The Effectiveness of Using Sewage Sludge as a Sealing Layer on Sulphide-rich Mine Tailings: A Pilot-scale Experiment, Northern Sweden

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A Remedial Solution to ARD: Composite Cover Design using Sewage Sludge

Aim of the Study
Evaluate the long-term effectiveness of using sewage sludge as a sealing layer to prevent oxygen diffusion to underlying sulphide-bearing mine tailings

Advantages of using Sewage Sludge

- Protective physical barrier reduces sulphide oxidation:
  \[ \text{FeS}_2 + \frac{15}{2} \text{O}_2 + \frac{7}{2} \text{H}_2\text{O} \rightarrow \text{Fe(OH)}_3 + 2\text{SO}_4^{2-} + 4\text{H}^+ \]
- Organic matter consumes oxygen:
  \[ \text{CH}_2\text{O} + \text{O}_2 \rightarrow \text{H}_2\text{O} + \text{CO}_2 \]
- Organic matter reduces sulphate:
  \[ 2\text{CH}_2\text{O} + \text{SO}_4^{2-} + 2\text{H}^+ \rightarrow 2\text{H}_2\text{CO}_3 + \text{H}_2\text{S} \] (pH < 7)
  \[ 2\text{CH}_2\text{O} + \text{SO}_4^{2-} + \text{H}^+ \rightarrow 2\text{H}_2\text{CO}_3 + \text{HS}^- \] (pH > 7)
- The reduced conditions may promote precipitation of metal sulphide:
  \[ \text{Me}^{n+} + \text{H}_2\text{S} \rightarrow \text{MeS} + 2\text{H}^+ \]
- Neutral pH environment may further immobilise elements

Disadvantages of using Sewage Sludge

- High concentrations of metals (Al, Fe, Mn, Cu, Ni, Zn, Cd)
- Organo-complexes may form altering the mobility of some metals
- May release elevated ion concentrations: NO$_3^-$, PO$_4^{3-}$ and NH$_4^-$
- Degradation of organic matter occurs:
  Layer thickness and integrity is compromised

Site Description and Materials

Georange Environmental Test Cells, Kristineberg
Original Material Composition

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<tr>
<th>Element</th>
<th>Tailings (ppm)</th>
<th>Sewage Sludge (ppm)</th>
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</thead>
<tbody>
<tr>
<td>Si</td>
<td>166878</td>
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<tr>
<td>Al</td>
<td>21435</td>
<td>52200</td>
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<tr>
<td>Ca</td>
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<td>K</td>
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<td>Mg</td>
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<tr>
<td>Mn</td>
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<td>Na</td>
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<td>P</td>
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<td>18900</td>
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<tr>
<td>Ti</td>
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Major Elements

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<tr>
<th>Element</th>
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<th>Sewage Sludge (ppm)</th>
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<tr>
<td>As</td>
<td>3610</td>
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<tr>
<td>Ba</td>
<td>128</td>
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<tr>
<td>Cd</td>
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<td>Cu</td>
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<td>S</td>
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<tr>
<td>Zn</td>
<td>5330</td>
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</tbody>
</table>

Minor Elements

Sampling and Analysis

- Dissolved (<0.22µm) elemental fraction collected using nitrocellulose membrane filters and analysed using ICP-AES and ICP-SFMS
- NO₃⁻, SO₄²⁻ and alkalinity HCO₃⁻ were sampled and analysed in 2009 using ion chromatography
- pH and dissolved Oxygen

Results and Discussion: Dissolved Iron and Sulphur

Results and Discussion: Heavy Metal Concentrations

Summary: Uncovered Tailings

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Summary: Sewage Sludge Remediated Tailings

\[ O_2 + H_2O \rightarrow O_2 \text{ Consumed} \]

Sulphate reduced

\[ Me^{2+} \rightarrow H_2S \]

Ca\(^{2+}\) HCO\(^{3-}\)

MeS

Low Metal + SO\(_4^{2-}\)

High buffer capacity + neutral pH

Conclusions

- Sewage Sludge is effective for reducing oxygen diffusion to underlying tailings for the study period of 8 years.
- The sealing layer cover efficiency has not been compromised over time proven by continually lowering metal and sulphate concentrations in the effluent leachate.
- Metal concentrations in the uncovered tailing effluent are 2 orders of magnitude higher in contrast, due to sulphide oxidation.
- Continued oxidation in the uncovered tailings may consume the remainder carbonates and produce an acidic, metal rich leachate in the future.
- In contrast the sewage sludge ensures a high buffering capacity, reduced environment with a neutral pH, promoting the removal of metals in the tailings profile.

Further Research

- Sediment Profiles Geochemistry
  - Oxidation
  - Precipitation
  - Sealing layer integrity

- Ageing effects of Sewage Sludge
  - Evolution over time

- Groundwater dispersion of sewage sludge constituents
  - How it effects mobility of heavy metals

Acknowledgements

Any Questions?

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