D.3 Release and Mobility of Nickel from Mine Waste: Theory and Case Histories

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Release and Mobility of Nickel from Mine Waste: Theory and Case Histories
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Nickel Geochemistry

- Sources of Nickel
  - Pentlandite (Fe₃Ni₄S₉)
  - Millerite (NiS)
  - Gersdorffite, Annabergite and other exotics
  - Impurity in Pyrrhotite (up to 1% by Mass)

Geochemistry

- Simple cation in water
- Ni²⁺
- pH controlled (Ni-hydroxide for pH > 8)
- Sorption onto Iron Hydroxides (pH > 7.5)

Ni(OH)₂ Control

Nickel in Mine Wastes

- Related to sulphur content
- Variable and site specific
- Because of simple geochemistry and high mobility, RELEASE RATES are critical

Voisey's Bay - Nickel versus Sulphur in Waste Rock
Kinetic Tests
- Provide an estimate of rates of oxidation/leaching
- Requires careful interpretation
  - "One size" does not fit ALL
- Consider "Lag Times"—time between observed metal leaching (or acid generation) and time of deposition (or exposure)

Voisey's Bay Waste Rock
- Standard Humidity Cells (1 kg rock)
- Column tests (5 to 8 kg)
**Raglan Waste Rock**

- Modified test to avoid Lag Times for Nickel
- pH adjusted to 5 to 6 range to avoid pH control on Ni release

**Water Quality Example for Ni from Waste Rock Piles**

**Showing Water Quality in Pile, Flow and Drainage Areas Needed to Avoid Guideline Exceedence**

<table>
<thead>
<tr>
<th>Pile Type</th>
<th>Flow² per MT rock for 25ppb (x 10⁶ m²/a)</th>
<th>Drainage Area³ per MT rock for 25ppb (km²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Waste Pile⁴</td>
<td>28</td>
<td>14</td>
</tr>
<tr>
<td>Fines</td>
<td>140</td>
<td>70</td>
</tr>
</tbody>
</table>

1. Assumes 200 mm/8 infiltration in waste rock pile
2. Assumes flow per Million Tons of waste rock to remain below 0.025 mg/L (25 ppb)
3. Assumes 100% of 450 m²
4. Assumes Rates are 1% and 3% of lab values for Pile and Concentrations, respectively

**Uranium Mine Rock**

- Elevated Ni, As, Co and U
- 0.2 % S
- 7 Mt Pile
- 20 to 30 m thick
- Field Samples of rock collected to 20 m depth
- 6 Trenches / 60 samples
- Pile age was approximately 15 years

**Reaction rates can be measured in the lab and in the field using similar concepts for cost-effective results. In this case, most infiltration was retained in the pile and dissolved mass was conserved.**

**Humidity Cells**

<table>
<thead>
<tr>
<th>Humidity Cells</th>
<th>1 kg</th>
<th>7 Mt Rock Pile</th>
</tr>
</thead>
<tbody>
<tr>
<td>mg/kg/week</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**7 Mt Rock Pile**
Soluble masses of selected constituents rinsed from waste rock samples. All values in mg/kg

<table>
<thead>
<tr>
<th>Samples</th>
<th>SO₄²⁻ (as S)</th>
<th>Ni</th>
</tr>
</thead>
<tbody>
<tr>
<td>SWEP 1 (n=7)</td>
<td>585</td>
<td>7.4</td>
</tr>
<tr>
<td>SWEP 2 (n=4)</td>
<td>355</td>
<td>1.4</td>
</tr>
<tr>
<td>Average SWEP</td>
<td>501</td>
<td>5.2</td>
</tr>
<tr>
<td>Kinetic 1</td>
<td>587</td>
<td>14</td>
</tr>
<tr>
<td>Kinetic 2</td>
<td>681</td>
<td>17</td>
</tr>
<tr>
<td>Kinetic 3</td>
<td>691</td>
<td>12</td>
</tr>
<tr>
<td>Kinetic 4</td>
<td>382</td>
<td>1.7</td>
</tr>
<tr>
<td>Kinetic 5</td>
<td>544</td>
<td>2.0</td>
</tr>
<tr>
<td>Average Kinetic</td>
<td>877</td>
<td>9.3</td>
</tr>
</tbody>
</table>

Estimated Percent of Constituents Leached over 15 Year History of Pile Masses expressed in "mg/kg"

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>SO₄²⁻ (as S)</td>
<td>2,522</td>
<td>577</td>
<td>3,059</td>
<td>19</td>
</tr>
<tr>
<td>Ni</td>
<td>46</td>
<td>9.3</td>
<td>55</td>
<td>17</td>
</tr>
</tbody>
</table>

Calculated Pore Water Concentrations in the Rock Pile (mg/L) – Based on measured Water Content values and Soluble Mass of Constituents and Observed Concentrations in Groundwater Adjacent to the Pile

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Ni</th>
<th>SO₄</th>
</tr>
</thead>
<tbody>
<tr>
<td>Estimated Porewater Concentrations in the Pile</td>
<td>190</td>
<td>34,600*</td>
</tr>
<tr>
<td>Maximum Observed in wells near Pile (rising trend)</td>
<td>30</td>
<td>6,200</td>
</tr>
</tbody>
</table>

*Porewater sulphate is unrealistic because of the presence of Gypsum that formed on the rock.

Modelled Loadings

- Geochemical model developed to assess loading rates for metals and pH of leachate
- Measured inventory of soluble loads included in model
- Provides estimates of loads to environment that can form the basis of a Risk Assessment

Calculated Sulphate Loadings With Time From 7 Mt Pile. Values in kg/year

Calculated Nickel Loadings With Time from 7 Mt Pile. Values in Kg/year
Conclusions

- Nickel leaching can occur at neutral pH
- Time dependent processes must be clearly identified (e.g., Time Lags) especially for short test periods (weeks to a few months)
- With careful measurements and interpretation, Mass Balance calculations (and simple models) can be used to provide CONSERVATIVELY estimates of loadings of many metals from mine wastes for Risk Assessment and Mitigation purposes