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

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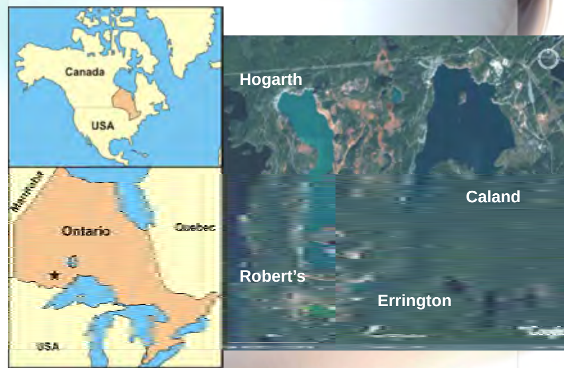
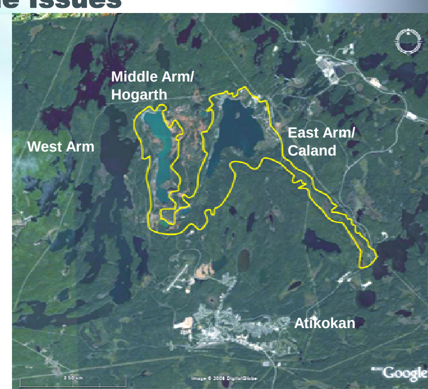
LUCAS
Lakehead

Location

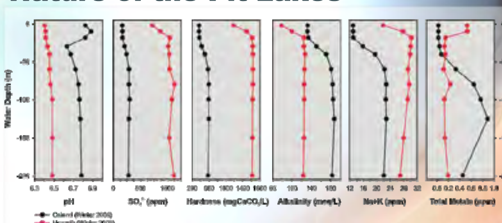


History

The Issues



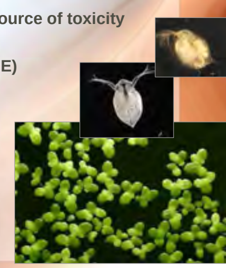
Nature of the Pit Lakes



- 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

Toxicity of the Hogarth Pit Lake

- Ten years of toxicity tests at Lakehead University:
  1. Explore nature of toxicity (*Daphnia magna* LC_{50} test)
  2. Determine changing nature and source of toxicity
     - *Ceriodaphnia magna* LC_{50} test
     - Toxicity Indicator Evaluation (TIE)
  3. Predict future nature of toxicity in merged pit lake with wall rock interaction
     - *Lemna minor* IC_{25} test



Acute and Chronic Tests

ACUTE

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

CHRONIC

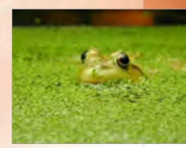
- November 2004 – July 2006:
  - *Ceriodaphnia dubia*
  - *Lemna minor*
- TIE tests
- Mock Effluent tests
  - *Ceriodaphnia dubia*
- Growth inhibition tests
  - *Lemna minor*

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

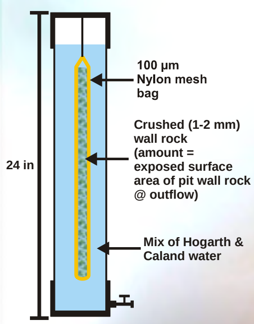
Predictive Modeling: Growth inhibition tests

Growth inhibition tests were conducted using Lemna minor

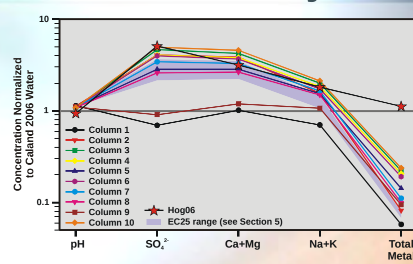
- Static column experiments:
  - Varying water ratios from the two pit lakes
  - Geological influence of wall rocks
- Resultant water represented future water quality of the merged pits as they fill:
  - Used in *Lemna minor* growth inhibition tests
- Analysis and Alternate Endpoints:
  - IC_{25} (ToxCalc v5.0)
  - Dry weights
  - Chlorophyll-a concentration
  - Frond surface area
    - (total, by colour – dark green, light green, yellow (chlorotic), white (necrotic)



Predictive Water Quality



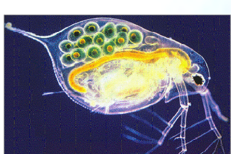
Predictive Water Quality



Column	1	2	3	4	5	6	7	8	9	10
Hogarth (water sample depth)	n/a	2 m	30 m	30 m	30 m	2 m	2 m	2 m	n/a	30 m
Caland (water sample depth)	2m	n/a	2 m	2 m	2 m	30 m	30 m	30 m	30 m	n/a
% Caland water	100%	0%	10%	25%	50%	10%	25%	50%	100%	0%

Acute Tests - Results

- 1999: *Daphnia magna*
  - LC_{50} = 100% mortality in 48 hours
  - Source: fluctuations in SO_4^{2-}, Ni^{2+}, Mg^{2+}, iron floc
- June and July 2004: Rainbow trout and *D. magna*
  - No mortality



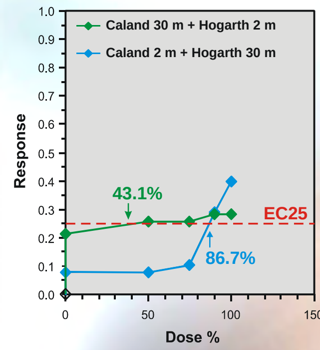
Chronic Tests - Results

- Nov. 2004: *Ceriodaphnia dubia*
  - IC_{50} > 100% Hogarth 2m
- Jan., May, June, Nov. 2004; Jan., June, July 2006:
  - Highly variable results
- All subsequent tests showed IC_{25} > 100% except winter months:
  - Cond., Ca^{2+}, Mg^{2+}, SO_4^{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/or some non-metal ions (Ca^{2+}, Mg^{2+})
    - Isolated elevated Pb 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

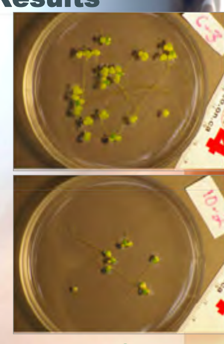
- Investigations into TDS-related toxicity:
  - Elevated TDS levels in Hogarth account for the majority of the toxicity
  - BUT: The reduction in toxicity due to EDTA addition (TIE tests) indicates that metals may be a minor toxicant as well
- *Lemna minor* was less affected than other species tested
  - Signs of stress at greater concentrations of Hogarth:
    - Small, unhealthy fronds, chlorotic tissue, shorter roots
    - Due to elevated TDS levels (2000 mg/L), mainly SO_4^{2-}

Predictive Modeling - Results

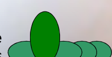


Predictive Modeling - Results

- Unexpected IC_{25} 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



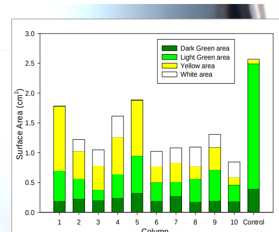
Compound side fronds

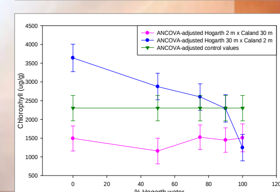


Side frond attaching narrowly

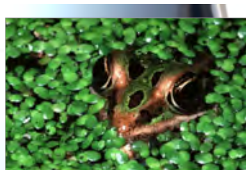
Predictive Modeling - Results

- One-way ANOVA:
  - 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 + IC_{25} 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 Ca^{2+}, Mg^{2+}, and SO_4^{2-}
- No longer acute toxic effects
- Dynamic nature of the pit lakes is producing a chronic toxic effect, now and in the future