Geochemical study of sulfidic mine tailings stored under a shallow water cover

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Acid Mine Drainage

Pyrite Oxidation:

$\mathbf{FeS_2} + 7/2\ O_2 + \mathbf{H_2O} \longrightarrow Fe^{2+} + 2\ SO_4^{2-} + 2\ H^+$ (1)

$Fe^{2+} + 1/4\ O_2 + H^+ \rightarrow Fe^{3+} + 1/2\ H_2O$ (2)

$Fe^{3+} + 3\ H_2O \longrightarrow Fe(OH)_3(s) + 3H^+$ (3)

$FeS_2 + 7\ Fe_2(SO4)_3 + 8\ H_2O \longrightarrow 15\ FeSO_4 + \mathbf{8\ H_2SO_4}$ (4)

- Major pyrite oxidants: O_2 et Fe^{3+}
- Fe(II) $\longrightarrow$ Fe(III) (2), limiting step,
  catalysed by micro-organisms such as *Thiobacillus ferroxidans*

Acid mine drainage prevention:

Physical barrier such as a water cover

↳ **Underwater disposal**

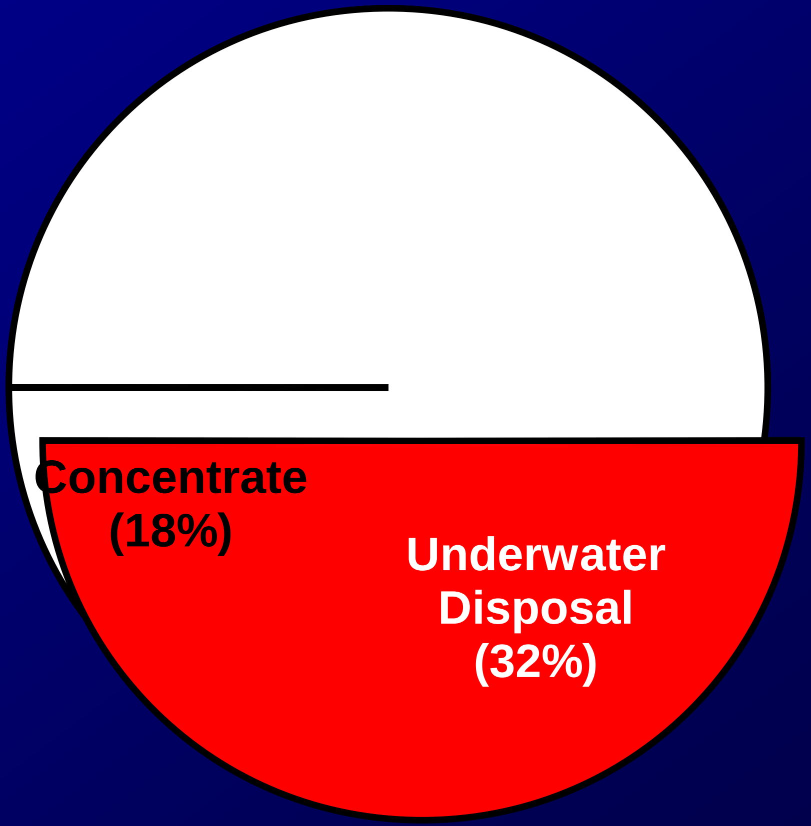
- reduced costs
- limited post-closure intervention required

Efficiency of an engineered shallow water cover ?

- **Erosion (resuspension, ice…)**
- **Periphyton**

Sampling Site

- **Located 20 km East of Val-D'Or (Québec)**
- **Base metals (Zn/Cu)**

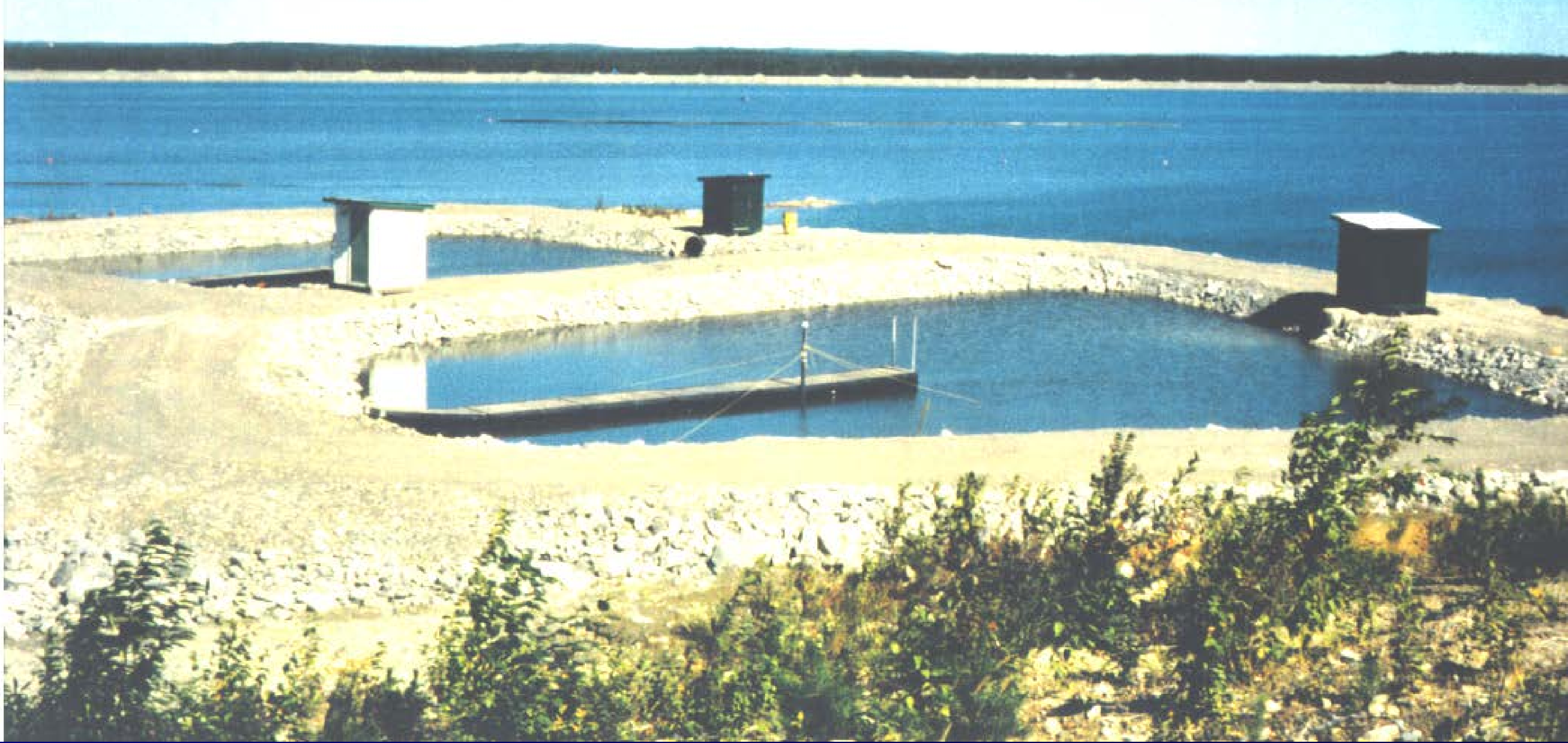


- **Reactive mine tailings (humidity cell tests)**

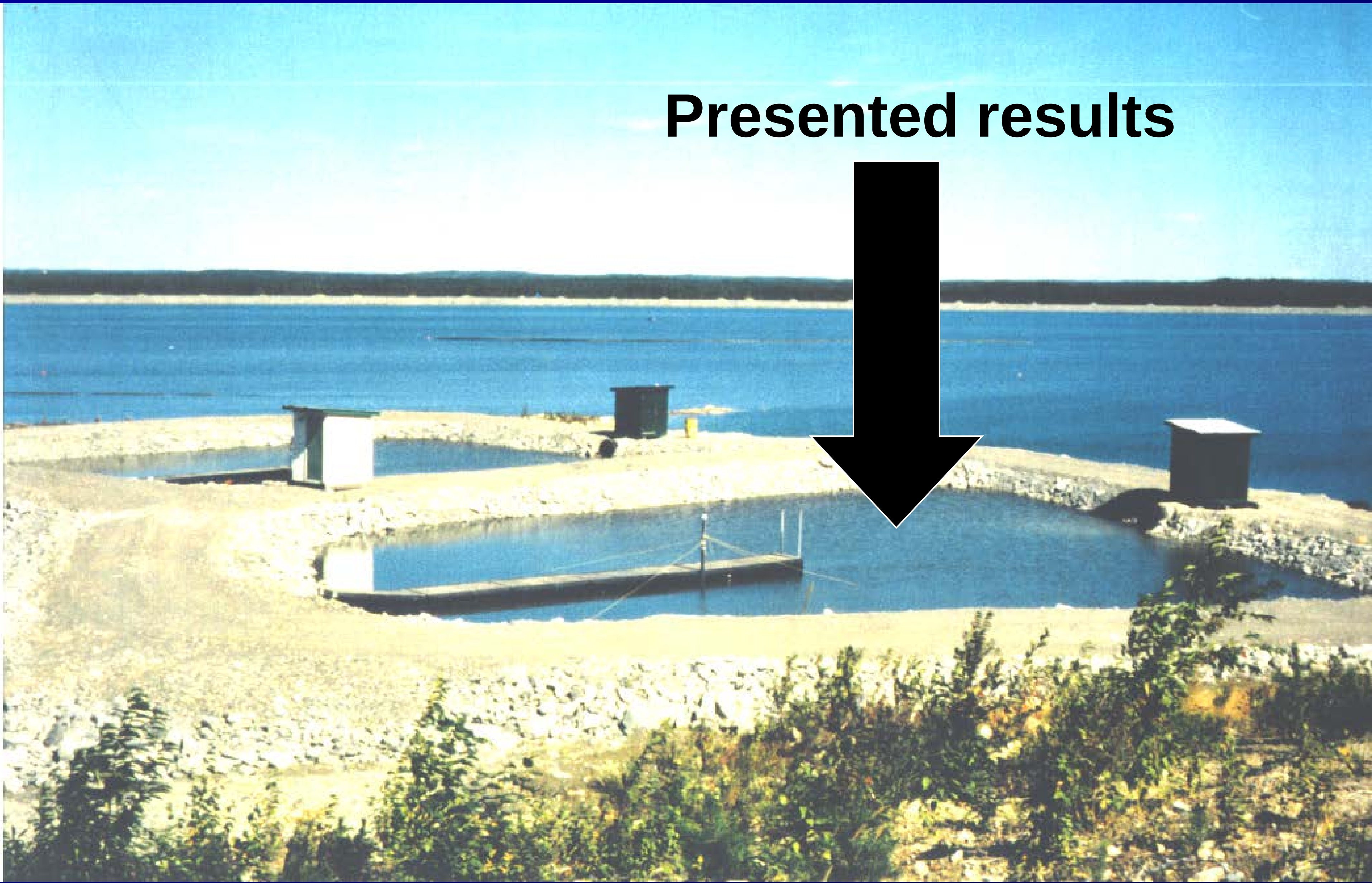
Sampling site

<u>Experimental cells (1996)</u>:

- **21 m x 21 m**
- **3 m of mine tailings**
- **0.3 m water cover**



Sampling site



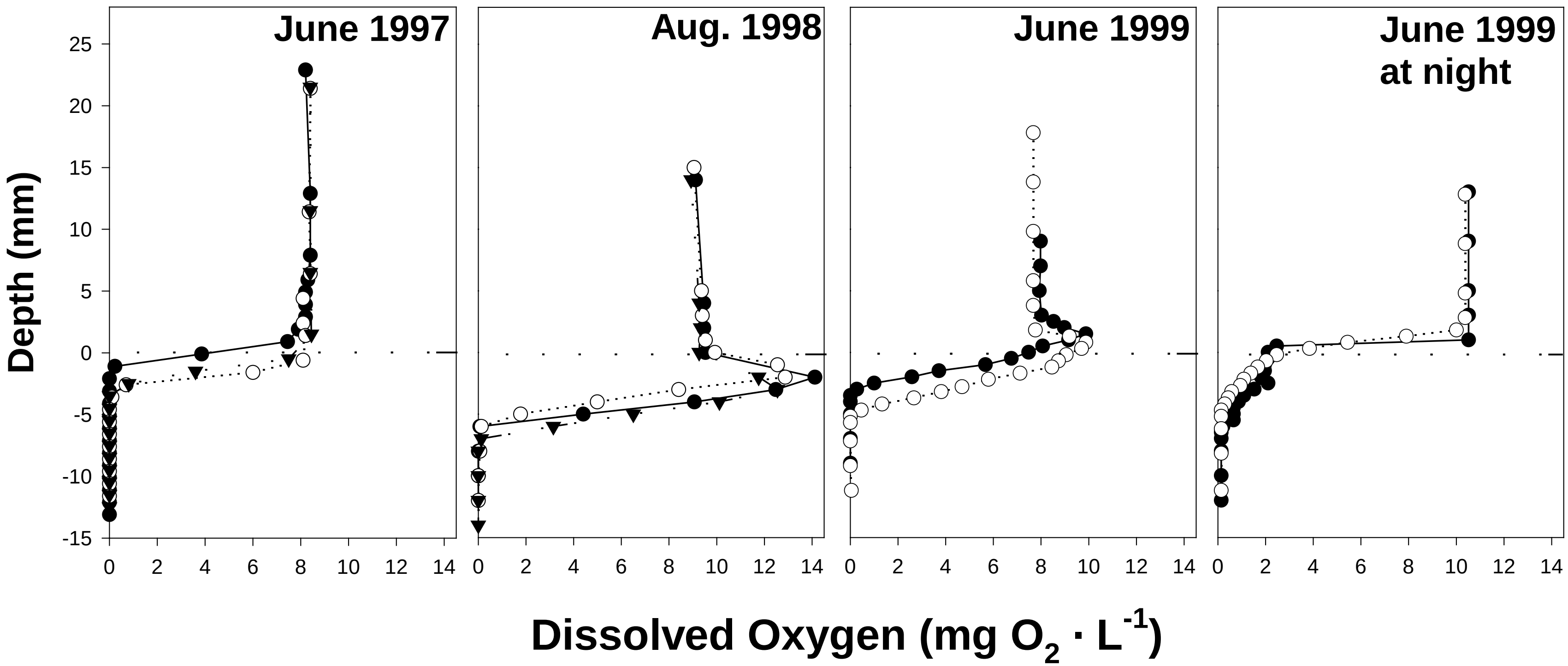
Micro-profiles

Electrochemical micro-profiles

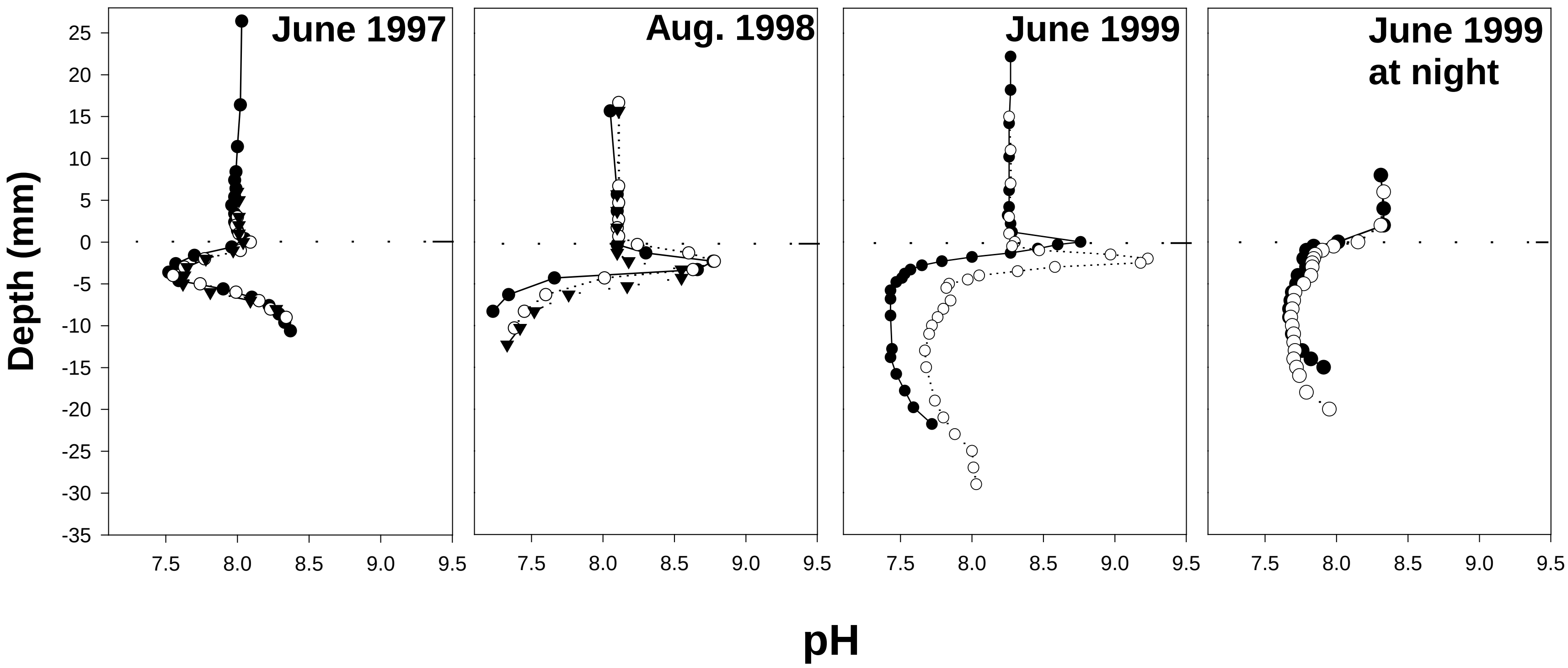
- pH et O_2
- Micromanipulator

1 mm vertical resolution

Micro-profiles, O_2

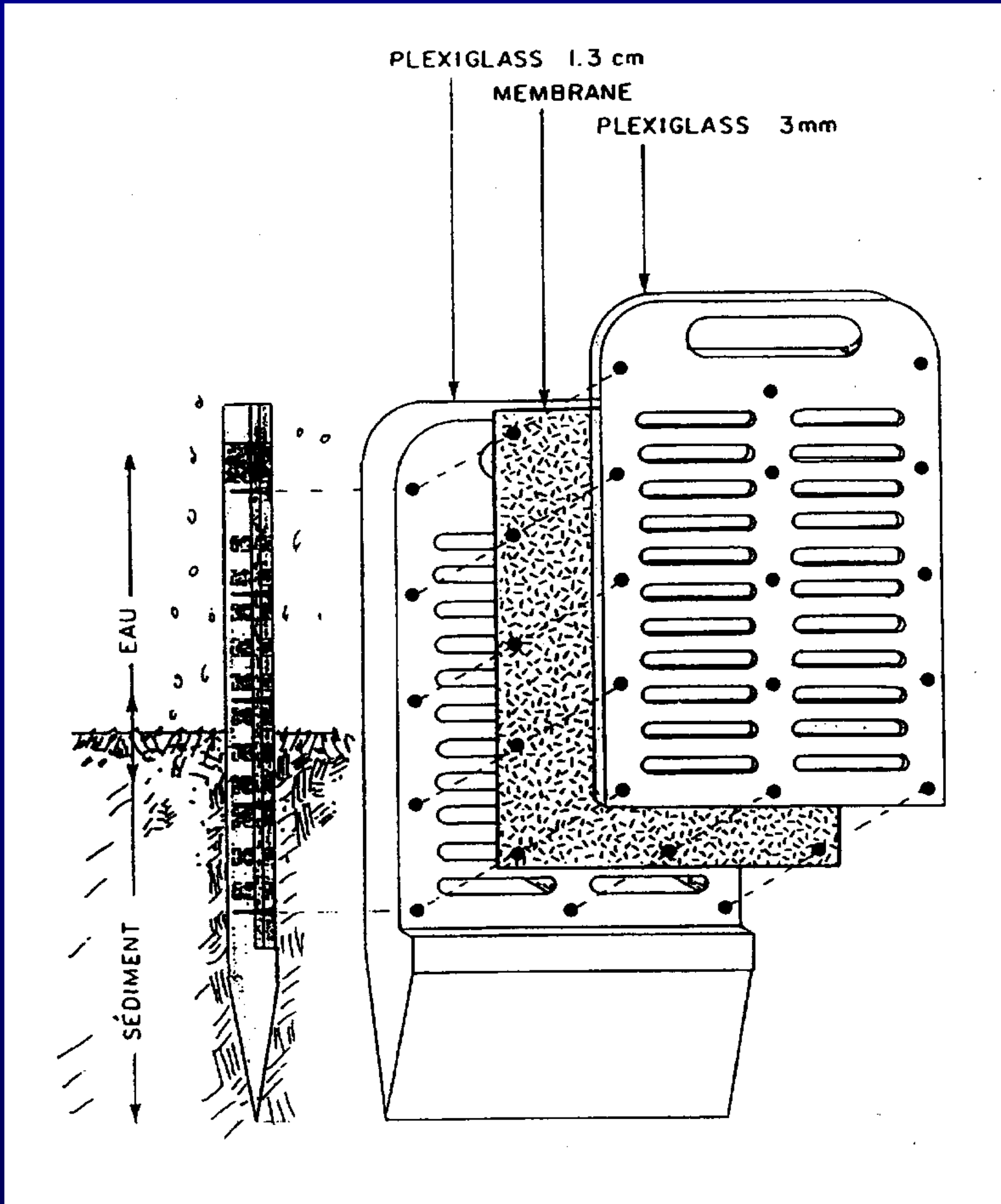


Micro-profiles, pH



Periphyton, oxic layer and anoxic layer

In situ dialysis



***In situ* dialysis**

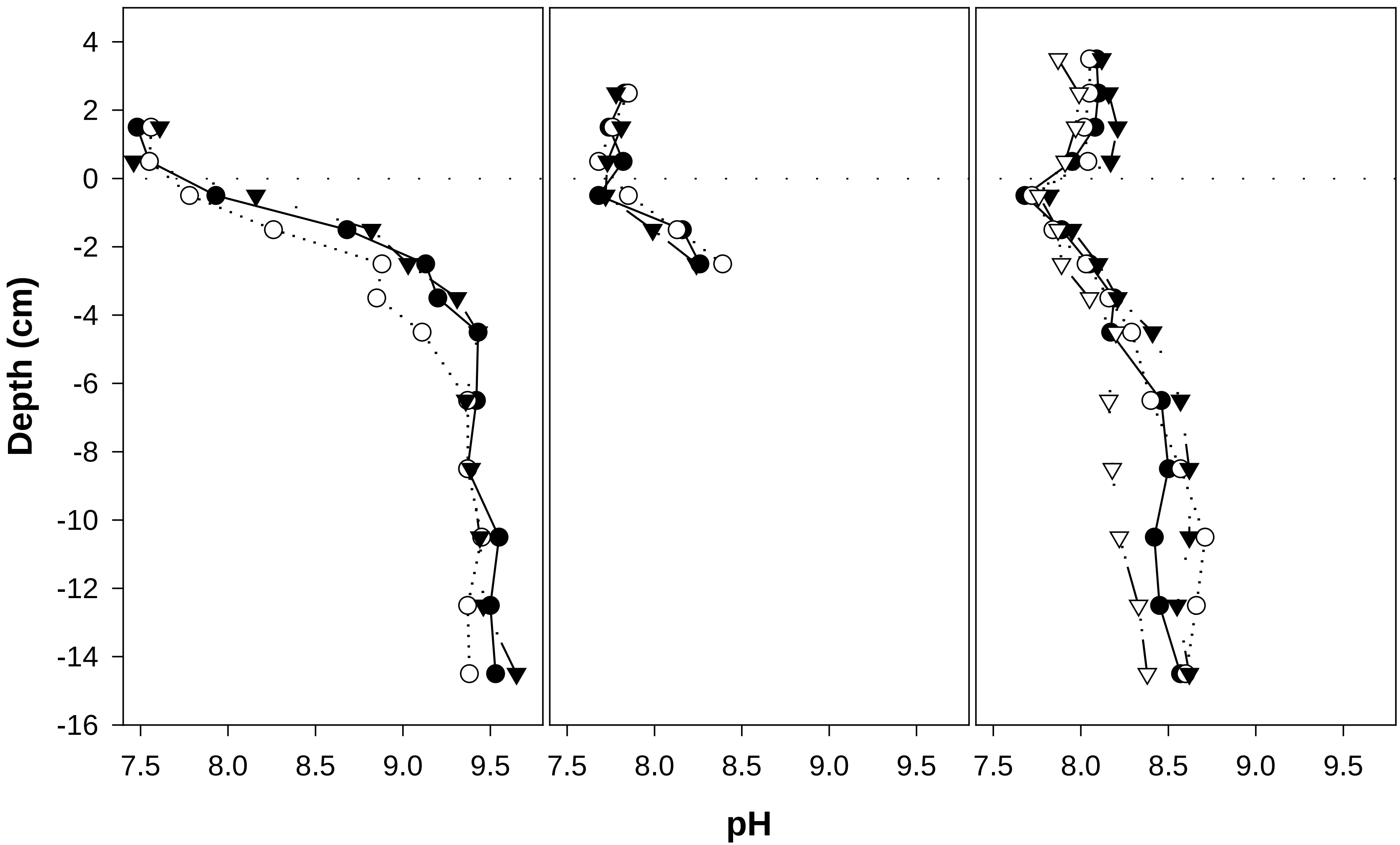
- Peepers

1 cm vertical resolution

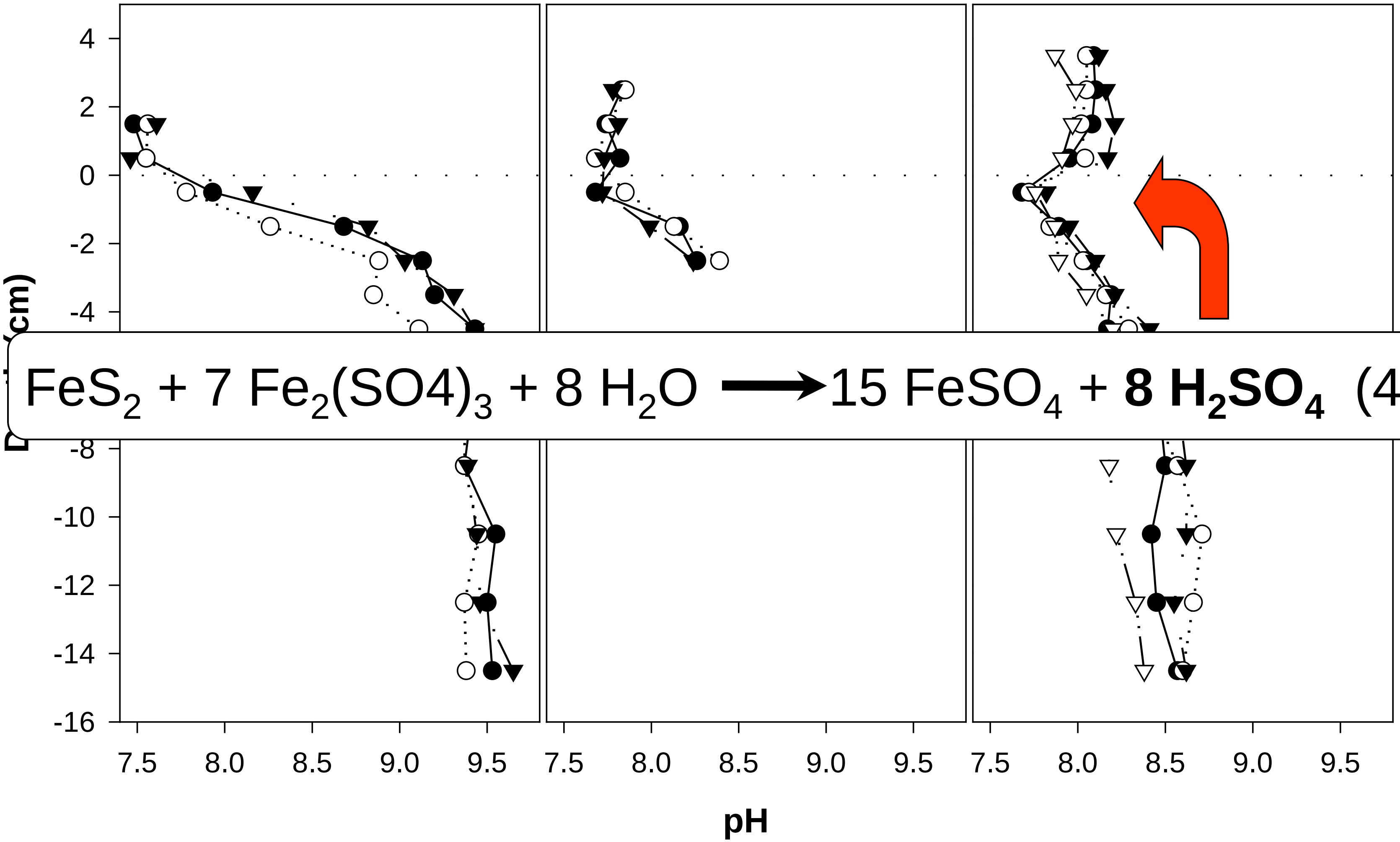
Interstitial water analysis:

- **pH**
- **[Cl^-] et [SO_4^{2-}]**
- **[ΣH_2S]**
- **[Cu], [Cd] et [Zn]**

In situ dialysis, pH

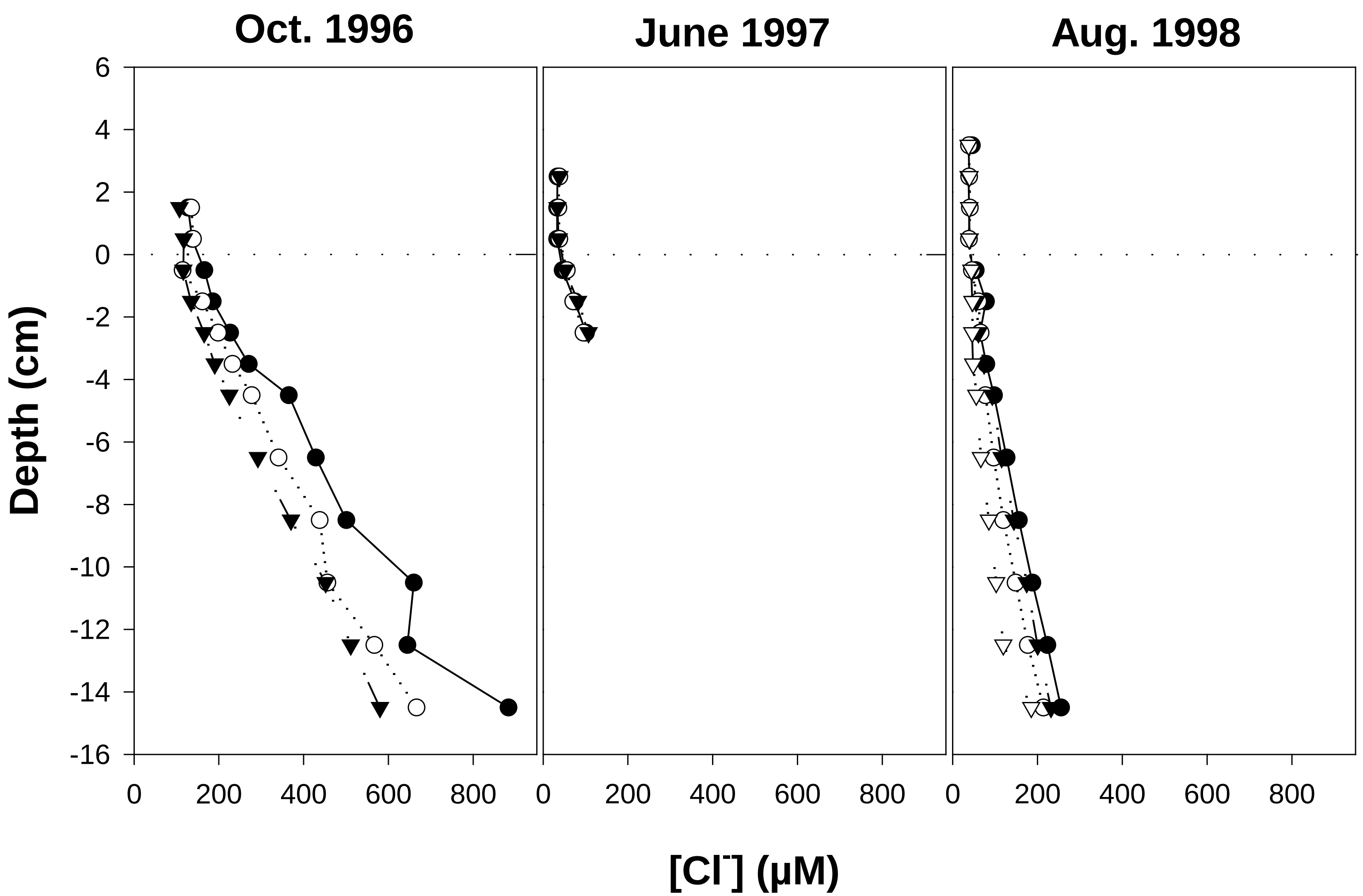


In situ dialysis, pH

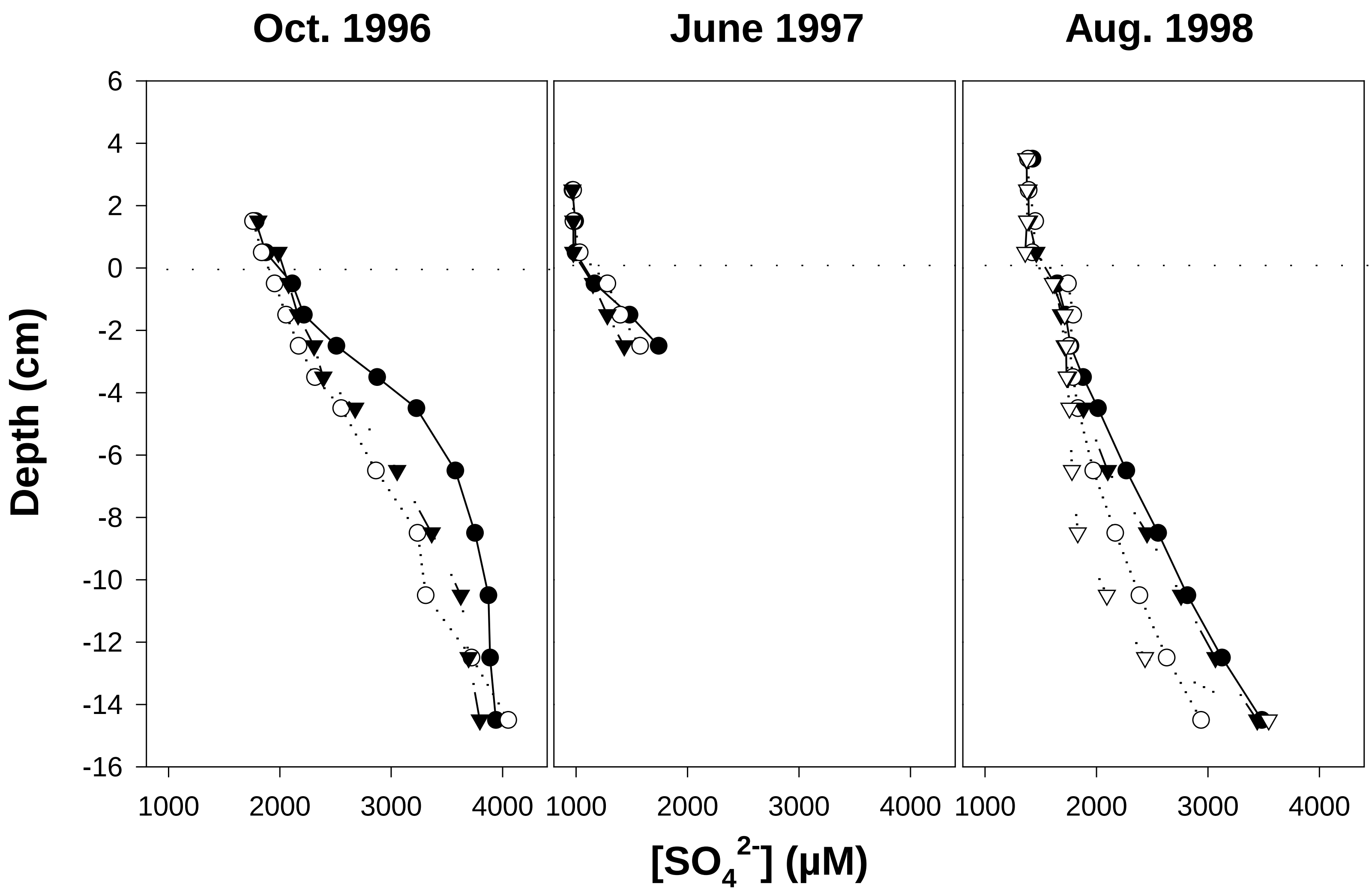


$$FeS_2 + 7\ Fe_2(SO4)_3 + 8\ H_2O \longrightarrow 15\ FeSO_4 + \mathbf{8\ H_2SO_4} \quad (4)$$

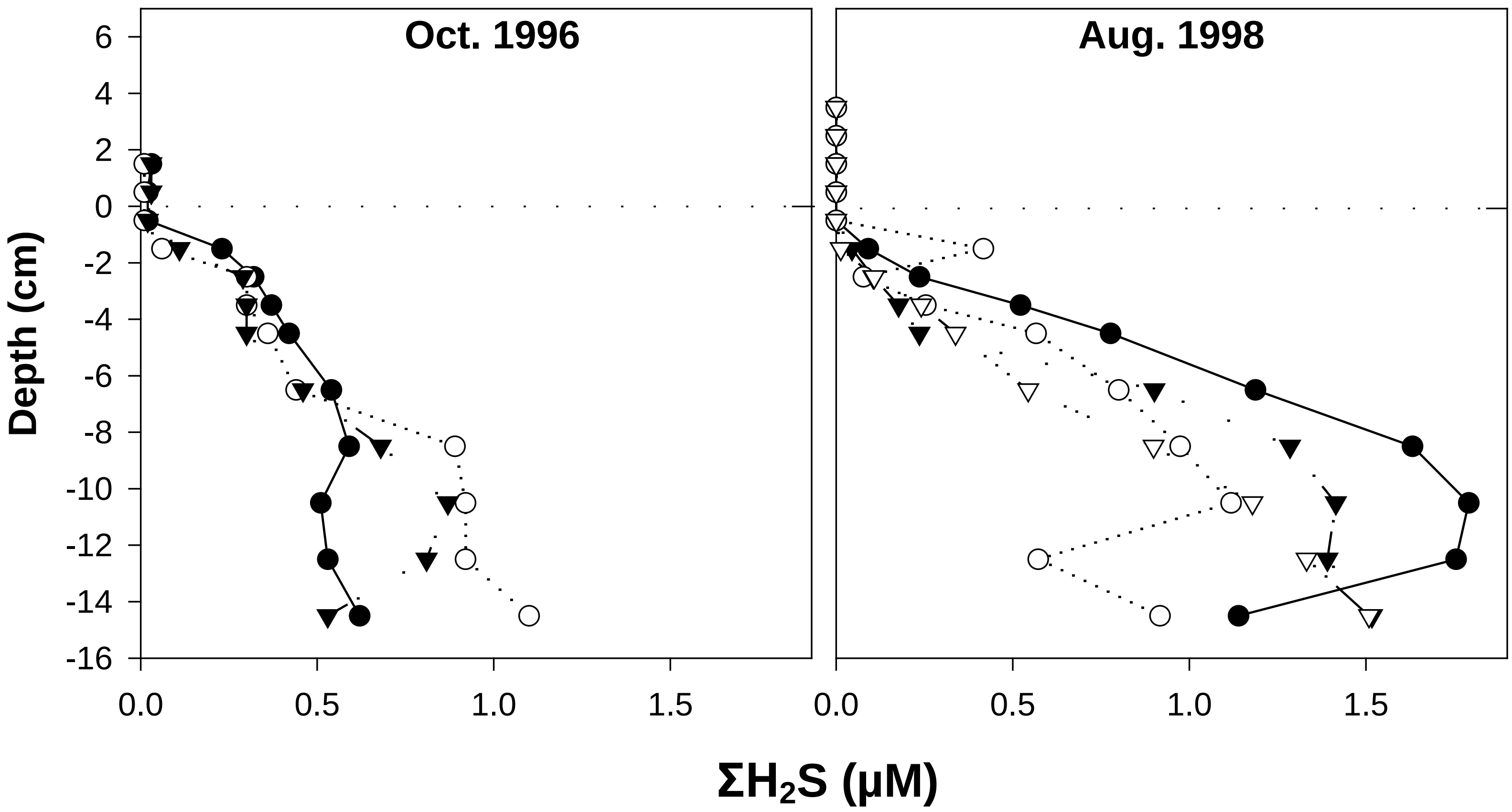
In situ dialysis, chloride



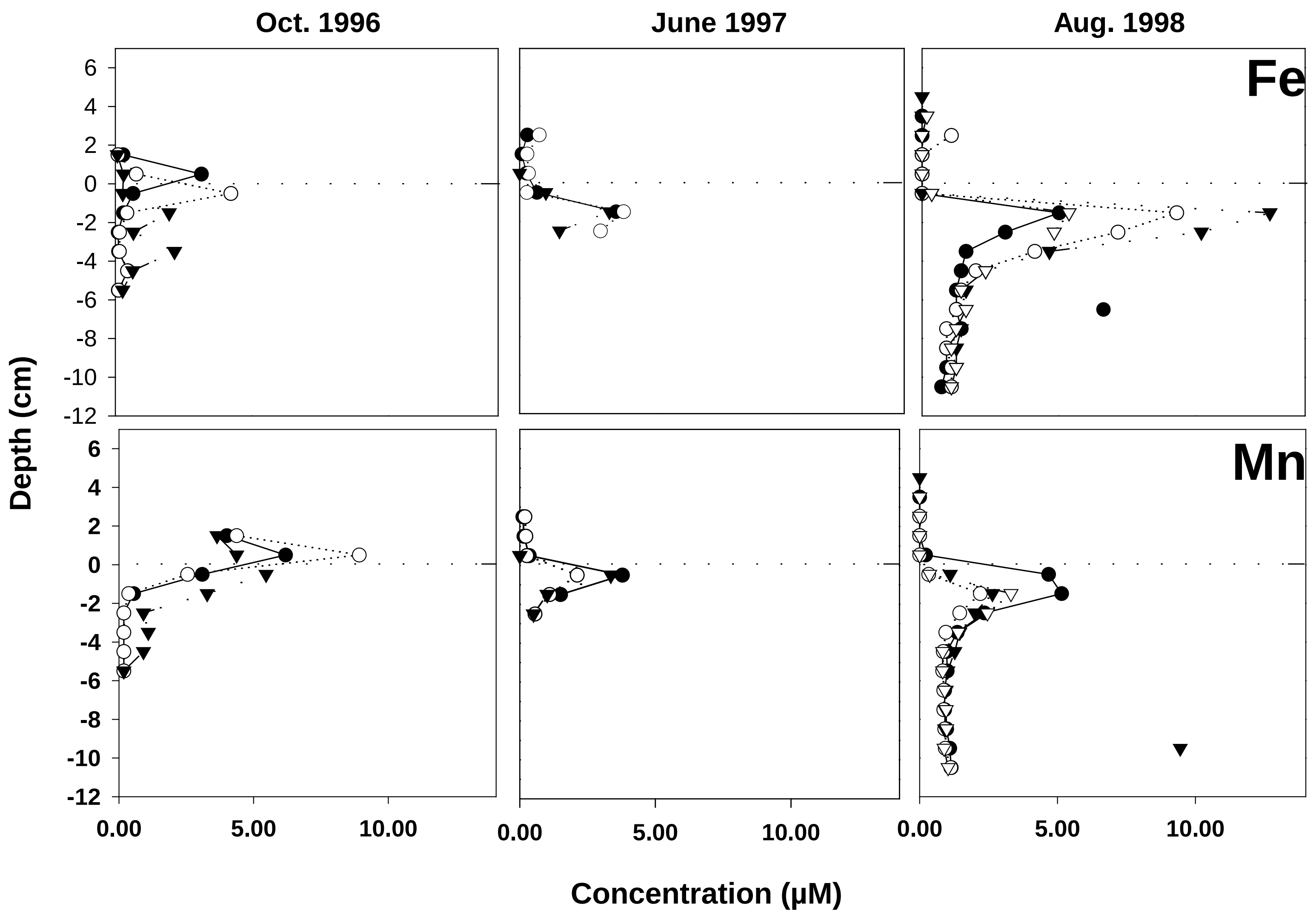
In situ dialysis, sulfate



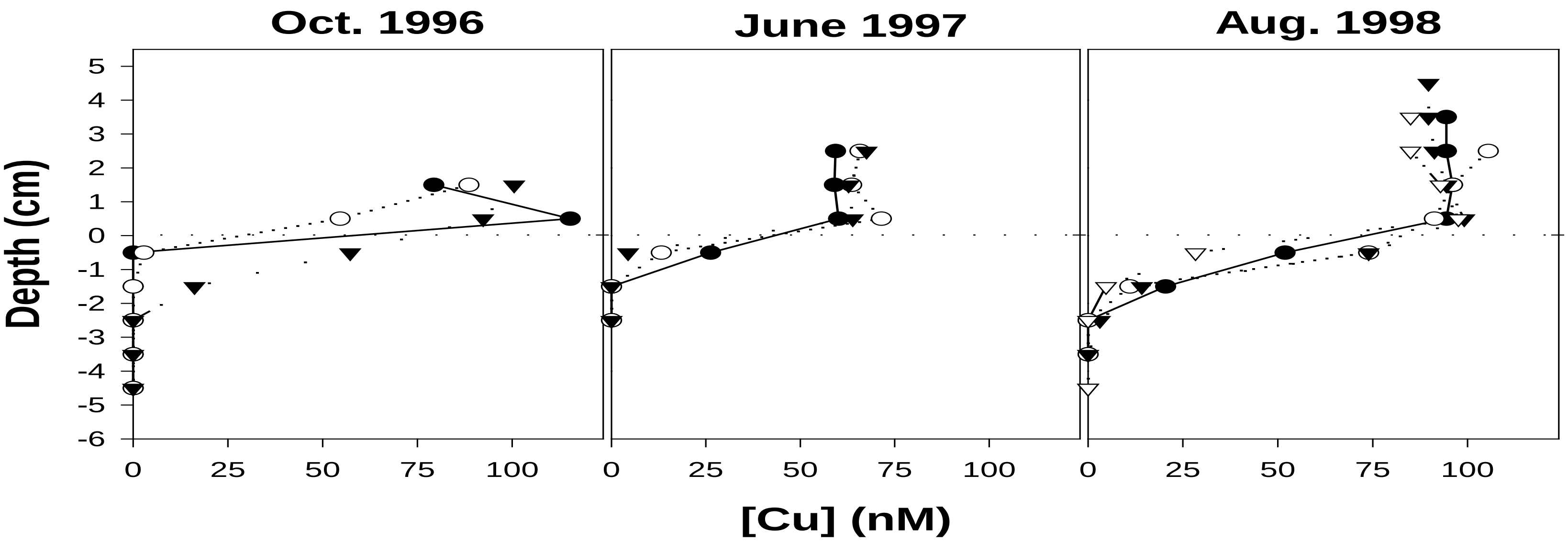
In situ dialysis, sulfide



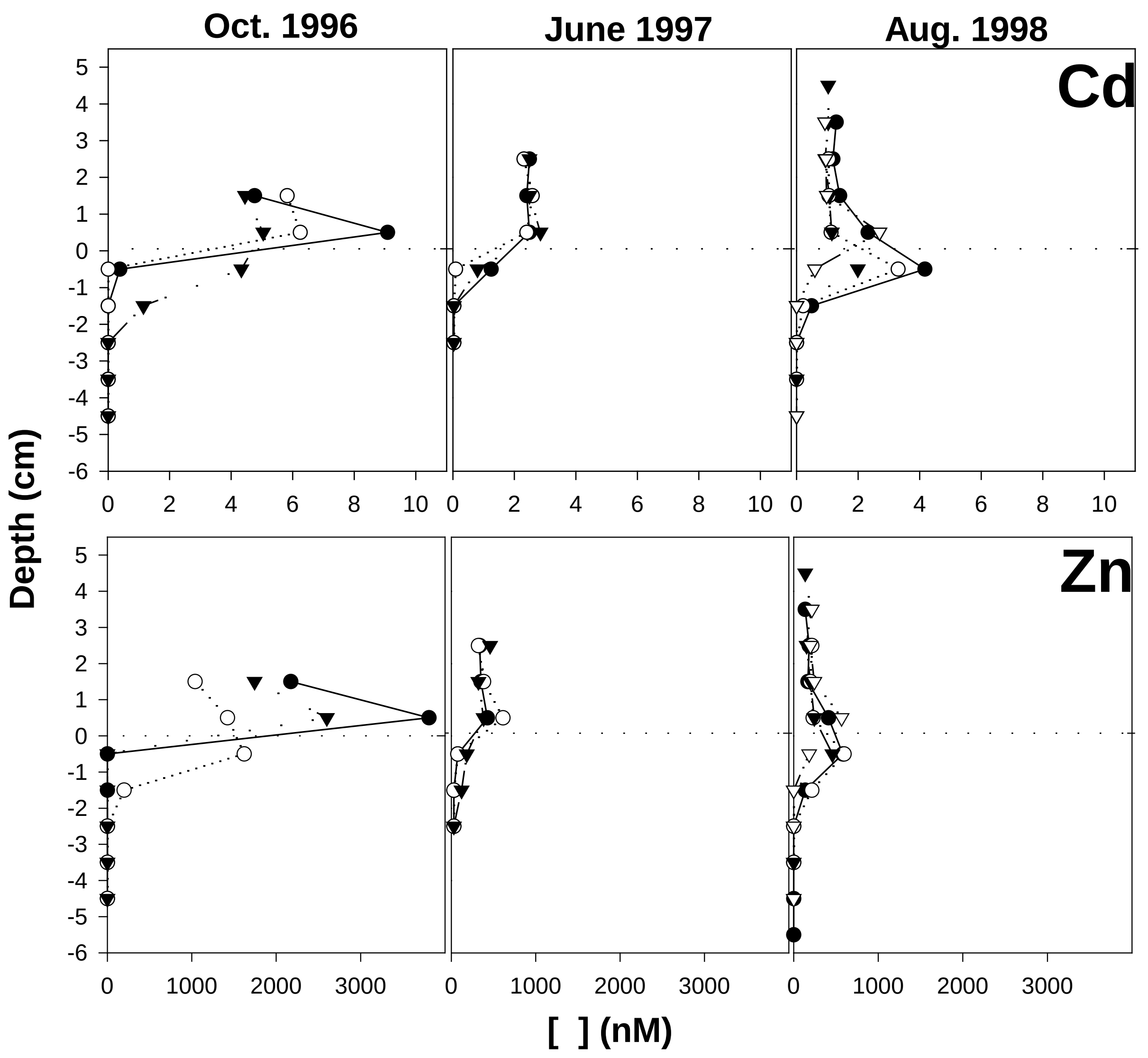
In situ dialysis, iron and manganese



In situ dialysis, copper



In situ dialysis, cadmium and zinc



Cadmium and zinc fluxes

Diffusion from the tailings to the overlying water

	Highest observed flux ($nmol \cdot cm^{-2} \cdot s^{-1}$)
Cd	1×10^{-9}
Zn	1.5×10^{-7}

What will be the impact on overlying water quality ?

Cadmium and zinc fluxes

For a hypothetical impoundment of 1.5 km^2, with a depth of 1 m and residence time of 1 year, Cd and Zn fluxes will have minor impacts on the overlying water quality:

	[ ] nM (ppb)	WQG† nM (ppb)
Cd	**0.3 (0.04)**	**0.44 (0.049)**
Zn	**47 (3)**	**460 (30)**

† **Canadian water quality guidelines for the protection of aquatic life (CCME, 1999)**

Solid phase analysis

Sequential extractions

- Core, surface layer extruded (0.5 cm)

Solid phase analysis

Sequential extractions

Consecutive metal extractions using:

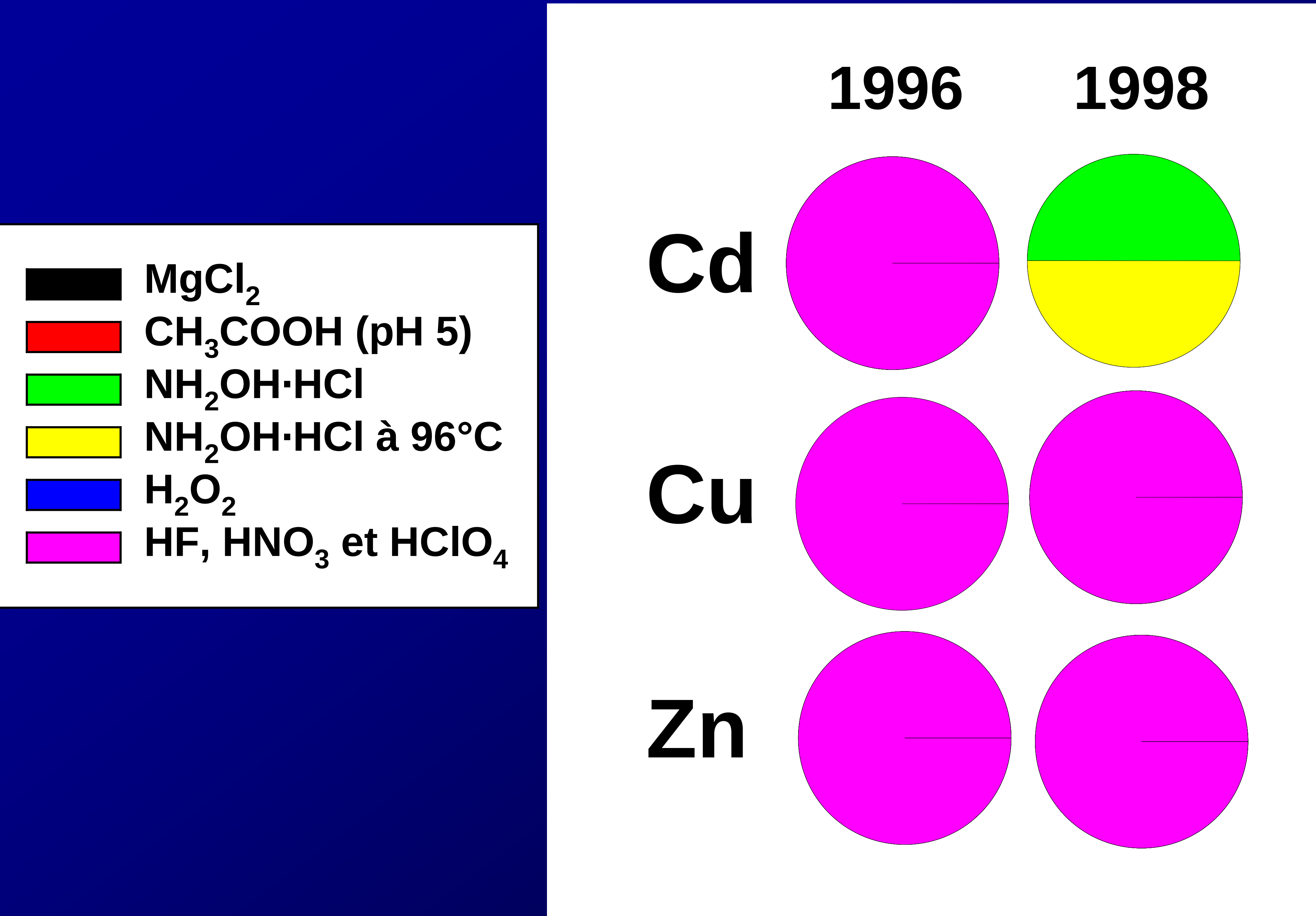
1. $MgCl_2$
2. CH_3COOH (pH 5)

3a. $NH_2OH \cdot HCl$

3b. $NH_2OH \cdot HCl$ à 96°C

4. H_20_2
5. HF, HNO_3 et $HClO_4$

Sequential extractions, distribution



Conclusion

A shallow water cover effectively reduces tailings oxidation:

- **Oxic layer < 10 mm and influenced by periphyton**
- **Oxygen comsumption reduced 2000 times compared to humidity cell tests**
- **No evidence of Cu mobilisation**

Conclusion

A limited oxidation of the tailings is observed at the mm scale beneath the tailings-overlying water interface:

- **peaks of [H^+] and [SO_4^{2-}]**

- **Weak diffusion of Cd and Zn to the overlying water having minor impacts on the water cover quality**

- **Displacement of Cd and Zn from refractory to more labile solid-phase fractions**

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Sequential extractions, total concentrations