The East-Sullivan Mine Site: Merging Prevention and Treatment of Acid Mine Drainage

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The East-Sullivan Mine Site

Val d’Or
North-Western Québec
Impoundment Characteristics

Cu, Zn (Au, Ag) Mining from 1949 to 1966

total area: 136 ha
(+ 68 ha spilled tailings)

total mass of tailings: 15 Mt

$S_{\text{sulphide}}$ : 3.5% (mainly pyrite)

total acid potential:
400 350 t. CaCO$_3$

total neutralizing potential:
50 280 t. CaCO$_3$
Abandonment: 1966 to 1984

Pond

Bourlamaque River
Water and Wind Erosions
Requirements for Mine Final Effluent

Acceptable pH: 6.0 - 9.5

Acceptable concentrations (mg/l):

<table>
<thead>
<tr>
<th></th>
<th>monthly average</th>
<th>maximum in a single sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fe:</td>
<td>3.0</td>
<td>6.0</td>
</tr>
<tr>
<td>Cu:</td>
<td>0.3</td>
<td>0.6</td>
</tr>
<tr>
<td>Zn:</td>
<td>0.5</td>
<td>1.0</td>
</tr>
<tr>
<td>Pb, As, Ni, etc.:</td>
<td>...</td>
<td>...</td>
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</tbody>
</table>

(Québec MDDEP)

To achieve these criteria, the mining industry needs tools to stop metal-rich acid drainage or to treat unacceptable effluents.
Acid Mine Drainage: Reactions

\[
FeS_2 + \frac{7}{2}O_2 + H_2O = Fe^{2+} + 2SO_4^{2-} + 2H^+
\]

(\textit{Acidiniobacillus ferrooxidans}: X 10^3 to 10^6)

\[
Fe^{2+} + \frac{1}{4}O_2 + H^+ = Fe^{3+} + \frac{1}{2}H_2O
\]

\[
Fe^{3+} + 3H_2O = Fe(OH)_3 + 3H^+
\]

\[
FeS_2 + 14Fe^{3+} + 8H_2O = 15Fe^{2+} + 2SO_4^{2-} + 16 H^+
\]

To stop AMD production:
limit oxygen and/or water access to sulphides
Objectives

To demonstrate that:

1. **Organic cover** does limit ...
   
   i- atmospheric oxygen migration
   
   ii- Acid Mine Drainage production

2. **Recirculation** through the organic cover allows AMD treatment via sulphate reduction processes
New Approach to Restoration: Organic Cover

Tailings

Wood Waste

2 m
1) Oxidation of organic matter: mirror image of $O_2$ and $CO_2$
2) Methanogenesis: confirmation of anoxic milieu

$O_2$ consumed: PYRITE OXIDATION IS HALTED
Groundwater Quality: Core of Plume

Fe$^{2+}$ (mg/l)

depth: 6 m
Treatment of AMD by Sulphate Reduction

- The problem:
  - Low water quality
  - Acid: \( H^+ \)
  - Mine: \( Me^{2+} \) and \( Me^{3+} \)
  - Drainage

- A solution:
  - Reduction of sulphates
    - Production of alkalinity
    - Sulphides rather than hydroxides precipitation

- Driving principle:
  - Redox reaction (Desulfovibrio sp.)
    - \( SO_4^{2-} + 2CH_2O = H_2S + 2HCO_3^- \)
    - Sulphate reduction: precipitation of metal sulphides
    - \( Me^{2+} + H_2S = MeS + 2H^+ \)
Alkalinity Distribution (1994)

Clay and Bedrock


Mine Tailings

alkalinity, mg-CaCO$_3$/l
watertable
control (piezometers and boreholes)
From Prevention To Treatment

1- AMD Collection

1998
From Prevention To Treatment

2- Recirculation System
Feed vs Pore Waters: pH

Feed Water vs Pore Water

pH

Feed vs Pore Waters: Fe

Feed Water ($Fe_{\Sigma}$)
Pore Water ($Fe^{2+}$)
Watertable
(2003)

- Mine Tailings
- Wood Waste
- Control

100 m
Surface Water: Mass of Fe

- Mass of Fe (X 1000 kg)
  - 0
  - 20
  - 40
  - 60
  - 80
  - 100
  - 120


- Reservoirs:
  - North Res.
  - South Res.
  - East Res.
  - West Res.

- Regions:
  - North R.
  - South Res.
  - East Res.
  - West R.

Graph showing the mass of Fe (in X 1000 kg) for different years and reservoirs.

- West Res.: Steep decrease from 1998 to 2002, then plateau.
- South Res.: Steep increase from 1998 to 2002, then decrease.
- North Res.: No significant change throughout the years.
Surface Water: Balance of Alkalinity

Alkalinity minus Acidity
X 1000 kg-CaCO$_3$

(all reservoirs)
Surface Water : pH

Note: Criteria are shown on the results slides of the East reservoir only as REFERENCE; the final effluent of the East Sullivan site is located south of the pumping station.
Surface Water : Fe

(criteria: maximum, average)

(East Reservoir)
Surface Water: BOD & Phenols

(East Reservoir)

BOD (mg/l)

Phenols (mg/l)


Concentration levels:
- BOD: 0.001, 0.01, 0.1, 1, 10, 100, 1000 mg/l
- Phenols: 0.0001, 0.001, 0.01, 0.1, 1, 10 mg/l
How is Nature Responding?
Conclusions

**Organic Cover**

- stops efficiently atmospheric oxygen migration
- allows higher infiltration of water that rises the watertable, implementing a 'wet cover' condition, which acts as a back up
Conclusions

Recirculation of AMD

- allows a more rapid flushing of pore water within the impoundment
- improves the quality of the effluents via sulphate reduction reactions; in fact, since 1999 the water quality of the final effluent meets the requirements of the Ministry du Développement durable, de l’Environnement et des Parcs du Québec.
Acknowledgements

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NEDEM
Thank you for your attention!