
  O A 24-hour holding pond prior to discharge – site specified.
# Full-Scale Costs

<table>
<thead>
<tr>
<th>50% Preliminary Estimates</th>
<th>EBR</th>
<th>Competing Bioreactor Provider</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reagents (nutrients, pH adjustment)</td>
<td>$108k</td>
<td>$338k</td>
</tr>
</tbody>
</table>
Thank You

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