Should metal bioavailability be considered in the evaluation of treatment and remediation methodologies for acid mine drainage?

Vigneault, B.*, Neculita, C.M., Zagury, G.J.**, Kwong, Y.T.J.* and Tisch, B.***

* CANMET-Mining and Mineral Sciences Laboratories

** École Polytechnique de Montréal

5th World Congres of the Society of Environmental Chemistry and Toxicology, Sydney, Australia, August 2008

Introduction : Context

- Treatment efficiency is often assessed based on metal removal alone
- More jurisdictions are implementing effluent toxicity requirements and discharge objective or limits based on generic water quality criteria

Introduction : AMD Treatment

- Acid Mine Drainage (AMD) is the most significant environmental issue related to mining world-wide
- AMD treatment most often involves of neutralization with lime
- AMD prevention and / or passive treatment are more preferable
- Prevention and treatment options include:
  - Water covers
  - Soil covers
  - Passive bioreactors

Introduction : Objective

The current presentation highlights the relevance of metal bioavailability in assessing alternative methods for AMD prevention and treatment:

I. Shallow water cover
II. Papermill sludge cover
III. Passive bioreactor

AMD Prevention : Water Cover

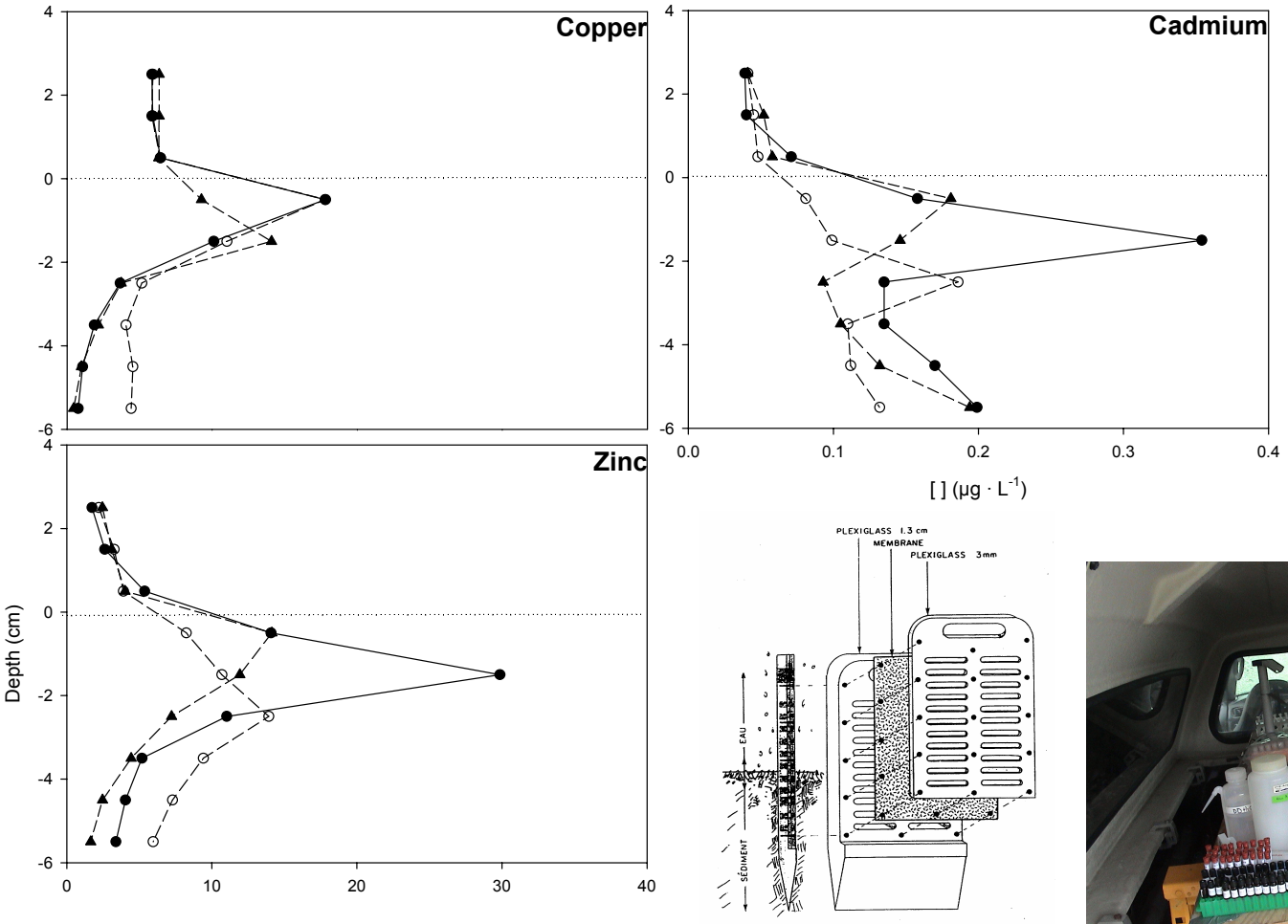
- Subaqueous disposal of reactive sulphide tailings is an effective way to prevent AMD
- Shallow water cover of ~ 30 cm is preferable for geotechnical considerations
- Formation of a biofilm has been found at the surface of the tailings

Materials and Methods: Water Cover

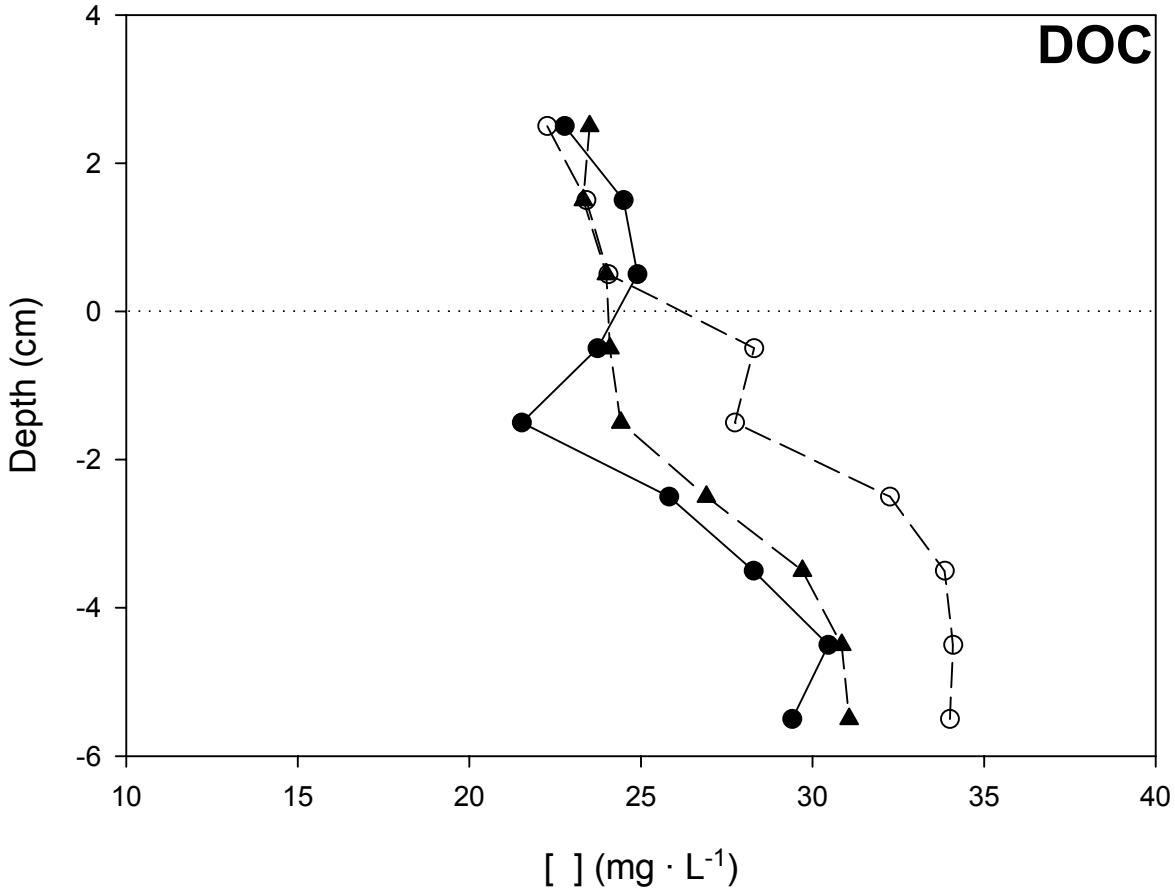
- Geochemical measurements were completed at the water/tailings interface to assess the impact of biofilm:
  - Micro-profiles of O_2 and pH
  - Profiles of metals, major ions, sulphides and DOC
  - Biotic Ligand Model (Hydroqual) to estimate the effect of DOC

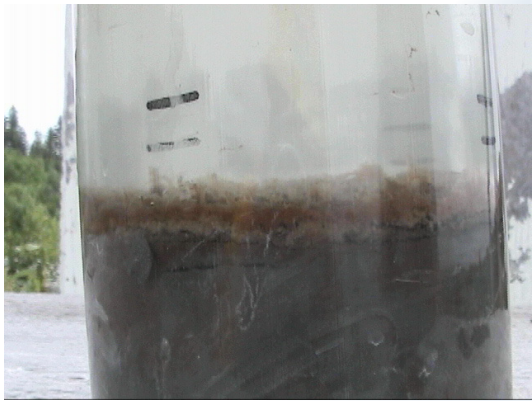
Vigneault et al. (2001) Wat. Res. 35(4): 1066-1076.

Water Cover: Trace metal profiles

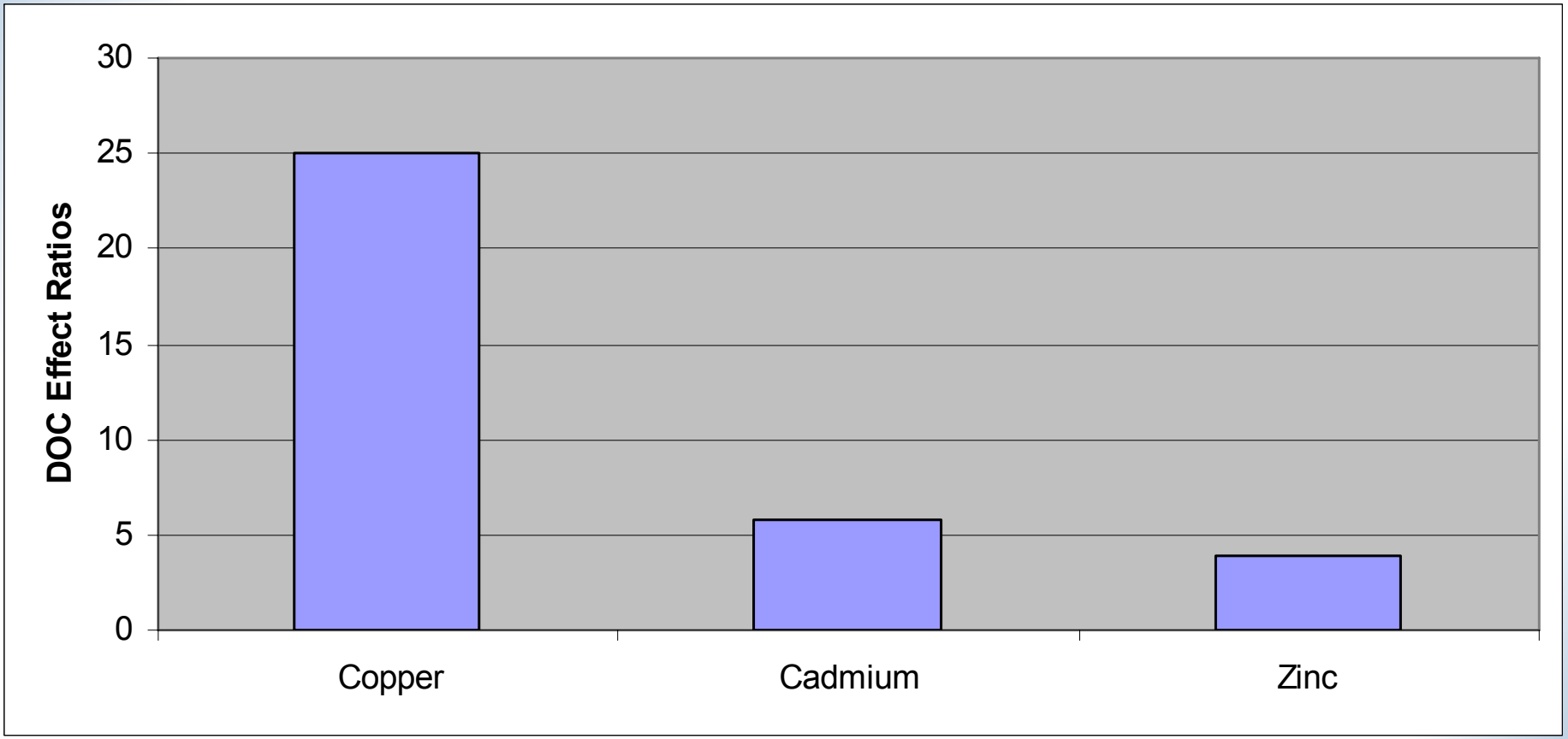


Water Cover: DOC Profiles





Water Cover: DOC Protective Effect



AMD Prevention : Paper Mill Biosolids

- Paper mill biosolids are used to reclaim mine tailings
- If possible, paper mill biosolid covers will be use to grow energy crops
- Besides suppressing metal mobilization, the utilization of paper mill biosolids may impact effluent composition

Materials and Methods: Biosolid Covers

- Pulp and paper sludge were obtained from two Canadian mills

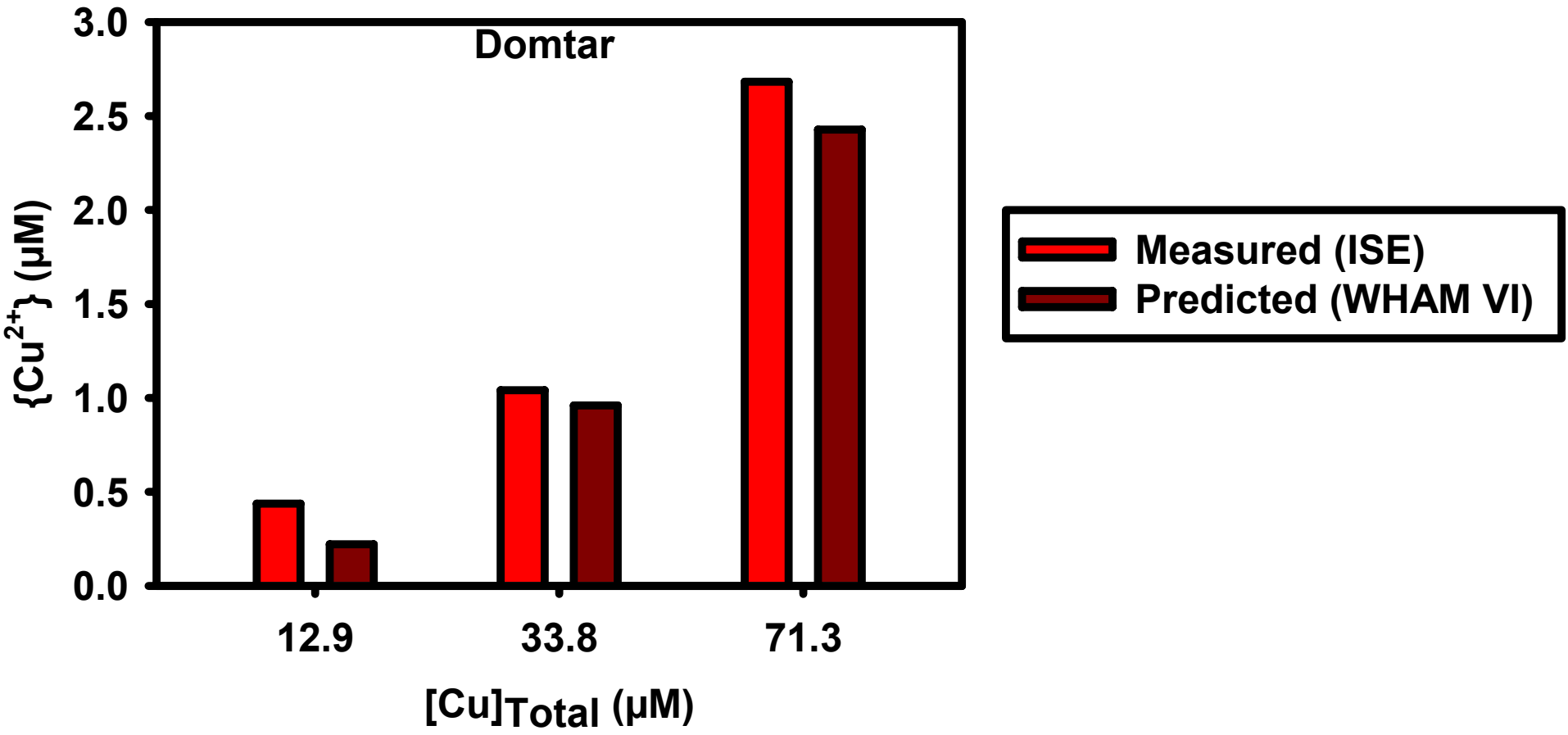
- Biosolids leachates tested for:

  - Direct toxicity
  - Copper complexation capacity
  - Effect on copper toxicity

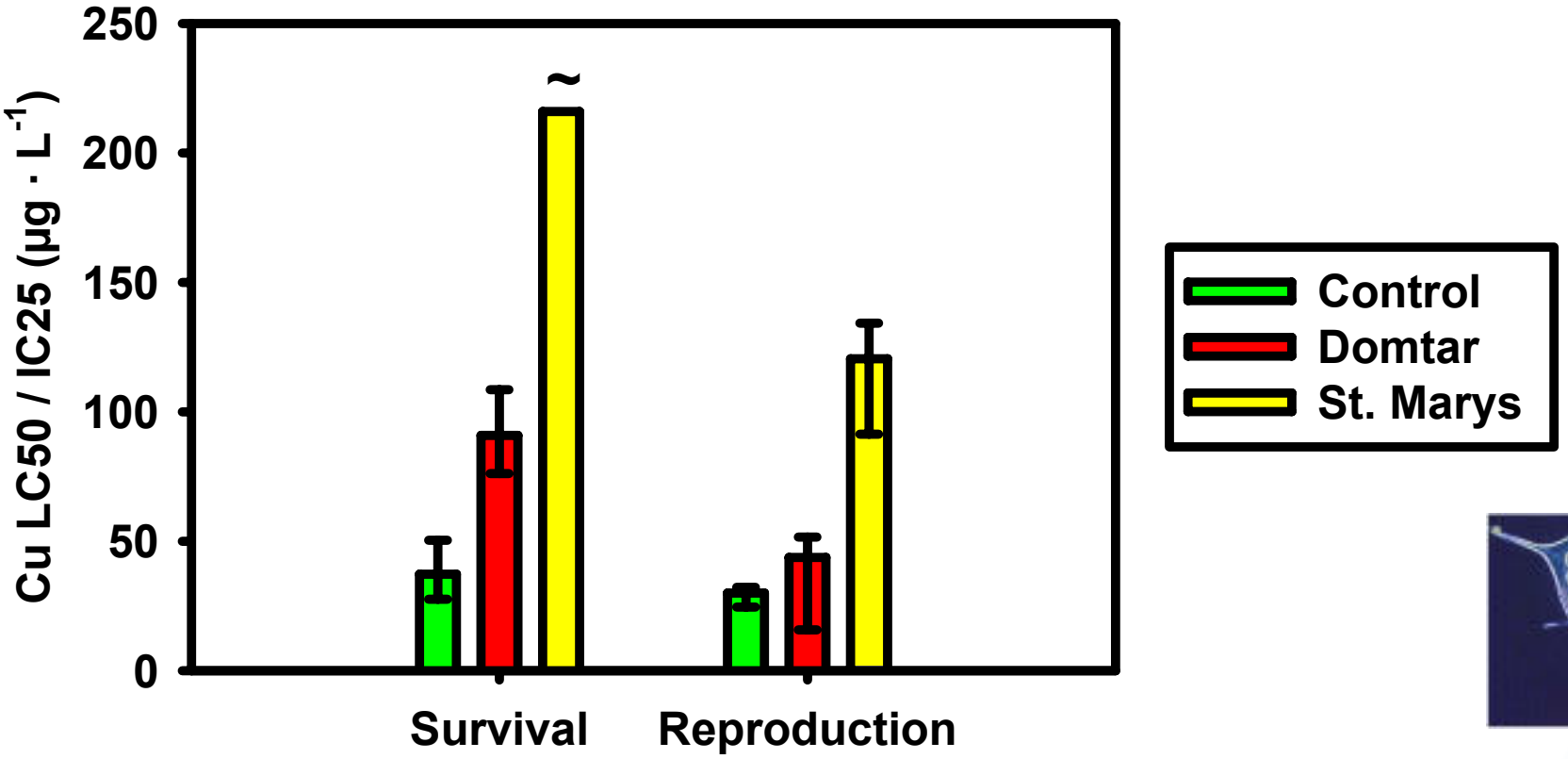
Materials and Methods: Metal Speciation

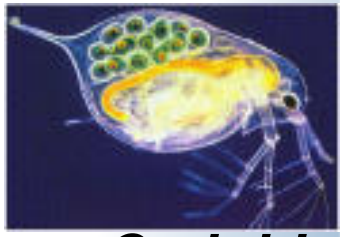
- Ion selective electrode for the determination of copper complexation capacity
- Effect of leachates on copper toxicity to *C. dubia* (7 day survival and reproduction) tested in laboratory water

Biosolid Covers: Cu Complexation



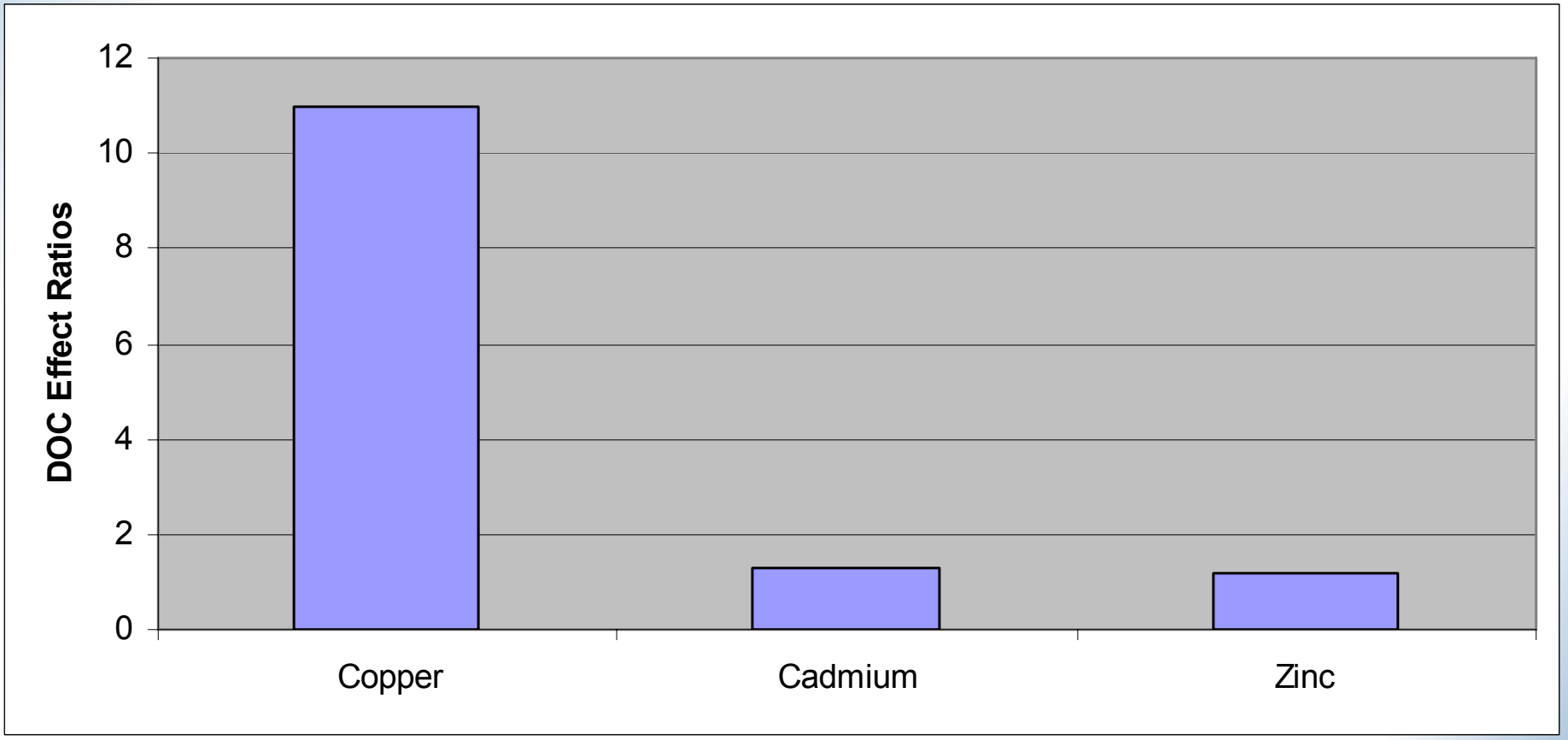
Biosolid Covers: Cu Toxicity





C. dubia

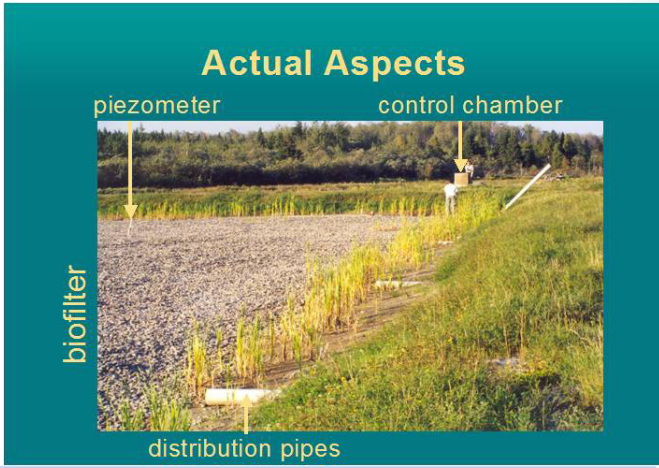
Biosolid Covers: DOC Protective Effect



AMD Treatment : Passive bioreactors

- Field passive bioreactors are effective to increase pH and remove metals

- Bioreactors require an organic amendment and can release DOC in the treated effluent



Materials and Methods: Passive Bioreactor

- Bioreactor with a hydraulic retention time up to 10 days used to treat artificial AMD

- Reactive mixture composed of 60% organic materials (10% maple wood chips, 20% sawdust, 10% poultry manure and 20% leaf compost) and 40% inorganic materials.

Materials and Methods: Metal Speciation

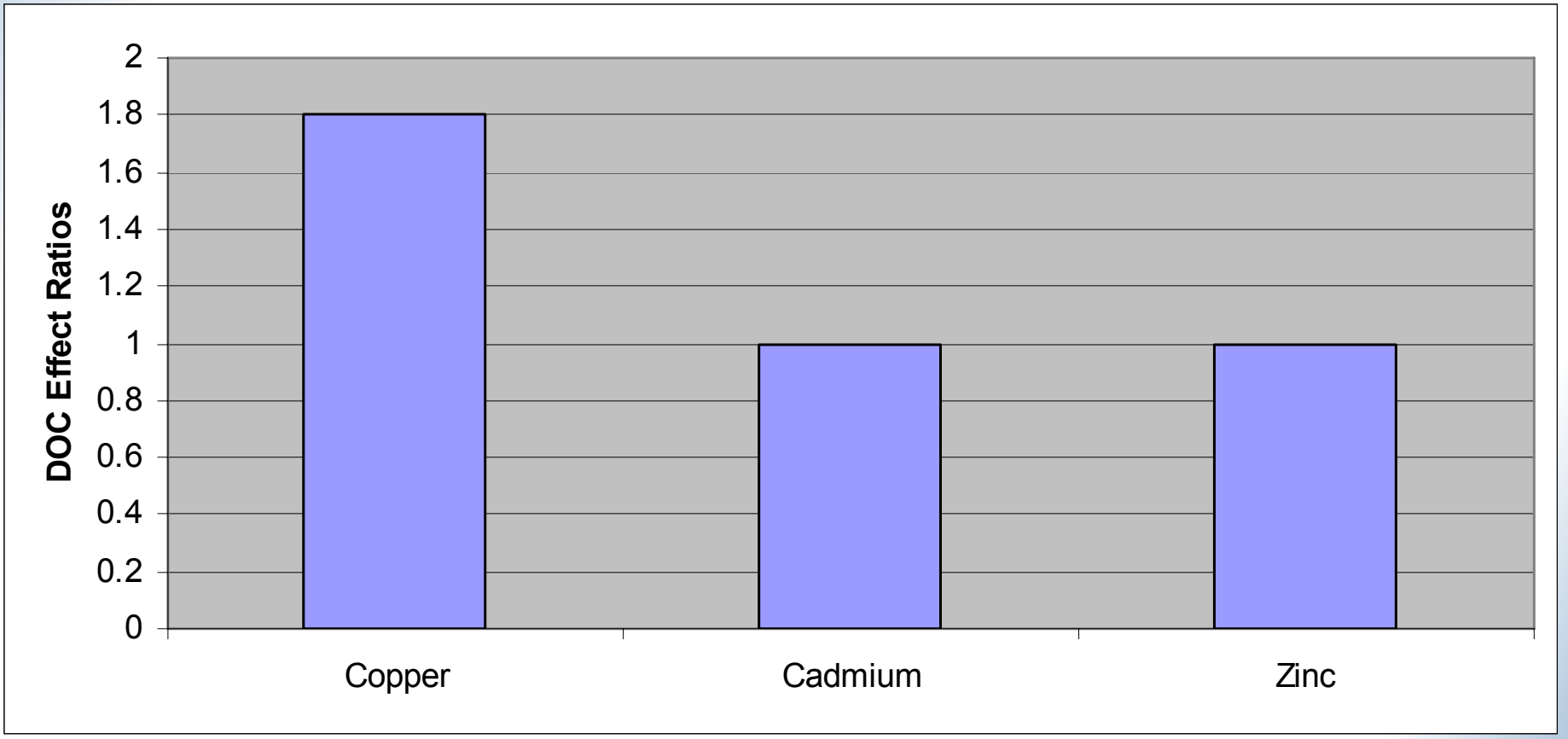
- Ultrafiltration used to determine truly dissolved metals
- Cadmium, nickel and zinc speciation estimated using WHAM VI (Tipping 1998)

Neculita, Vigneault and Zagury (2008) Env. Toxicol. Chem. 27(8): 1659-1667.

Passive Bioreactor: Metal Speciation

- Treated effluent had a pH of 6.2 and a DOC of 7 mg · L^{-1}
- The majority of cadmium and zinc was < 1 Kda
- Predicted fraction of metal bound to dissolved and particulate organic matter was only 0.2% for nickel and 0.4% for zinc and cadmium

Passive bioreactor: DOC Protective Effect



Conclusions

- **Shallow water cover: metal toxicity can potentially be reduced by 4 x to 25 x**

- **Biosolid covers: copper toxicity in limed effluent could be reduced by ~ 10 x as supported by the copper toxicity tests and copper speciation measurements**

- **Passive bioreactor: metal toxicity is not expected to be largely affected by the released organic matter**

Conclusions

- Expected organic matter releases are significant (~ 10^1 mg · L^{-1}) for the 3 tested methods

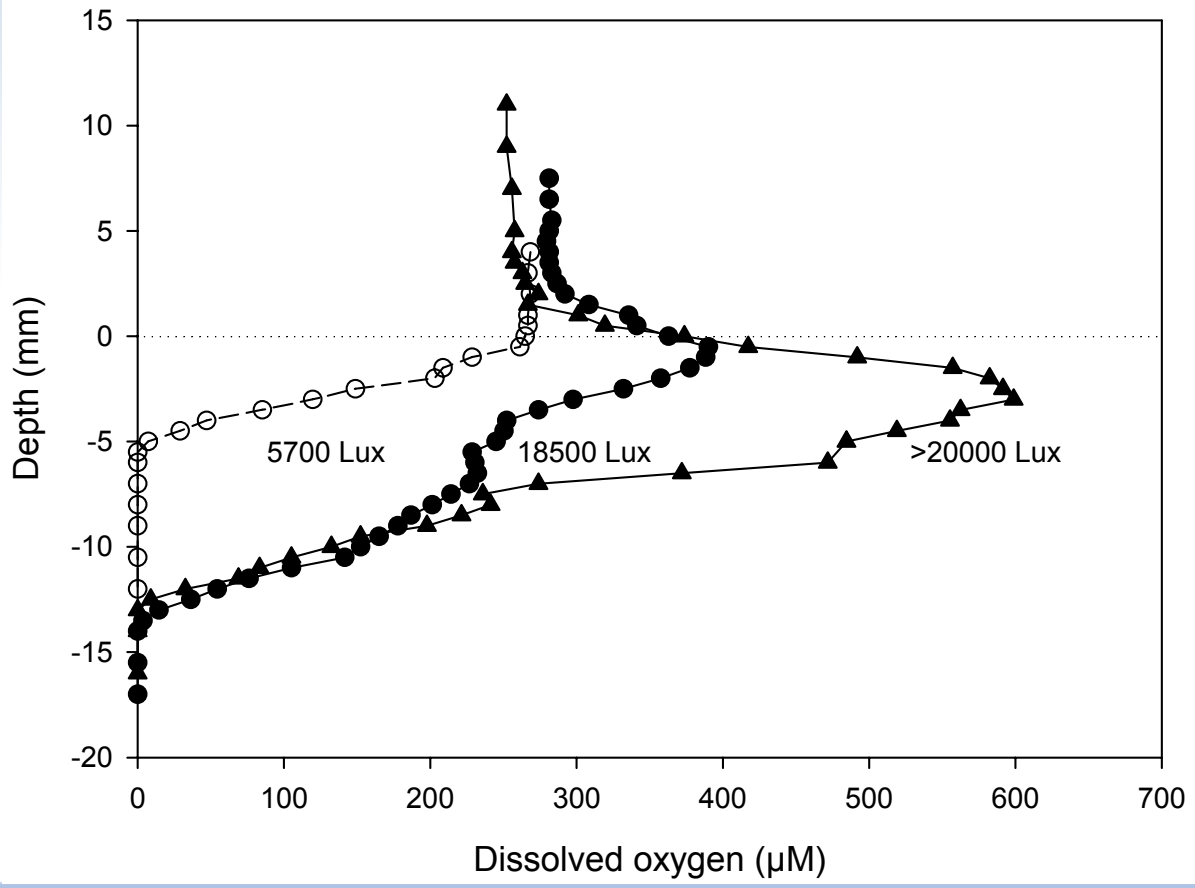
- Data suggest that the released organic matter can significantly affect metal toxicity and should be considered when using water quality guidelines to establish discharge objectives

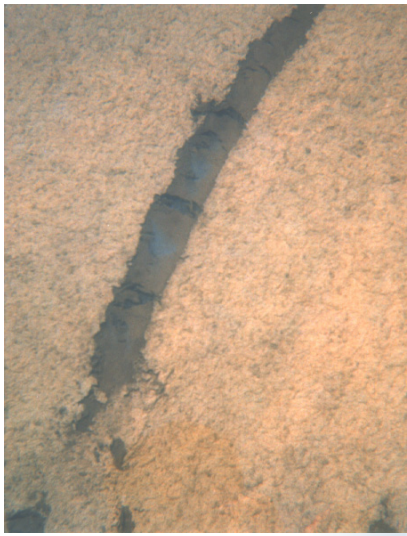
Acknowledgements

- Natural Resources Canada
- Vale Inco
- Teck Cominco
- INRS-ETE

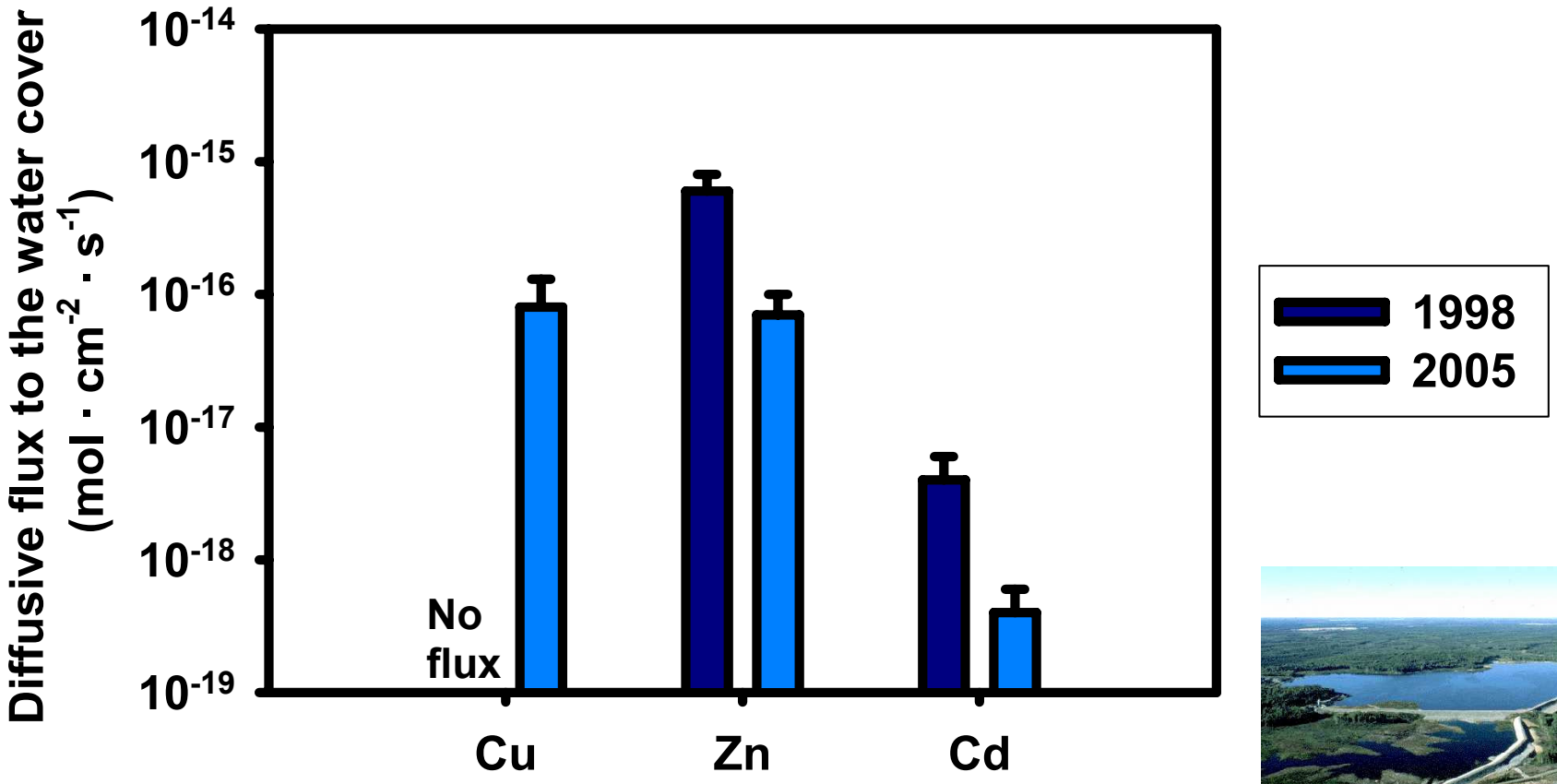

Thank You !

Water Cover: Oxygen micro-profiles





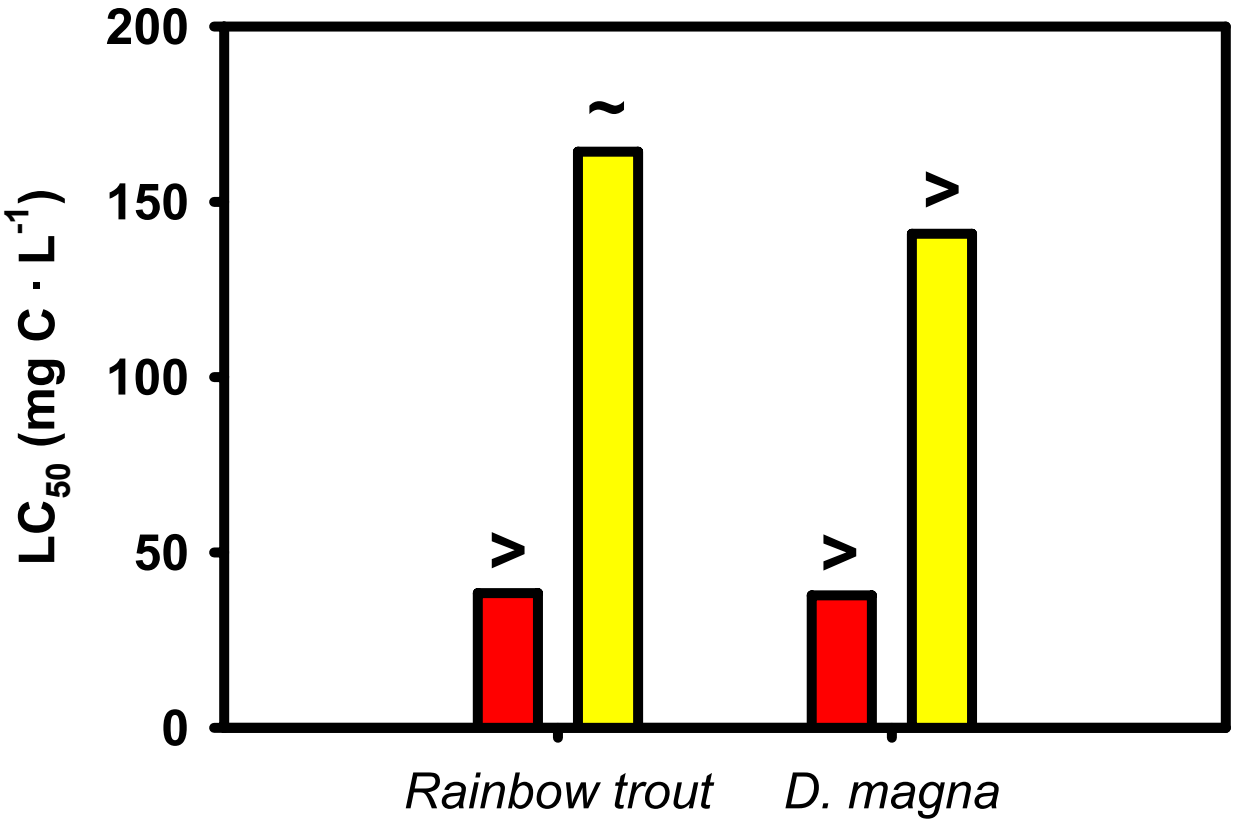
Water Cover: Trace metal fluxes



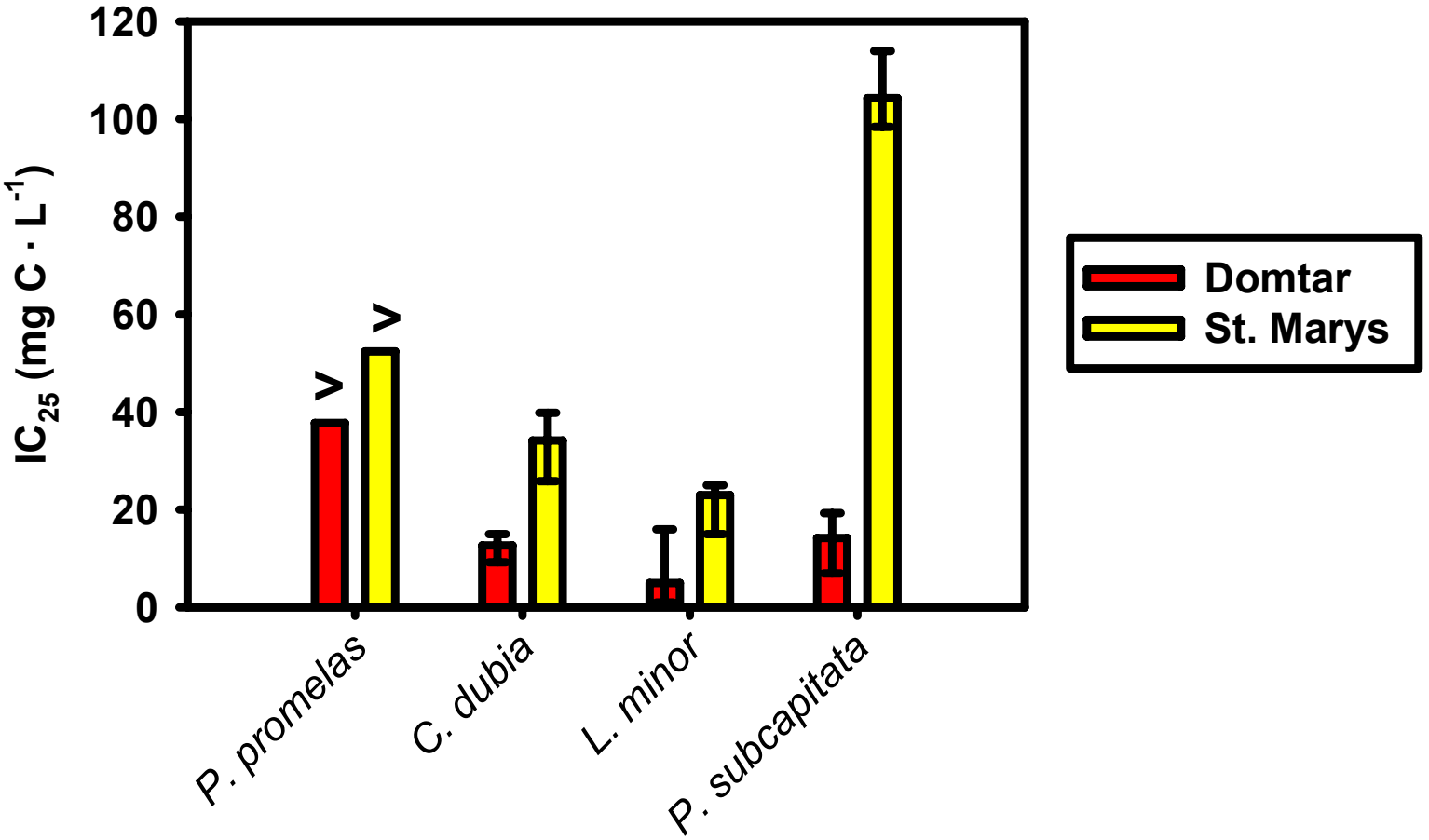
Materials and Methods: Toxicity Tests

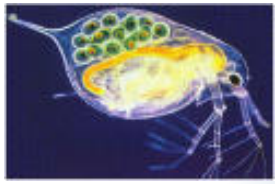
- **Canadian Metal Mining Effluent Regulations:**
  - **acute lethality to *Daphnia magna* and rainbow trout**
  - **sublethal toxicity to *Pseudokirchneriella subcapitata*, *Lemna minor*, *Ceriodaphnia dubia* and *Pimephales promelas***

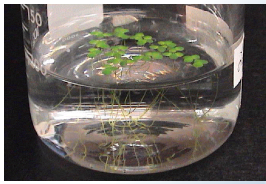
Biosolid Covers: Leachate Toxicity

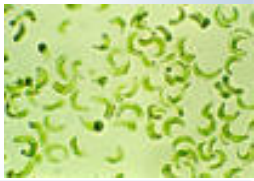


Biosolid Covers: Leachate Toxicity

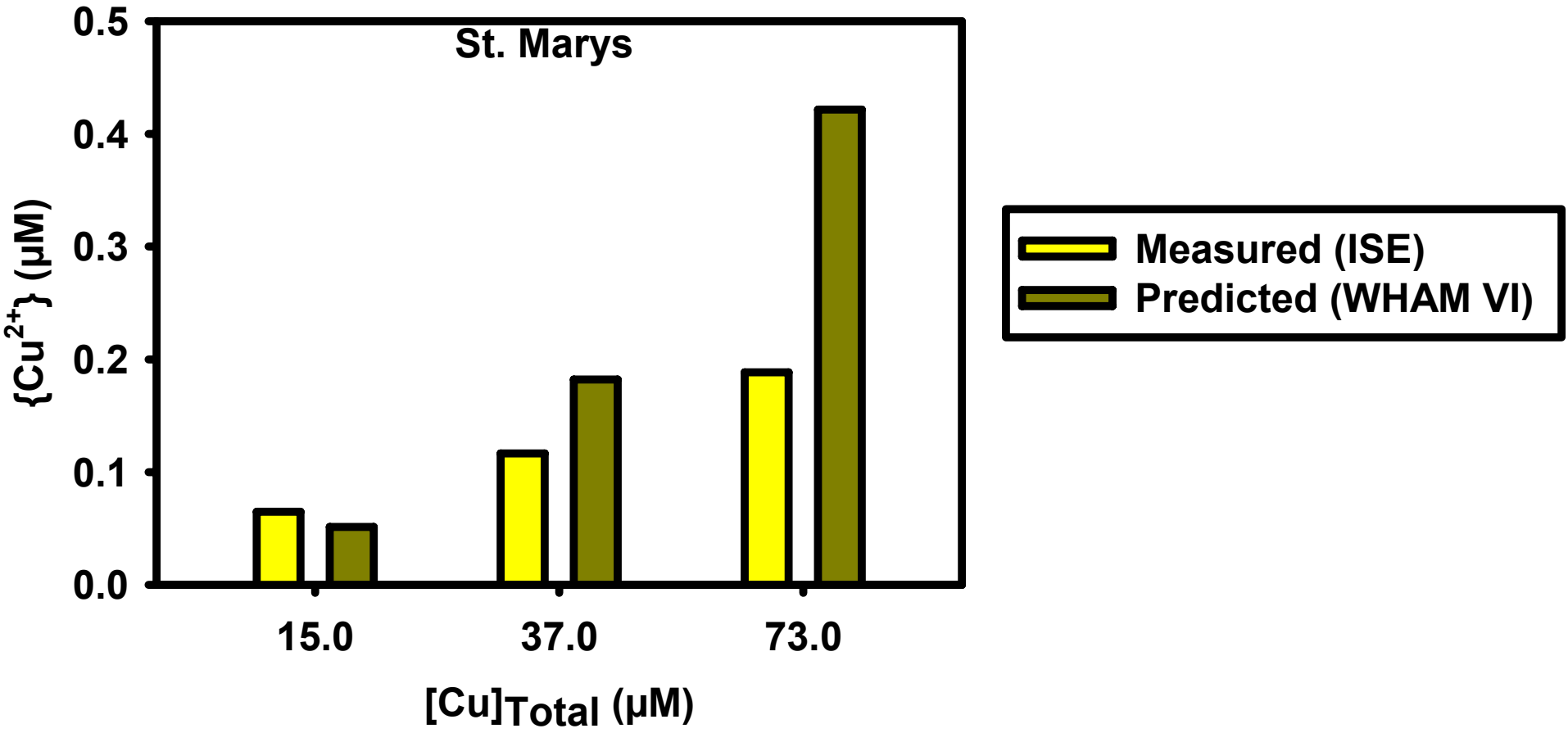








Biosolid Covers: Cu Complexation



Passive bioreactor: Truly Dissolved Metals