The role of biofilm on the long-term performance of a shallow water cover to limit reactive tailings oxidation and metal mobilisation.

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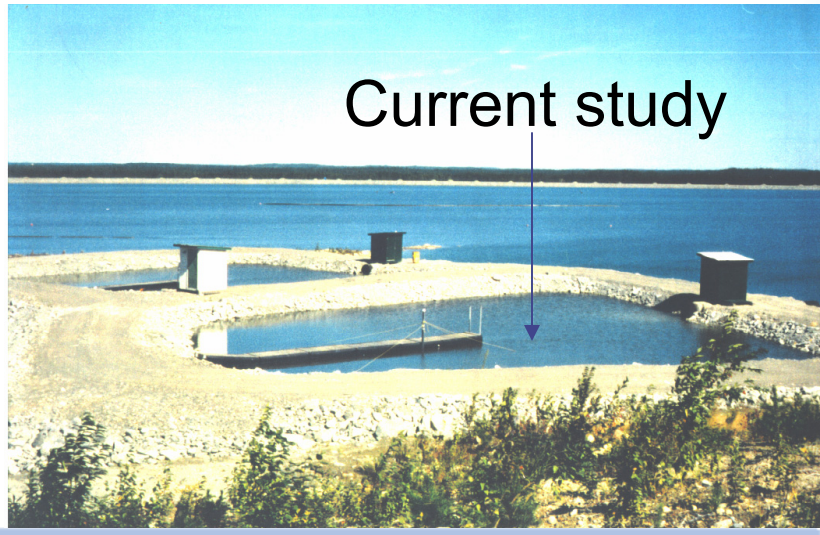
Louvicourt Mine Experimental Cells

- Constructed in 1996 to study the performance of shallow water cover to limit oxidation of reactive tailings
- 21 m x 21 m
- 3 m of mine tailings
- 0.3 m water cover
- First geochemical field study conducted from 1996 to 1999 (MEND project 2.12.1, report published in 2002)



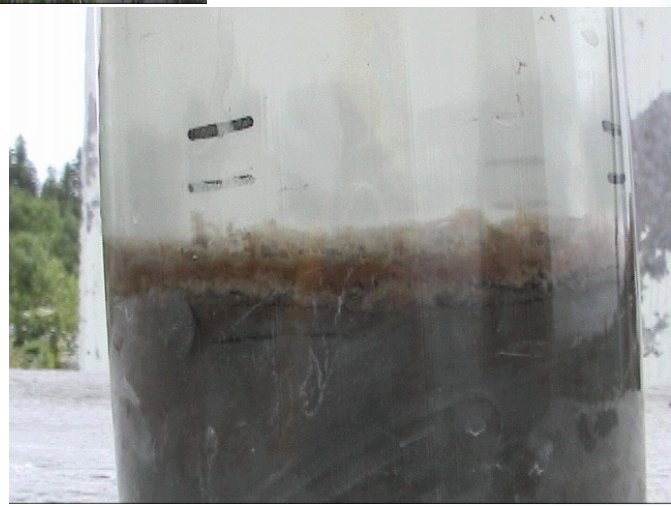
Louvicourt Mine Experimental Cells

- Current study, initiated 7 years after the last measurements
- Cells decommissioned in 2005

July 2005

August 2005

Biofilm



Project Objectives

- To assess the long-term performance of the shallow water cover by determining porewater chemistry and submerged tailings geochemistry nine years after disposal.

- To provide additional information on the role and impacts of the fully established periphyton layer at the tailings–water interface and on observable changes in geochemistry and mineralogy of the submerged tailings.

Methodological Approach

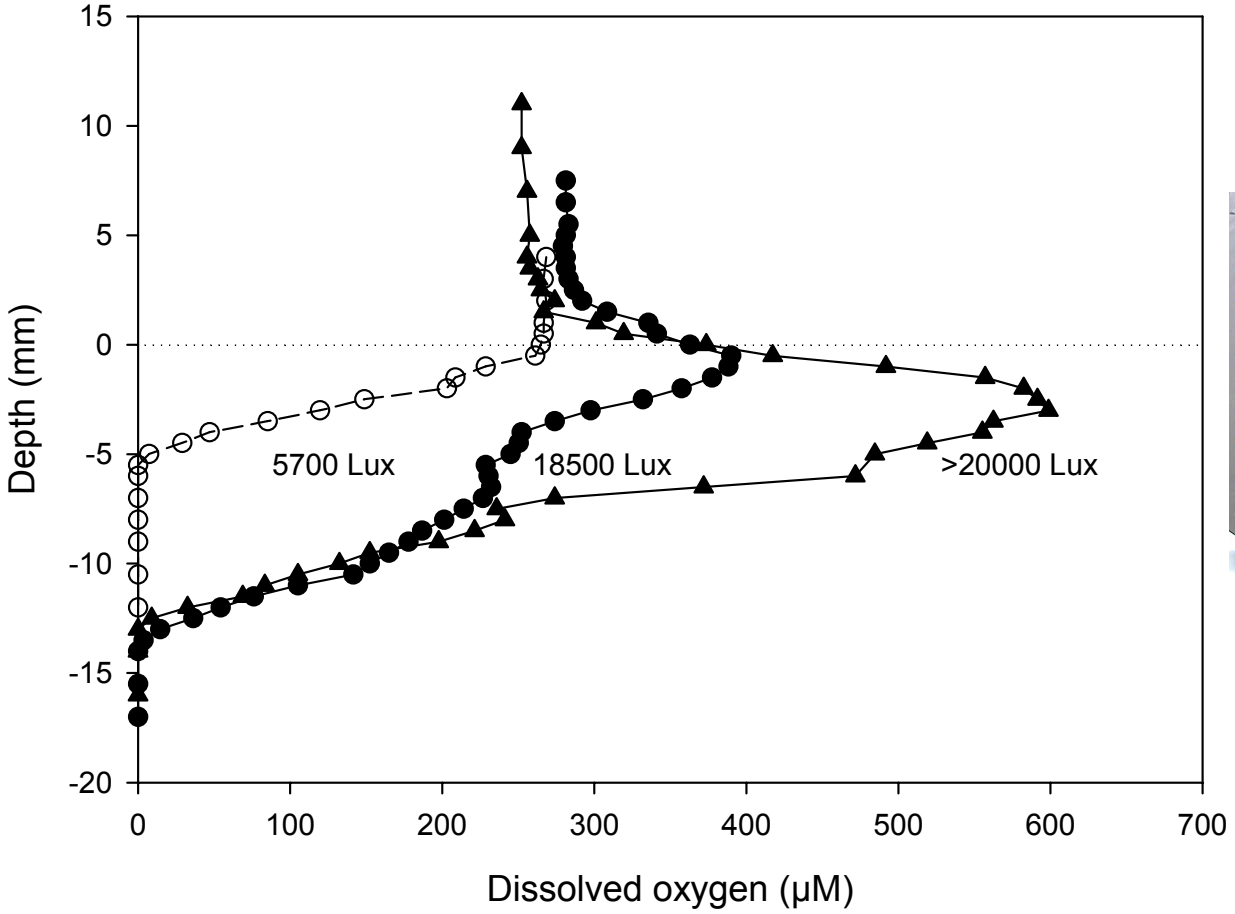
Sampling and porewater analysis

- Electrochemical micro-profiles
- Interstitial water profiles

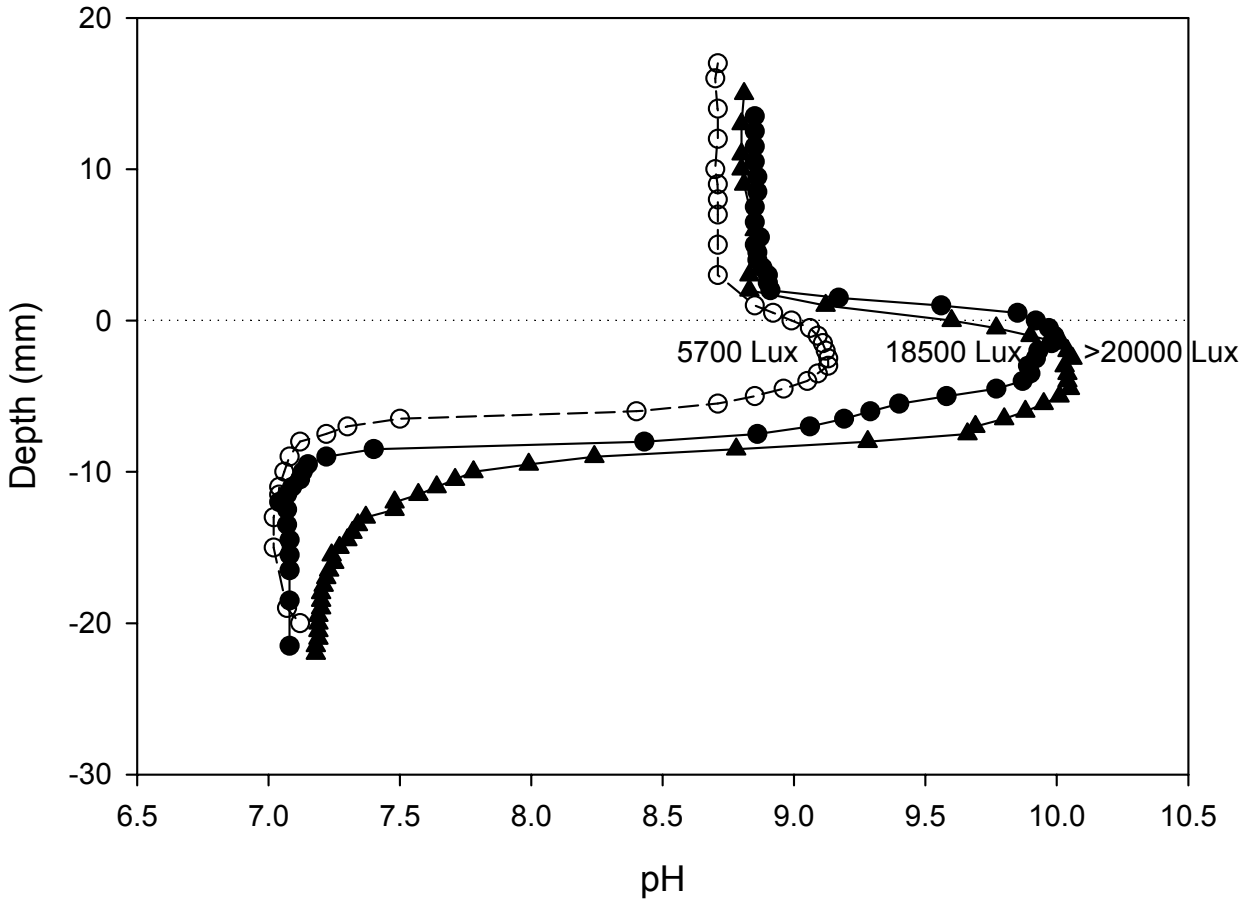
Biofilm/Tailings Analysis

- Core sampling and extrusion
- Sequential extraction analysis
- Mineralogical analysis (SEM-EDX)
- Molecular biological analysis

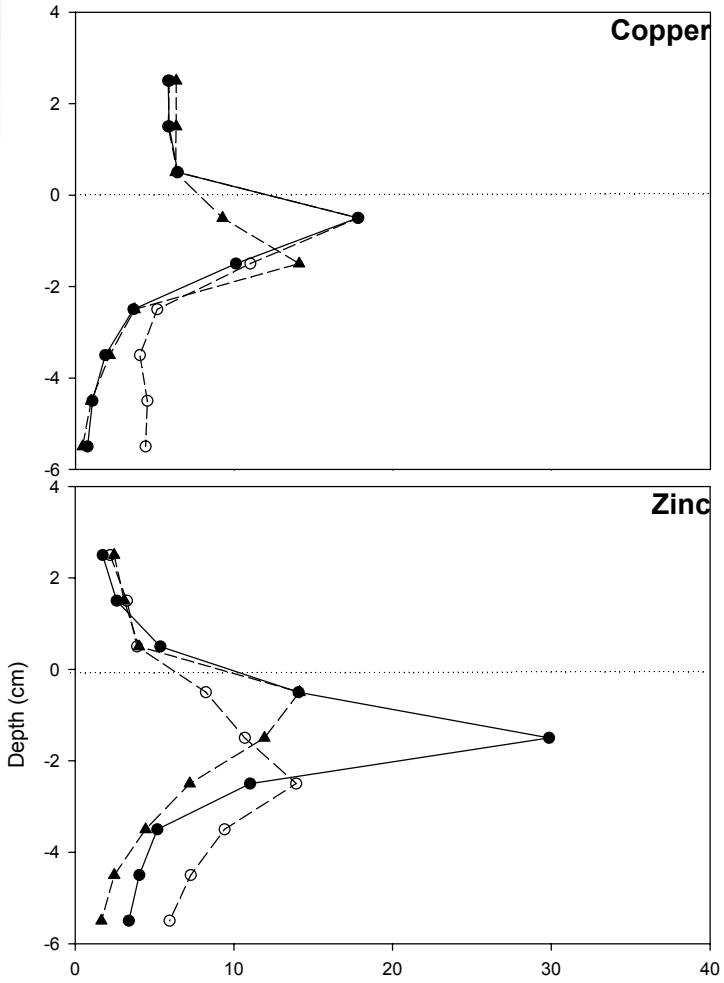
Micro-Profiles – O_2

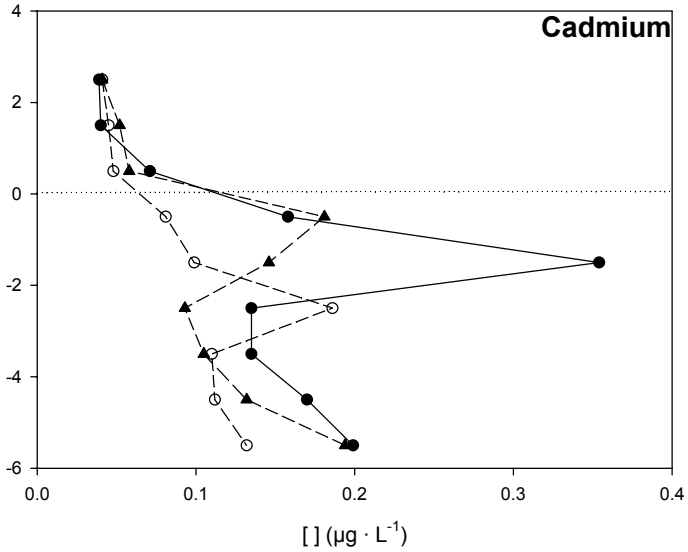


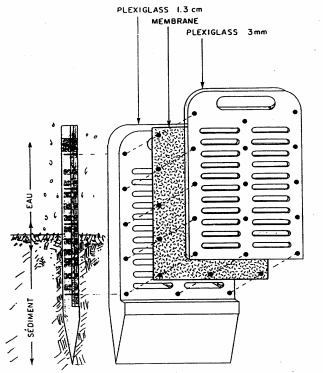
Micro-Profiles - pH



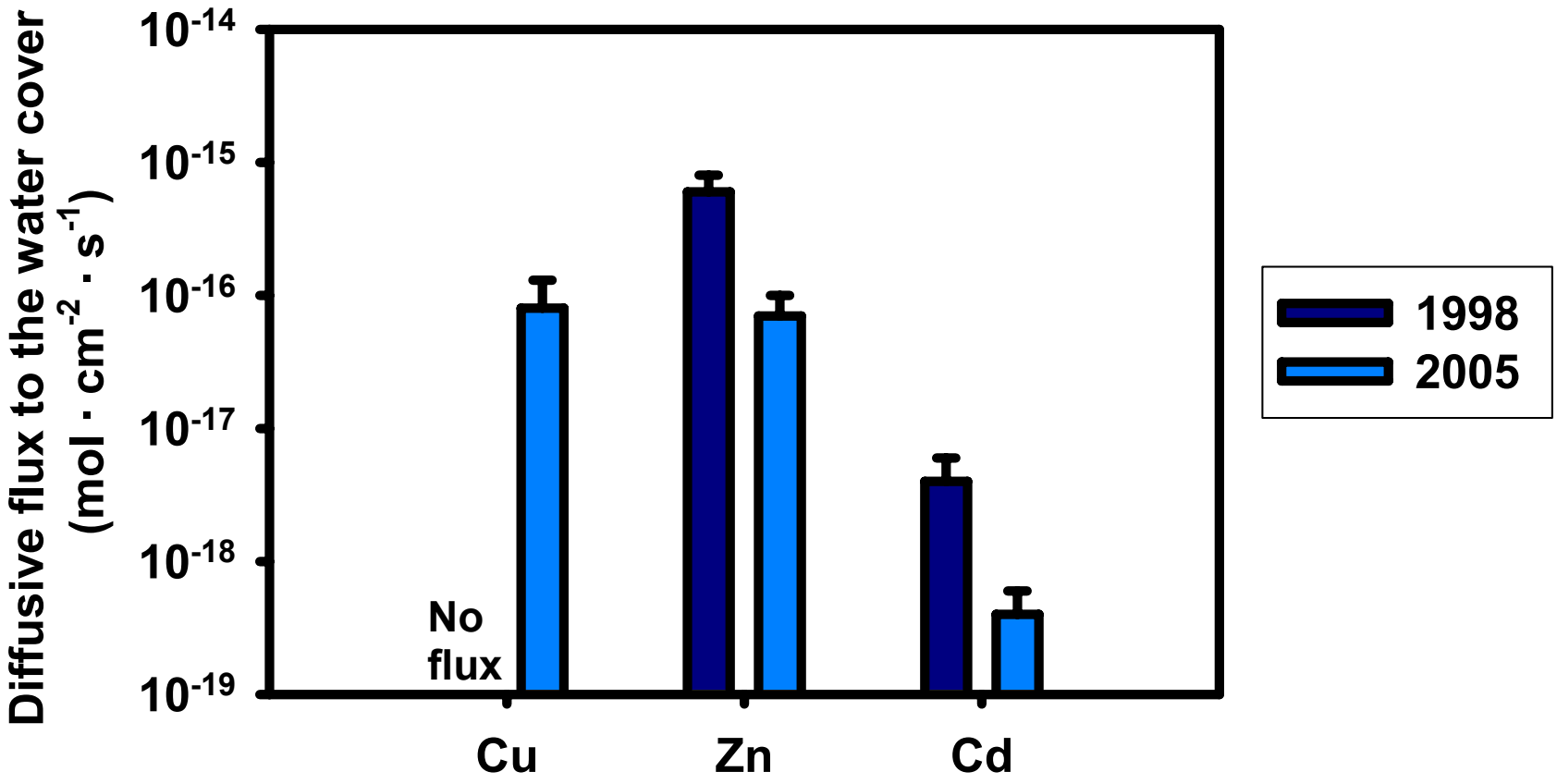
Porewater


Copper
Zinc
Depth (cm)
4
2
0
-2
-4
-6
0
10
20
30
40


Cadmium
0.0
0.1
0.2
0.3
0.4
[ ] (µg · L-1)


PLEXIGLASS 1.3 cm
MEMBRANE
PLEXIGLASS 3mm
EAU
SÉDIMENT

Porewater - Metal Fluxes



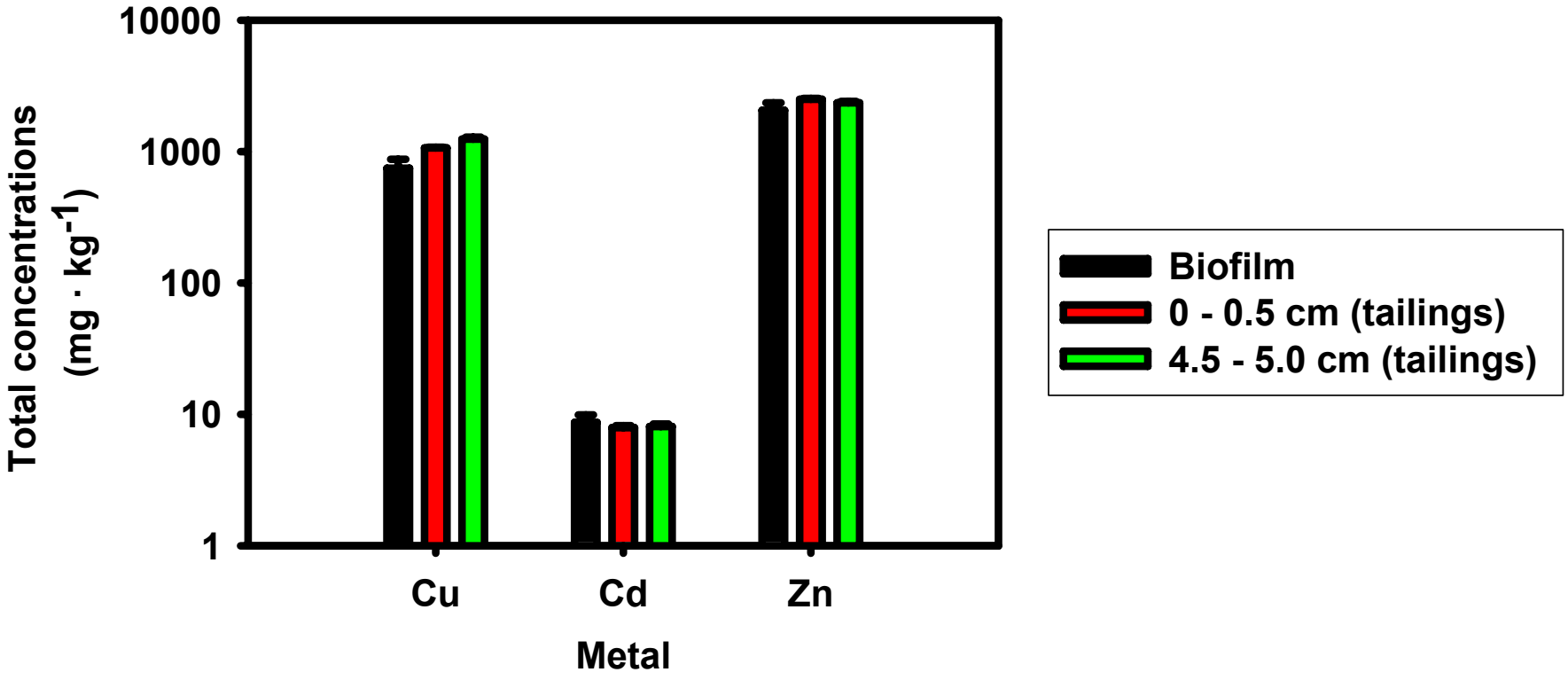
Core Extrusion

biofilm

0 - 0.5 cm of tailings

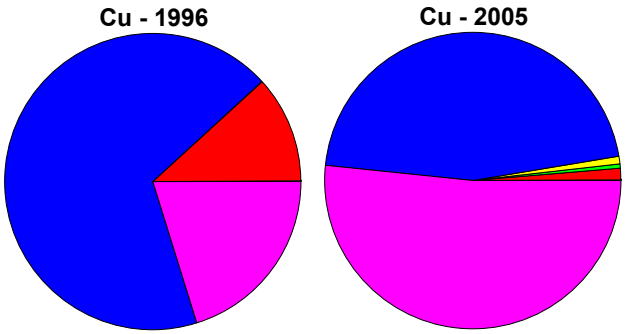
4.5 – 5.0 cm of tailings

Total Concentrations (2005)

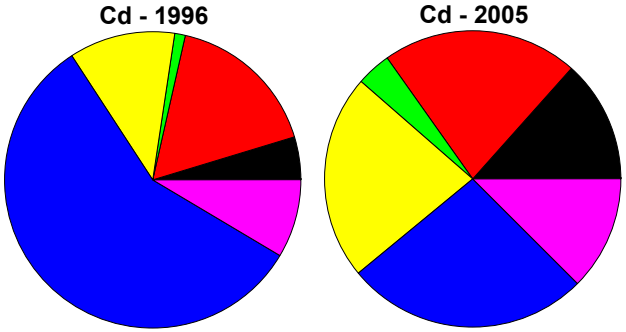


Seq. Ext. – First 0.5 cm of Tailings

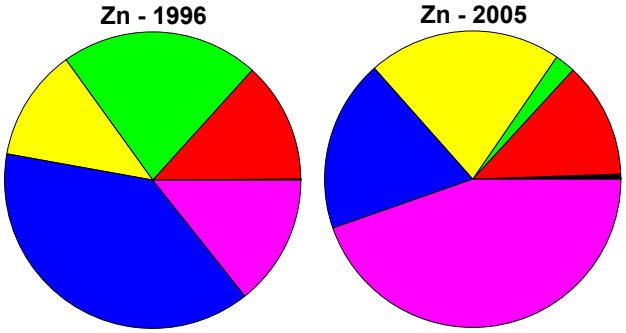
Cu

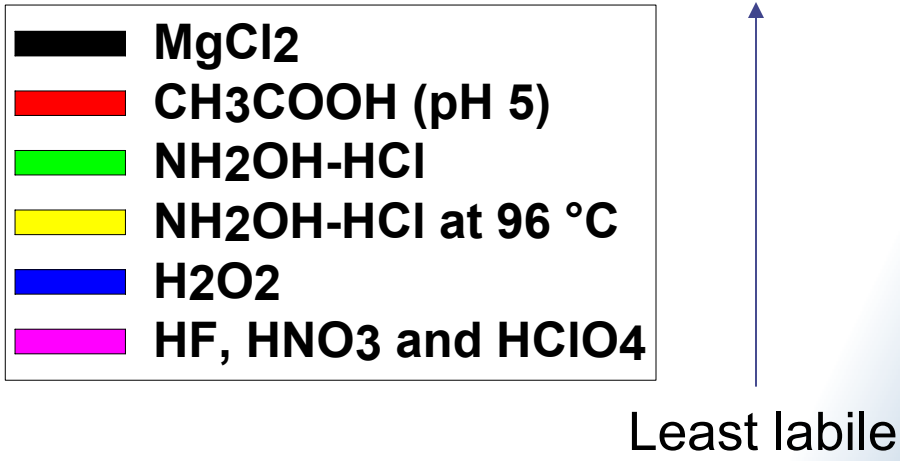


Cd



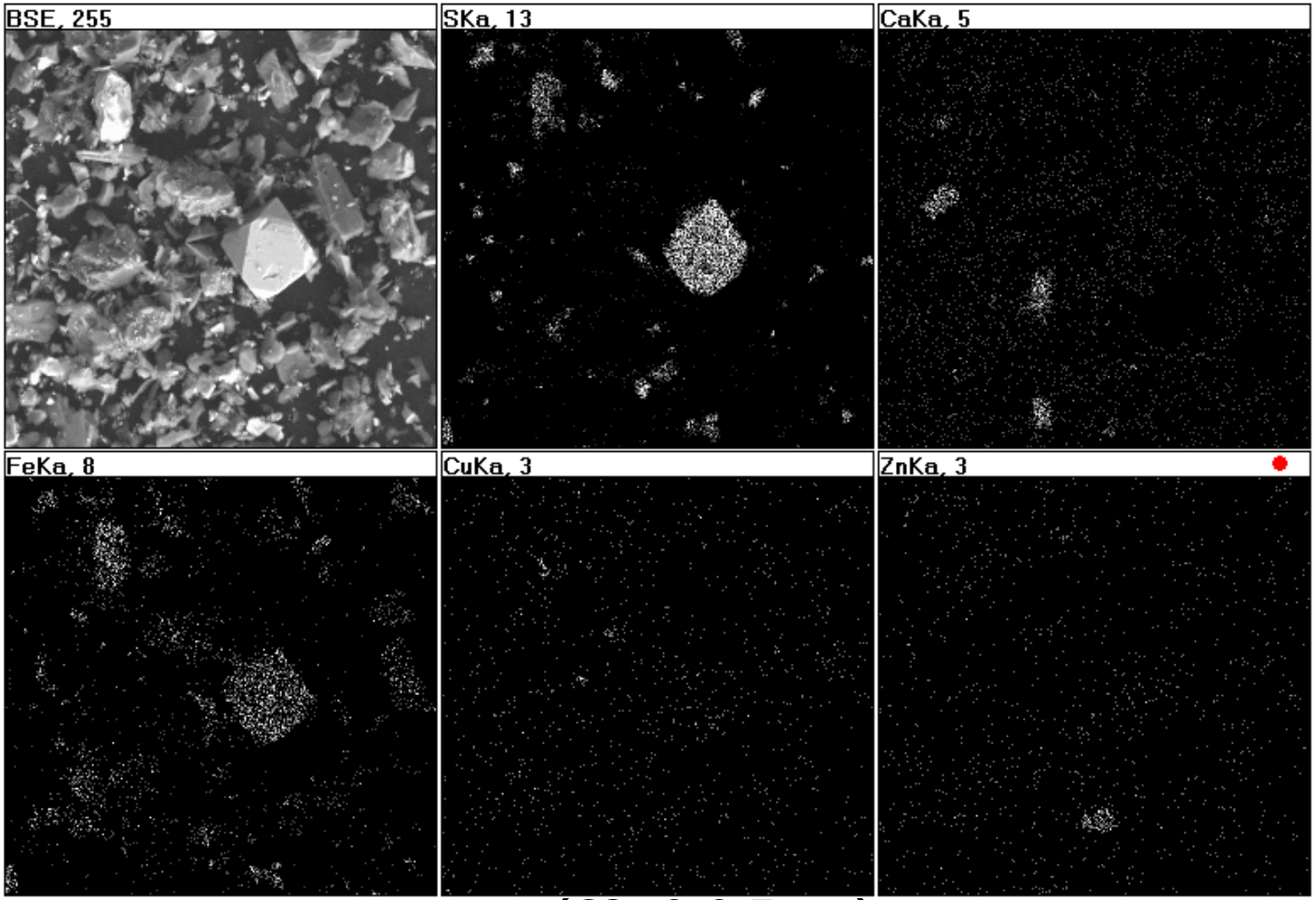
Zn





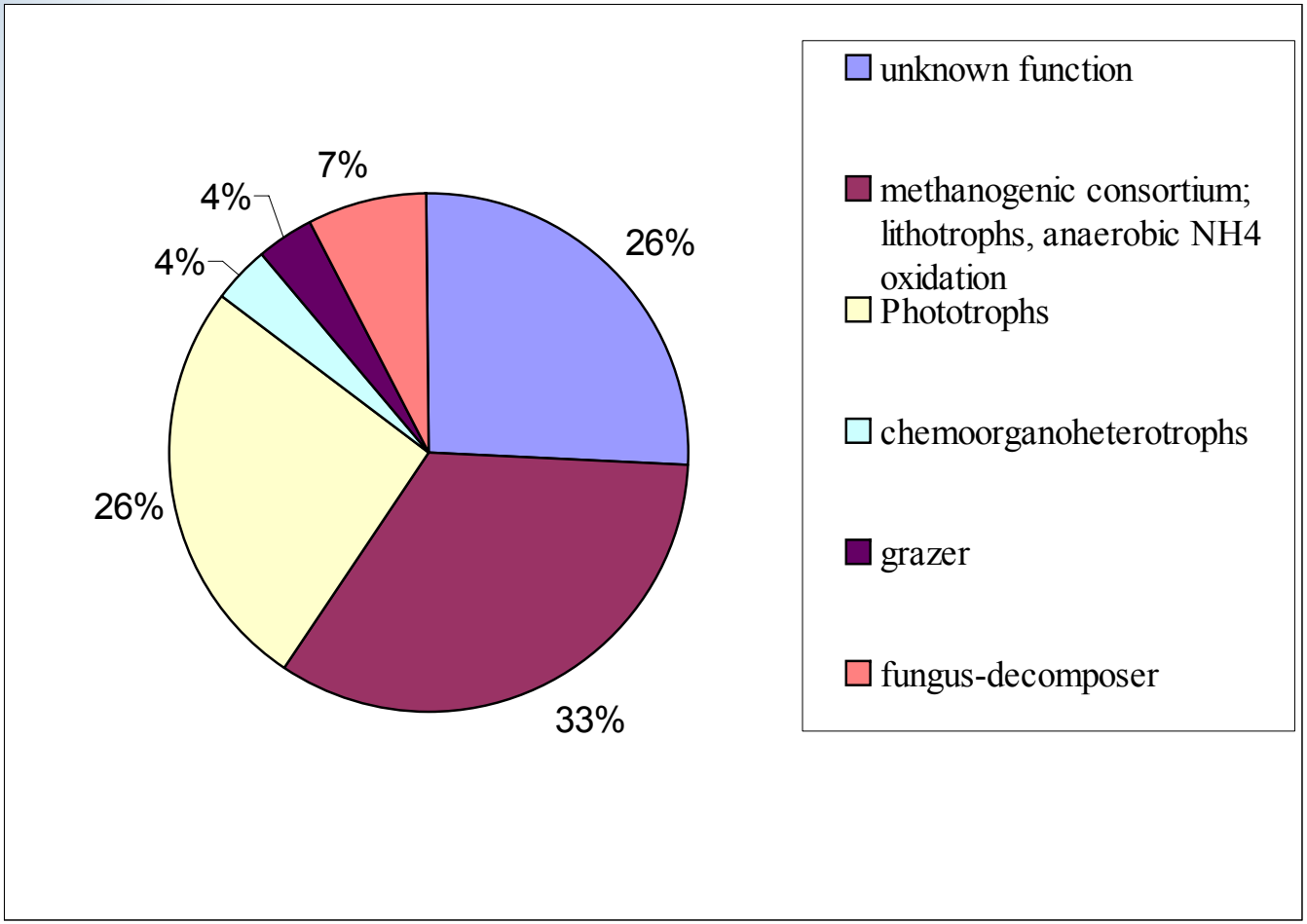
Mineralogical Observations

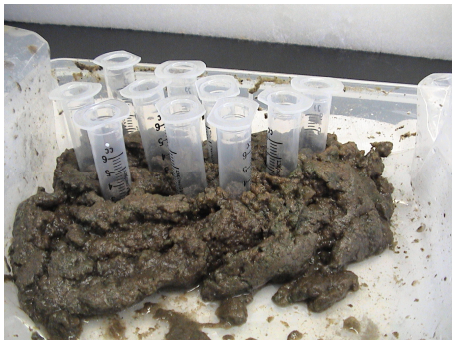
Increasing abundance of sulfides with depth but well crystalline pyrite persists at tailings-water interface

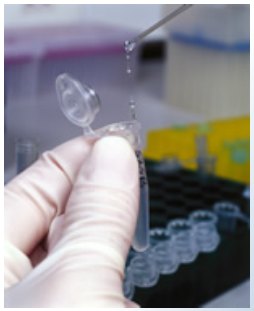


(C2: 0-0.5 cm)

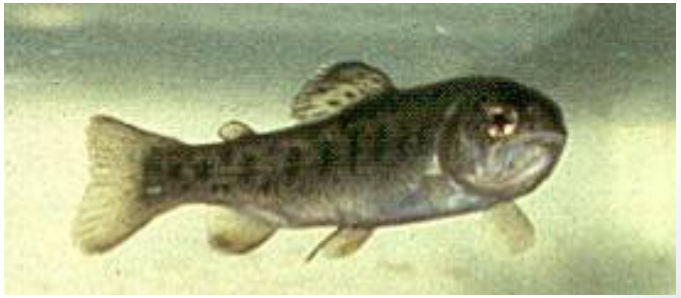
Molecular Biological Analysis







Does the biofilm affect metal toxicity of discharged water?

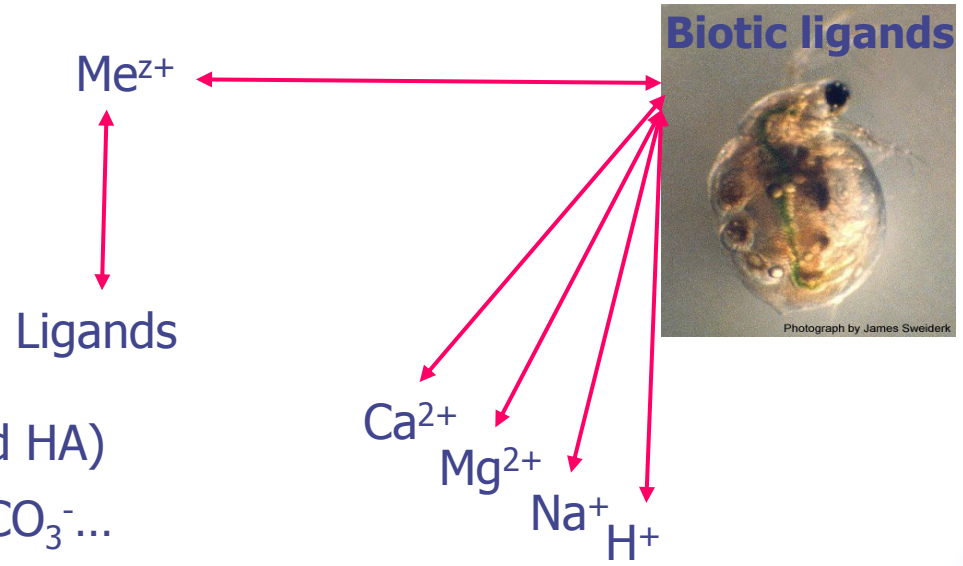


Assessing the Biological Impacts of Submerged Tailings

- Update of the MEND literature review conducted in 1993
- Methods reviewed included the Biotic Ligand Model for the prediction of metal toxicity in water
- The BLM approach allows prediction of acute toxicity of several metals within a factor of 2 to 3.

The Biotic Ligand Model approach

Protective effect of DOC derived from the biofilm in the Louvicourt water cover?



$L_{org.}$ = **DOC** (FA and HA)

$L_{inorg.}$ = Cl^-, SO_4^{2-}, HCO_3^-...

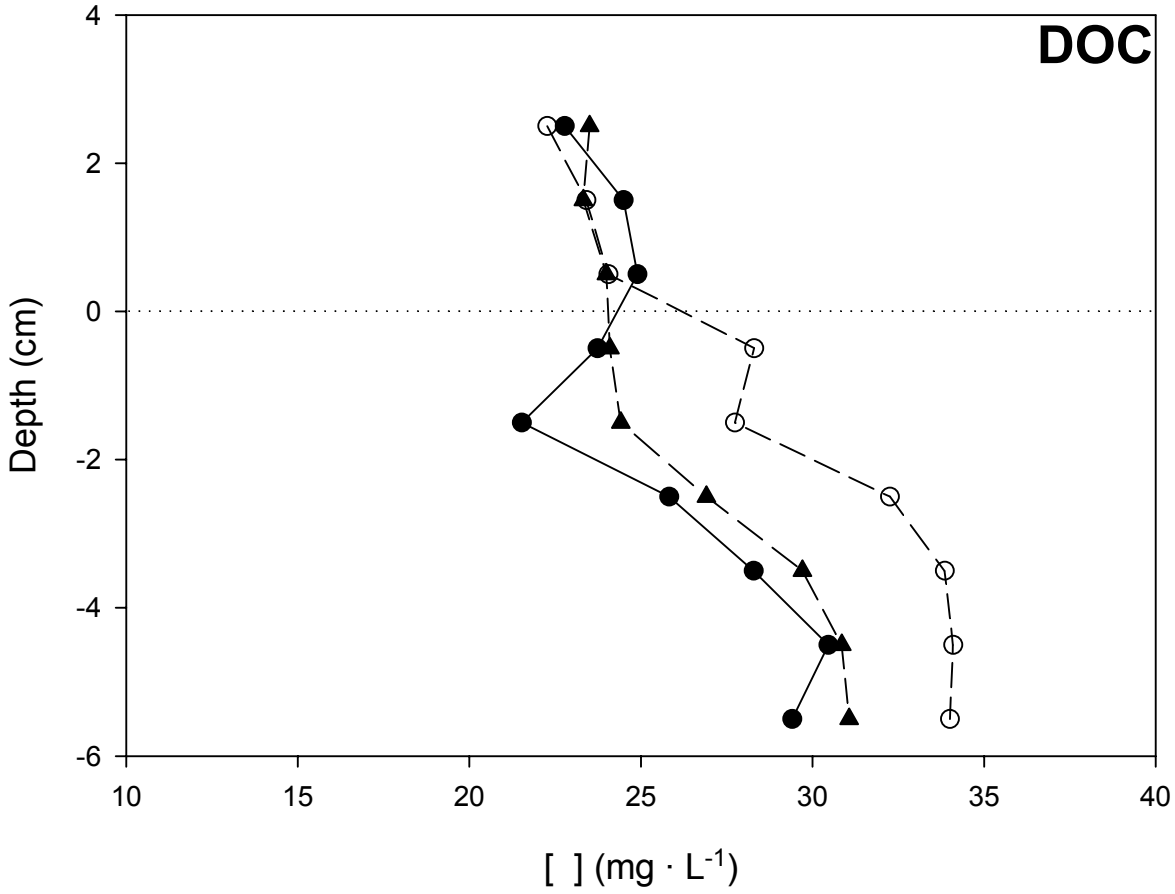
complexation

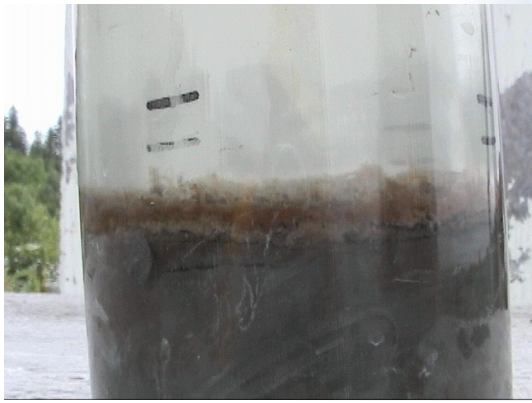
reactions with dissolved ligands

cationic competition

interactions at toxic binding sites

Water Cover: DOC Profiles





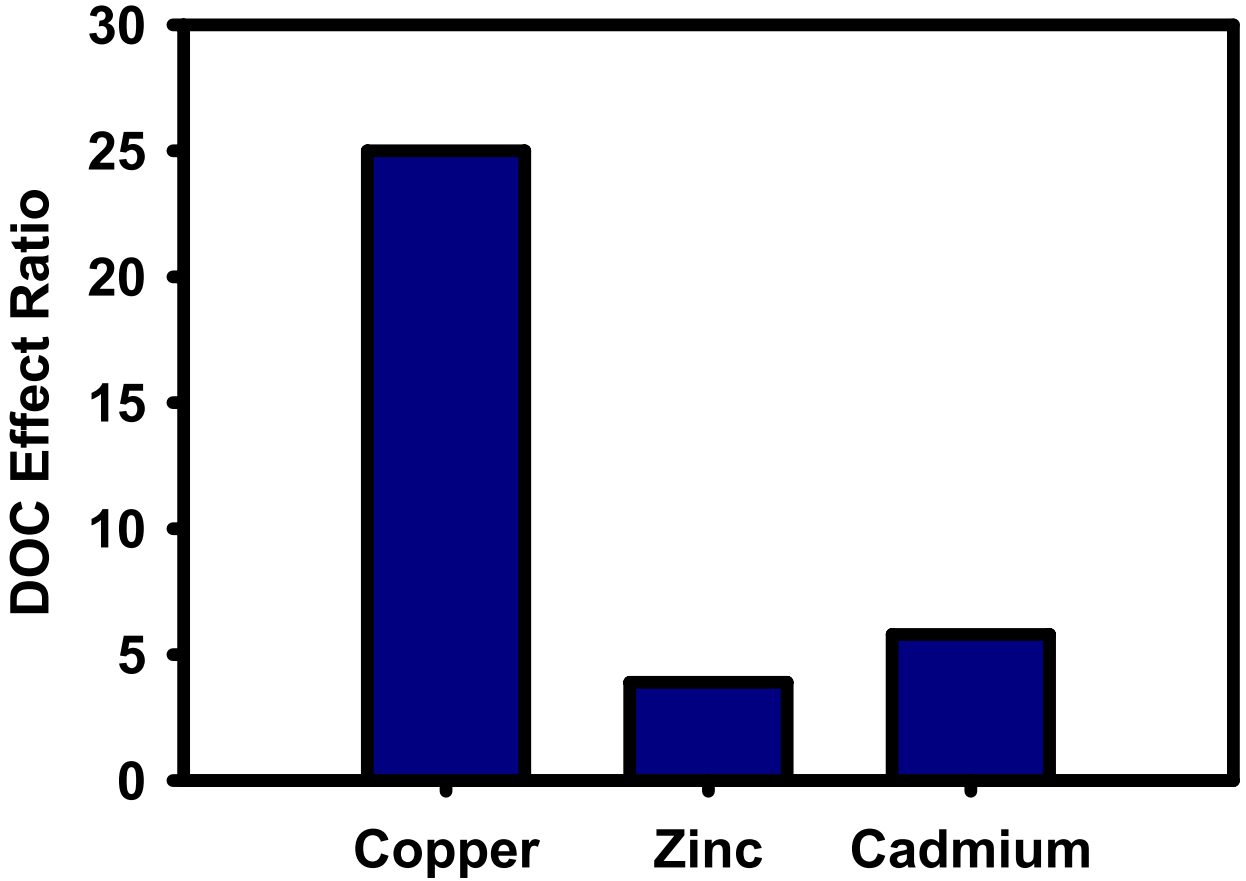
Water Cover: DOC Protective Effect

Effect Ratio Rainbow trout = $\frac{\text{Toxicity with DOC}}{\text{Toxicity without DOC}}$

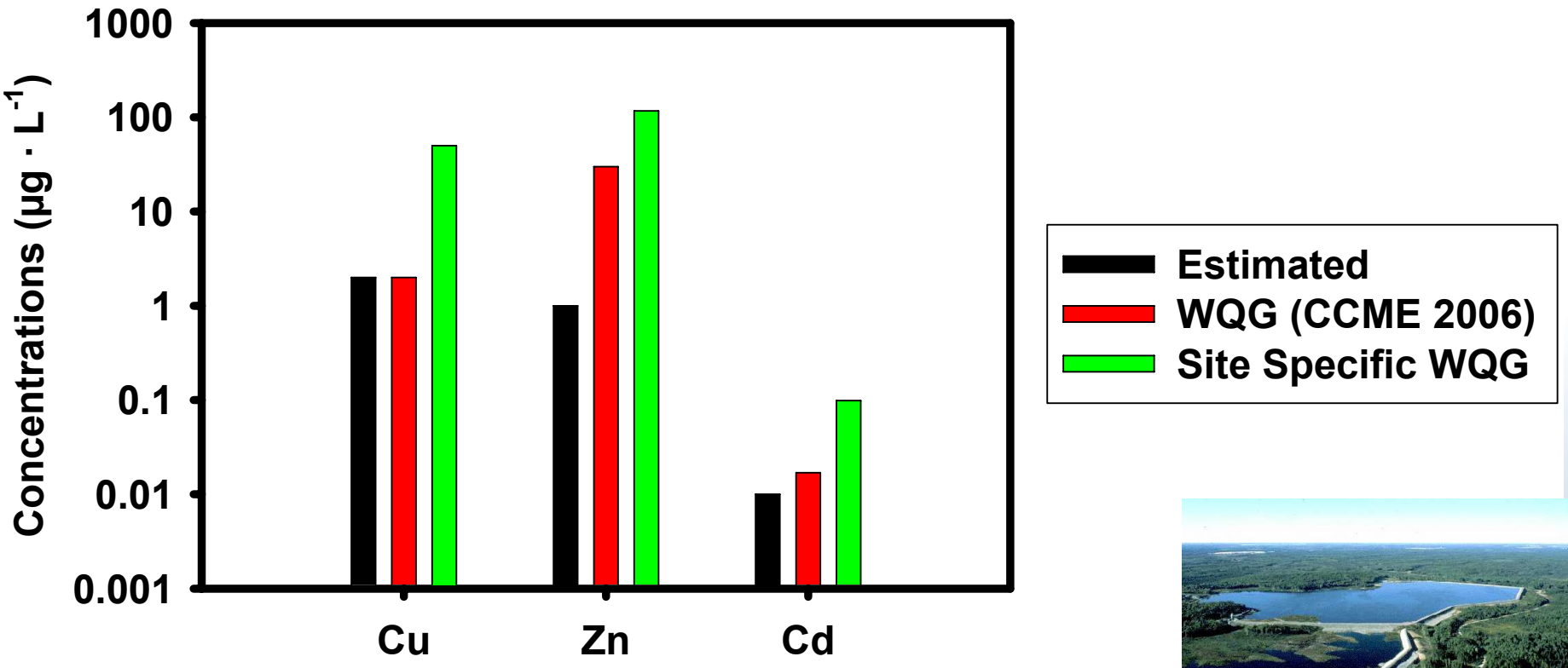
(also for *Daphnia magna or Ceriodaphnia dubia*)

- Hydroqual BLM used to predict median lethal concentrations (LC50)
- The final effect ratio is the geometric mean of the effect ratios (CCME 2005).

Water Cover: DOC Protective Effect



Water Cover: DOC Protective Effect



Conclusions

- The system had not reached equilibrium after nine years of operation.
- Mobilisation of trace metals occurred at the tailings surface but the overlying biofilm effectively trapped the released metals.
- Given the water volume in the actual tailings pond the observed Cu, Cd and Zn fluxes would not lead to exceedance of water-quality guidelines.
- Biofilm development on submerged tailings is generally beneficial for the application of water covers.

Future Work

Biofilms has a key component of shallow water cover tailings disposal:

- **At Louvicourt, the conditions in the actual tailings impoundment might differ from the experimental cells**
- **Biofilms have likely developed at other sites with shallow water covers**
- **Can biofilm be used as tool ?**

Acknowledgements

- John Chaulk (CANMET-MMSL)
- Teck (formerly Aur Resources)
- INRS-ETE
- Mine Environment Neutral Drainage (MEND) Program
- Mining Association of Canada

Summary of Observations

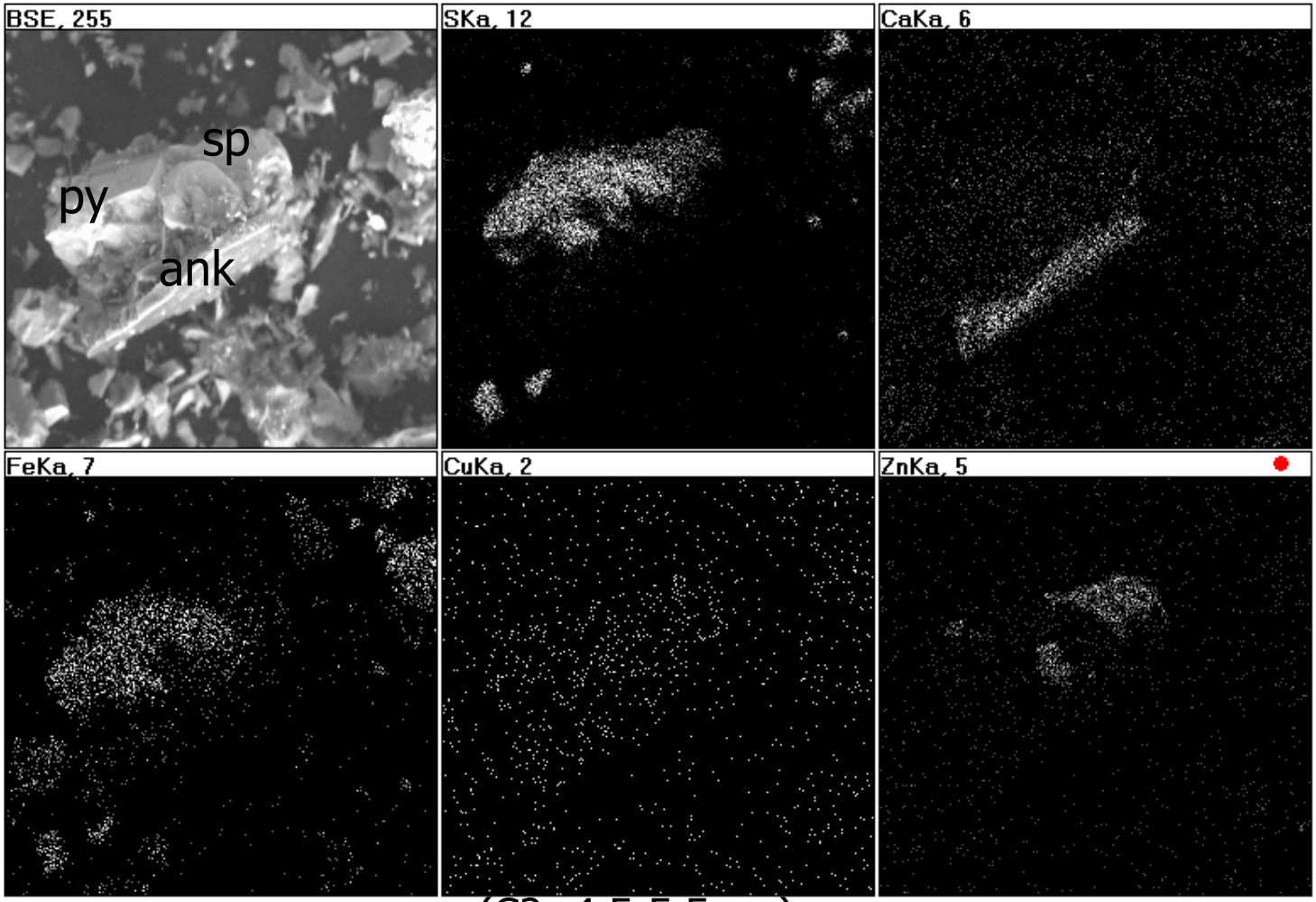
- O_2 is limited to the first -0.5 mm to -1.4 mm of the biofilm/tailings with concentration affected by photosynthesis.
- pH is locally elevated near the tailings/water interface due to photosynthesis.
- Fluxes for Zn and Cd to the overlying water are 10x lower than those obtained 7 years ago but the tailings have become a source of Cu to the overlying water.
- Between 1996 and 2005, there is a notable reduction in H_2O_2-oxidizable Cu, Cd and Zn (presumably as sulfides) in the surface tailings and the amount of Zn in the more labile fractions has significantly decreased while that for Cd has slightly increased.

Summary Observations (cont.)

- Sulfide abundance increases with depth but well crystalline pyrite persists at tailings-water interface.
- There is evidence of galvanic interaction among the prevailing sulfides which could explain the efflux of Cu observed in 2005.
- The biofilm and associated tailings & Fe-oxyhydroxide have elevated metal concentrations.
- The biofilm was a highly dynamic system in terms of vertical distribution and temporal variation.

Evidence of Galvanic Interaction

- Note that Cu is also widespread among the sulfide phases
- This could explain the efflux of Cu undetected previously



(C2: 4.5-5.5 cm)