Using Hydrogeochemical Data to Improve Remediation of Historical Gold Mine Tailings in Nova Scotia

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Historical Setting
- Gold in NS discovered 1858
- 64 operational districts within Meguma slates & graywackes
- Unregulated mining activities
  - >3,000,000 tonnes of tailings generated
  - Slurried into local waterways
- Arsenic 9 ppm to >300,000 ppm
- Expanding residential development

Tailings & Water Characteristics
- Nova Scotia gold mine tailings: As-rich (mean 1 wt.%), mineralogically complex, and variable redox conditions
- Surface waters pH-neutral, variable pore water pH
- Arsenopyrite-oxidation has altered to various As-hosting secondary phases
  - Iron arsenates
  - Ca-Fe arsenates

Study Purpose
- Focus: Processes controlling arsenic release and attenuation
- Characterization is essential for:
  - Choosing appropriate strategies for remediation – do multiple phases require multiple approaches?
  - Assessing the potential for remediation-induced geochemical changes on As-bearing phases and pore waters

Study Location - Montague
- Located within Halifax Regional Municipality
- Tailings slurried into Mitchell Brook (1860s – 1940s)
- Posted signs warning of high As concentrations by Province of NS, 2006
- Continued recreational activity

Study Location - Goldenville
- 50 km south of Antigonish
- Tailings continue for at least 6 km out to the Atlantic Ocean
- Annual 4x4 rally cancelled in 2006
- Posted signs
- Continued recreational activity

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Methods

To assess stability pre- and post-remediation: water-mineral interactions

Water Sampling
- Vadose zone
- Saturated zone
- Surface waters

Water Analyses
- Digestion, ICP-OES
- IC

Coring
- Vadose through saturated zones

Solid Analyses
- Bulk chemistry
- Petrography
- µ-XRD, SEM, EPMA

Results

Visual Distinctions in Tailings Types
- Heterogeneous tailings: Grain size, saturation, colour, composition

Water Sampling
- Fine grained, always gray
- Hardpan, near surface
- “Typical”, coarse grained, oxidized near surface

Chemistry Results

<table>
<thead>
<tr>
<th>Tailings Types</th>
<th>PORE WATERS (ppm)</th>
<th>SOLIDS (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>pH</td>
<td>As</td>
</tr>
<tr>
<td>Vadose Zone</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coarse grained</td>
<td>5.42</td>
<td>5.25</td>
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<tr>
<td>HP-bearing</td>
<td>2.4</td>
<td>16.1</td>
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<tr>
<td>Fine grained</td>
<td>6.79</td>
<td>15.2</td>
</tr>
<tr>
<td>Saturated Zone</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coarse grained</td>
<td>8.05</td>
<td>1.19</td>
</tr>
<tr>
<td>Below HP-bearing</td>
<td>6.7</td>
<td>48</td>
</tr>
<tr>
<td>Fine grained</td>
<td>6.85</td>
<td>92.7</td>
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</tbody>
</table>

For Comparison:
- Arsenic guidelines: 0.5 ppm
- Drinking Water Quality Guideline = 0.01 ppm
- Soil Quality Criteria = 12 ppm

Controls on Arsenic Mobility

- Arsenopyrite oxidation
- Scorodite and hydrous ferric arsenate (HFA) precipitation

Remediation Challenges

- Heterogeneous tailings composition
  - Variable degrees of weathering have produced wide-ranging As-bearing phases

- Phase stability
  - Scorodite & HFA → acidic pH, oxidizing environments
  - Yukonite & Ca-Fe arsenates → neutral pH, oxidizing environments
  - Arsenopyrite → reducing environments

- Remediation
  - Potential of a traditional cover can create reducing conditions

Current Conditions

<table>
<thead>
<tr>
<th>pH</th>
<th>Redox</th>
</tr>
</thead>
<tbody>
<tr>
<td>acidic</td>
<td>oxidizing</td>
</tr>
<tr>
<td>basic</td>
<td>reducing</td>
</tr>
</tbody>
</table>

Cover Application

- Creates reducing conditions
- Limits sulphide oxidation, pH increases

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Conclusions

- A complex mix of secondary As minerals provide a temporary form of natural attenuation
  - These may not be stable under changing geochemical conditions
- Mineral stability must be considered in developing an appropriate remediation strategy
- On-going work:
  - More detailed hydrogeology
  - Investigating altered redox conditions in column experiments

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Questions?