Predicting toxicity of future combined pit lakes at the former Steep Rock Iron Mine near Atikokan, Ontario

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Location

History

Hogarth Pit looking southeast, ca. 1970's

Nature of the Pit Lakes

• Typical pH for both pit lakes is 7 to 8
• Caland
  – Stratified (only upper 20 m oxygenated)
  – Non-toxic (hosted a fish farm)
• Hogarth
  – Previously non-stratified
  – Oxygenated
  – Toxic

The Issues

Toxicity of the Hogarth Pit Lake

• Ten years of toxicity tests at Lakehead University:
  1. Explore nature of toxicity (Daphnia magna LC₅₀ test)
  2. Determine changing nature and source of toxicity
     • Ceriodaphnia magna LC₅₀ test
     • Toxicity Indicator Evaluation (TIE)
  3. Predict future nature of toxicity in merged pit lake with wall rock interaction
     • Lemna minor IC₅₀ test
Acute and Chronic Tests

**ACUTE**
- May 1999: *Daphnia magna*
- June & July 2004: Rainbow trout, *Daphnia magna*

**CHRONIC**
- November 2004 – July 2006: *Ceriodaphnia dubia, Lemna minor*
- TIE tests
- Mock Effluent tests: *Ceriodaphnia dubia*
- Growth inhibition tests: *Lemna minor*

**PREDICTIVE MODELING:**
- Growth inhibition tests using *Lemna minor*

Predictive Modeling: Growth inhibition tests

Growth inhibition tests were conducted using *Lemna minor*.

- Static column experiments:
  - Varying water ratios from the two pit lakes
  - Geological influence of wall rocks
- Resultant water represented future water quality of the merged pits as they fill.
  - Used in *Lemna minor* growth inhibition tests

**Analysis and Alternate Endpoints:**
- IC25 (ToxCalc v5.0)
- Dry weights
- Chlorophyll-a concentration
- Frond surface area
  - Total, by colour – dark green, light green, yellow (chlorotic), white (necrotic)

Predictive Water Quality

Water:rock ratio (by mass) = 10:1

- Crushed (1-2 mm) wall rock
- Mix of Hogarth & Caland water

Predictive Water Quality

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<tbody>
<tr>
<td>Hog06 EC25 range (see Section 5)</td>
<td>Hogarth (water sample depth) n/a 2 m 30 m 30 m 30 m 2 m 2 m n/a 30 m</td>
<td>Caland (water sample depth) 2 m n/a 2 m 2 m 2 m 30 m 30 m 30 m 30 m n/a</td>
<td>% Caland water 100% 0% 10% 25% 50% 10% 25% 50% 100% 0%</td>
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Acute Tests - Results

- 1999: *Daphnia magna*
  - LC50 = 100% mortality in 48 hours
  - Source: fluctuations in SO4^2-, Ni^{2+}, Mg^{2+}, iron floc

- June and July 2004: Rainbow trout and *D. magna*
  - No mortality

Chronic Tests - Results

- Nov. 2004: *Ceriodaphnia dubia*
  - IC50 > 100% Hogarth 2m
- Jan., May, June, Nov. 2004; Jan., June, July 2006:
  - Highly variable results
- All subsequent tests showed IC50 > 100% except winter months:
  - Cond., Ca^{2+}, Mg^{2+}, SO4^{2-}, TDS elevated during winter months

- TIE Tests: January 2005
  - Only the EDTA 8 mg/L manipulation reduced toxicity
    - Indicates toxicity due to cationic metals and some non-metal ions (Ca^{2+}, Mg^{2+})
    - Isolated elevated Pt event (0.0885 mg/L) > CWQG 0.007 mg/L
  - January 2006 TIE manipulations resulted in no reductions in toxicity
    - No sources determined
Mock Effluents - Results

• Investigations into TDS-related toxicity:
  – Elevated TDS levels in Hogarth account for the majority of the toxicity
  – BUT: The reduction in toxicity due to EDTA addition (TIE tests) indicates that metals may be a minor toxicant as well
• *Lemna minor* was less affected than other species tested
  – Signs of stress at greater concentrations of Hogarth:
    • Small, unhealthy fronds, chlorotic tissue, shorter roots
    • Due to elevated TDS levels (2000 mg/L), mainly SO₄²⁻

Predictive Modeling - Results

• Unexpected IC₅₀ values (>100 % Hogarth 30 m water)
  – Plants showed definite signs of stress
    • Small fronds, chlorotic and necrotic tissue, colony destruction
• One-way ANOVA:
  – No differences in dry weights in any treatments

Predictive Modeling - Results

- Lower total frond surface area in all treatments compared to controls
- More chlorotic and necrotic tissue in certain treatments
- Once the effect of dry weight was controlled, chlorophyll-a content was shown to be reduced by Hogarth 2 m water

Conclusions

• Frond counts + IC₅₀ calculations
  – GREATLY underestimate toxicity
    • Include small fronds and dead or chlorotic fronds
• Chlorophyll-a and surface area measurements give better estimates of toxicity:
  – Future pit lake water quality will negatively impact aquatic macrophytes
    • Likely due to elevated Ca²⁺, Mg²⁺, and SO₄²⁻
• No longer acute toxic effects
• Dynamic nature of the pit lakes is producing a chronic toxic effect, now and in the future