

# NICKEL EFFECTS ON BENTHIC MACROINVERTEBRATE COMMUNITY COMPOSITION IN FIELD-CONTAMINATED SEDIMENTS

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## Background

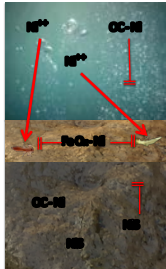


Figure 1: Bioavailable (arrow) and unavailable (line with bar) metal (Ni) at the sediment-water interface of a lotic ecosystem.

- Sediment geochemistry strongly influences adsorption and dissolution of metals in natural waters, which in turn affects bioavailability. The cycling and toxicity of Ni is coupled to other elemental cycles
- Metal partitioning in sediments has been primarily linked to sulfides (AVS) and organic carbon (OC) in anoxic sediments, and Fe and Mn oxides in oxic sediment.
- Current bioavailability and regulatory models generally only consider AVS and OC as solid-phase ligands that can modify the toxicity of metals in sediment.
- Oxic sediments can constitute an important factor influencing toxic metal availability and oxic ligands that can modify toxicity should be incorporated into risk assessment.

## Research Objective & Hypotheses

**Objective:** Assess Ni bioavailability in lotic sediments exposed to effluent from a Ni mine and evaluate Ni toxicity to indigenous benthic macroinvertebrate community.

### Hypothesis:

Lotic sediment will be less toxic to native invertebrate community than expected by current criteria thresholds due to the formation of an oxic layer rich in FeO<sub>x</sub> and MnO<sub>x</sub> that will bind Ni<sup>2+</sup> and render it unavailable for uptake by biota (Fig. 1).

## Sample Site & Data Collection

**Study Areas:** Thompson and Birchtree Mines, Manitoba, Canada

### Invertebrate Samples:

- Petite ponar grabs
- Sediment Geochemistry:
  - Intact sediment cores:
    - ↳ Paired with invertebrate samples
    - ↳ Subdivided into surface ("oxic layer", 2cm) and deep ("anoxic layer", 2cm) samples

### Water Chemistry:

- Filtered and unfiltered surface water samples



## Data Analysis

### Invertebrate Samples:

- Individuals sorted and identified to family

### Sediment Geochemistry:

- Sediment digestion (total metals)
- Acid-volatile sulfide (AVS) and simultaneously extracted metal (SEM)
- Selective extractions of metal oxides
- Elemental analyzer (organic C)
- ICP-OES

### Water Chemistry:

- Physicochemical properties assessed *in situ*:
  - ↳ pH, temperature, conductivity
- Laboratory analysis:
  - ↳ ICP-MS (water column Ni<sup>2+</sup>), ion chromatography (sulfate)

Table 1: Geochemical characteristics of Weir and Birchtree's surface sediments.

Sediment	AVS (μmol/g)	Total C (%)	Oxidized Fe (mg/kg)
Birchtree	0.67	4.5	11.18
Weir	0.79	5.22	96.15

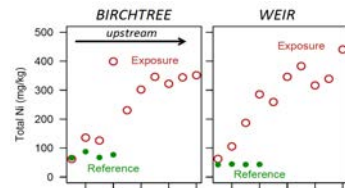


Figure 2: Scatterplot of total sediment Ni concentration in reference and exposure sites of the Birchtree and Weir mines sites.

## Results

### Sediment Geochemistry

- Sediment Ni in effluent-exposed sites ranged from 75-450 mg/kg (Fig. 2) with up to 90% associated with metal oxides (Fig. 5).
- Exposure tributaries received a significant input of SO<sub>4</sub><sup>2-</sup> from mine effluent, which elevated AVS in exposure sites.
- Roughly 80% less AVS (Fig. 3) and 38% more Fe oxides in surface sediments (Fig. 4).
- Different tributaries were geochemically similar (Table 1), but Weir had 9x greater Fe-oxides concentrations in sediment and sorbed more nickel (Fig. 4).

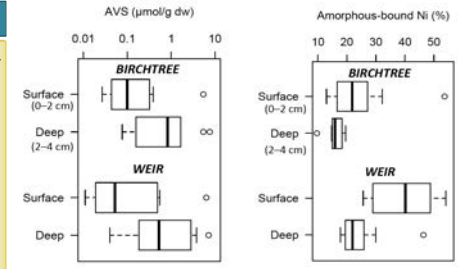


Figure 3: AVS concentration in μmol/g of dry weight in surface and deep sediment samples from Birchtree and Weir mine sites

Figure 4: Proportion of nickel bound to amorphous oxides in surface and deep sediment samples from Birchtree and Weir mine sites

### Invertebrate Community

- Mayflies responded to sediment Ni:
  - ↳ Relative abundance declined with increased nickel concentration in surface and deep sediments of exposed tributaries (Fig. 6).
- Weir site sediments had higher EC10 than Birchtree (Table 2), which indicates the role of Fe-oxides in complexing Ni and limiting its toxicity.
- SEM-AVS bioavailability model could not adequately explain variation in EC10.
- PCA explains ~43% of variation in the community, and the first two principal components are related to sediment and water chemistry (Fig. 7, Table 3).

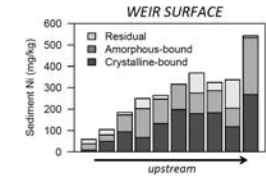


Figure 5: Proportion of sediment nickel bound to different oxides in surface sediment samples from Weir mine site. Upstream sites are closer to the mine effluent.

Table 2: Effective concentrations (EC10) computed for Total Nickel (mg/kg) and SEM-AVS (μmol/g) in deep sediments.

Sediment	Total Ni EC10 (mg/kg)	SEM-AVS EC10 (μmol/g)
Birchtree	121	1.0
Weir	248	3.3

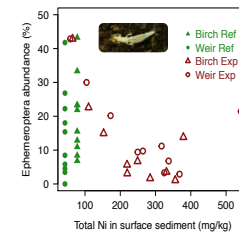


Figure 6: Scatterplots of Ephemeroptera relative abundance and Total Ni (mg/kg) in surface sediments.

Table 3: Model results relating principal components extracted from PCA to sediment and water chemistry.

Axis	Variables	Coefficient
PC1	Conductivity	(-)
	SO <sub>4</sub> <sup>2-</sup>	(+)
	SEM-Fe surface	(-)
	AVS surface	(-)
PC2	Total Ni surface	(+)
	Ni bound to amorphous FeO <sub>x</sub>	(-)

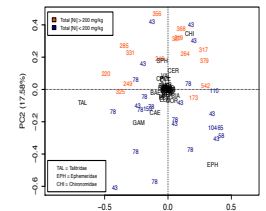


Figure 7: Principal components analysis of Hellinger-transformed community data. 3-letter codes are benthic invertebrate families, and numbers reference to total nickel concentration in surface sediments.

## Conclusions

- Higher EC10 on Fe oxide-rich sediment indicates the role of this ligand in trapping metals and rendering them unavailable for uptake by biota.
- Principal components analysis suggests sediment nickel explains some of the variation in the community shift towards more resistant taxa at higher metal concentrations.
- Field-contaminated sediments were similar to laboratory spiked sediments that have been aged for extended periods of time (>30 days), which suggests a need to appropriately prepare sediments for laboratory toxicity tests used for metal risk assessment.

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