Coal Mine Planning and Selenium in British Columbia

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Se

NAME

Selenium

[Ar]3d^{10}4s^{2}p^{4}

ATOMIC NUMBER

34

DENSITY at 300 K

g/cm^{3}

4.8

MELTING POINT, K

958

BOILING POINT, K

494

ATOMIC WEIGHT

78.96

OXIDATION STATES

-2, 4, 6

ELECTRON CONFIGURATION
Senelium
(səˈnɛl ɪ əm)
Noun: from Latin senilis, to drive one crazy!
20th Annual British Columbia – MEND ML/ARD Workshop

Senelium

34
958
494
0.0

78.96

Too Many

POTENTIAL PROJECT WITH PROPOSED PERPETUAL BIOTREATMENT PLANTS

WEIGHT ON OUR SHOULDERS, Kg

BOILING POINT of CLIENTS, K

MELTING POINT of REGULATORS, K

DENSITY of BRAIN AFTER THINKING ABOUT SENELIUM, g/cm³

[Ar]Help⁴

Senelium

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Senelium

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OXIDATION STATES

ELECTRON CONFIGURATION
Outline

- BC coal
- Project effects on selenium water quality
- Mitigation
- Water treatment
- Considerations for mine planning
BC Coal

- Most coal mined in NE and SE BC is metallurgical coal
- BC is well known for its high quality steel making met coal
Mine Effects on Selenium

- Primary driver for effects on selenium is from unsaturated spoils
- Loadings from exposed, open pit walls are typically much lower than spoils
- Saturated spoils and coal refuse (tailings and CCR) Se loadings are typically negligible
Mine Effects on Selenium

- Snowmelt driven hydrograph – highly variable flow
Mine Effects on Selenium

- Spoil Se signature typically inverse to flow
Mine Effects on Selenium

- Bypass considerations
- Surface water management infrastructure typically designed to manage flow and TSS
- Should also consider leakage and long-term storage (closure)
Mitigation Options

Diversions and storage

• Diversion of contact waters away from sensitive habitat or low flow drainages
• Strategic release during higher flow or to larger water bodies
• Discharges must be managed to avoid sensitive (lentic) habitat
  • Initial dilution zone regulations apply to fish bearing waters
• Flow reductions must be evaluated to determine serious harm (new DFO regulation supplants HADD)
  • Evaluating and determining serious harm is more complex
  • Decision-making uncertainty
• Compensation should be considered in mitigation options
Mitigation Options
Attenuation by design

• Flooded pits
• Saturated backfill
• Permeable reactive barriers
• Engineered wetlands

• Design considerations:
  • residence time and flow rate;
  • nitrate and selenium removal rates
Mitigation Options
Attenuation by design

- Selenium bioremediation is microbially mediated.
- Selenium speciation and removal strongly dependent on redox conditions.
- Suboxia is required for effective removal.
Mitigation Options
Attenuation by design

- Selenium attenuation is inhibited by nitrate

<table>
<thead>
<tr>
<th>Decreasing Redox Potential</th>
<th>Increasing Free Energy Yield</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Oxygen (O₂) Consumption:</td>
<td></td>
</tr>
<tr>
<td>[ O₂ + 4H^+ + 4e^- \rightarrow 2H₂O ]</td>
<td></td>
</tr>
<tr>
<td>2. Nitrate (NO₃⁻) Reduction (Denitrification)</td>
<td></td>
</tr>
<tr>
<td>[ 2NO₃^- + 12H^+ + 10e^- \rightarrow N₂ + 6H₂O ]</td>
<td></td>
</tr>
<tr>
<td>3. Selenate (SeO₄²⁻) Reduction:</td>
<td></td>
</tr>
<tr>
<td>[ SeO₄^{2-} + 3H^+ + 2e^- \rightarrow HSeO₃^- + H₂O ]</td>
<td></td>
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<tr>
<td>4. Manganese Oxide (MnO₂) Reduction:</td>
<td></td>
</tr>
<tr>
<td>[ MnO₂(s) + 4H^+ + 2e^- \rightarrow Mn^{2+} + 2H₂O ]</td>
<td></td>
</tr>
<tr>
<td>5. Fe Oxide (FeOOH) Reduction:</td>
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<tr>
<td>[ FeOOH(s) + 3H^+ + e^- \rightarrow Fe^{2+} + 2H₂O ]</td>
<td></td>
</tr>
<tr>
<td>6. Sulfate (SO₄²⁻) Reduction:</td>
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</tr>
<tr>
<td>[ SO₄^{2-} + 9H^+ + 8e^- \rightarrow HS^- + 4H₂O ]</td>
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</tr>
</tbody>
</table>
Mitigation Options

Flooded pits

- Flooded pits are facilities that commonly exist in mine environments following surface development.
- Large repositories of mine-influenced waters.
- Tendency for water column stratification and development of suboxic bottom waters.
Mitigation Options
Flooded pits

Vertical mixing is restricted in flooded pits:
• deep water column
• short fetch
• topographic sheltering (pit walls)

- Tendency for seasonal and/or permanent stratification
- Natural tendency to develop suboxic bottom waters
Mitigation Options
Flooded pits

Expected Se removal mechanisms:
- Dissimilatory reduction of Se oxyanions and precipitation as elemental Se [Se(0)].
- Reduction of selenate [Se(VI)] to selenite [Se(IV)] and adsorption of selenite to particles.
Mitigation Options
Saturated backfilled pit

- Design considerations
- Flow rate, removal rates, and residence time

![Graph showing RT vs. Removal rate](image)

- Se removal rate
- NO3-N removal rate
Mitigation Options
Saturated backfilled pit

- Increasing removal rates = higher treatment flow rates
- Nitrate removal considerations

![Removal rate vs. Flow rate](image)
Mitigation Options
Flooding pits

- Flooded pits can be used as passive remediation cells
- Increased capacity results in increased RT and treatment potential
Mitigation Options
Flooded pits

- Flooded pits offer potential to treat large volumes of water at relatively low cost.
- Semi-passive attenuation and water management considerations:
  - Residence time, oxygen demand and nitrate/selenium removal rates.
  - Conveyance of contact flows to pit.
  - Withdrawal of treated water from pit.
  - Polishing prior to discharge to environment.
Mitigation Options
Flooded pits

Flooded pits are well suited for bioremediation

- Typically ultra-oligotrophic
- Respond well to nutrient amendments
- Natural algal communities (Inoculation not required)
- Low cost and easy to implement
- Seasonality of primary production
Mitigation Options

Flooded pits

Conceptual model for Se attenuation

Selenium removal in suboxic bottom waters
Mitigation Options
Flooded pits
Mine water management – semi-passive treatment

Diagram showing a flooded pit with zones for Oxic, Suboxic, and Mixing/Attenuation, with processes like Fertilization/Inoculation and Metals Removed.
Mitigation Options
Saturated backfilled pit

- Saturated backfill may be designed and managed to treat contact water for Se and nitrate removal
Mitigation Options

Attenuation in pits

Maximize saturated storage volumes

- Mine planning (pit morphometry and timing)
- In-pit berms
- Mine waste management – saturated backfill
- Water management
Mitigation
Water Treatment

• Biotreatment
  • Nitrate and nitrate are reduced to nitrogen gas
  • Selenate and selenite are reduced to particulate elemental selenium
  • Nitrate inhibits selenium bioreduction
  • Biotreatment plants must be designed for denitrification
Mitigation

Water Treatment

• Biotreatment
  • Complicating factors include:
    • Storage and water management
    • Temperature – influent may require heating
    • Highly variable influent (Se, nitrate, TSS)

• Potential effects from biotreatment effluent
  • Temperature
  • Ammonia
  • Phosphorous
  • TSS
  • BOD and dissolved oxygen
Mitigation
Water Treatment

• Biotreatment has been demonstrated at numerous industrial facilities

• Limited application in natural settings typical of BC coal mines

• Two facilities currently under construction in BC, scheduled to be commissioned in 2014
Summary

- Managing selenium is complex
  - Highly variable flow and concentrations
  - Flow reductions considerations
  - Nitrate inhibition

- Design for closure

- Understanding of passive attenuation continues to be refined
  - Further study necessary to inform mine planning and design

- Active treatment scheduled for commissioning in 2014
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