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Development of a prediction method for contaminated neutral drainage: Case of Lac Tio, Québec

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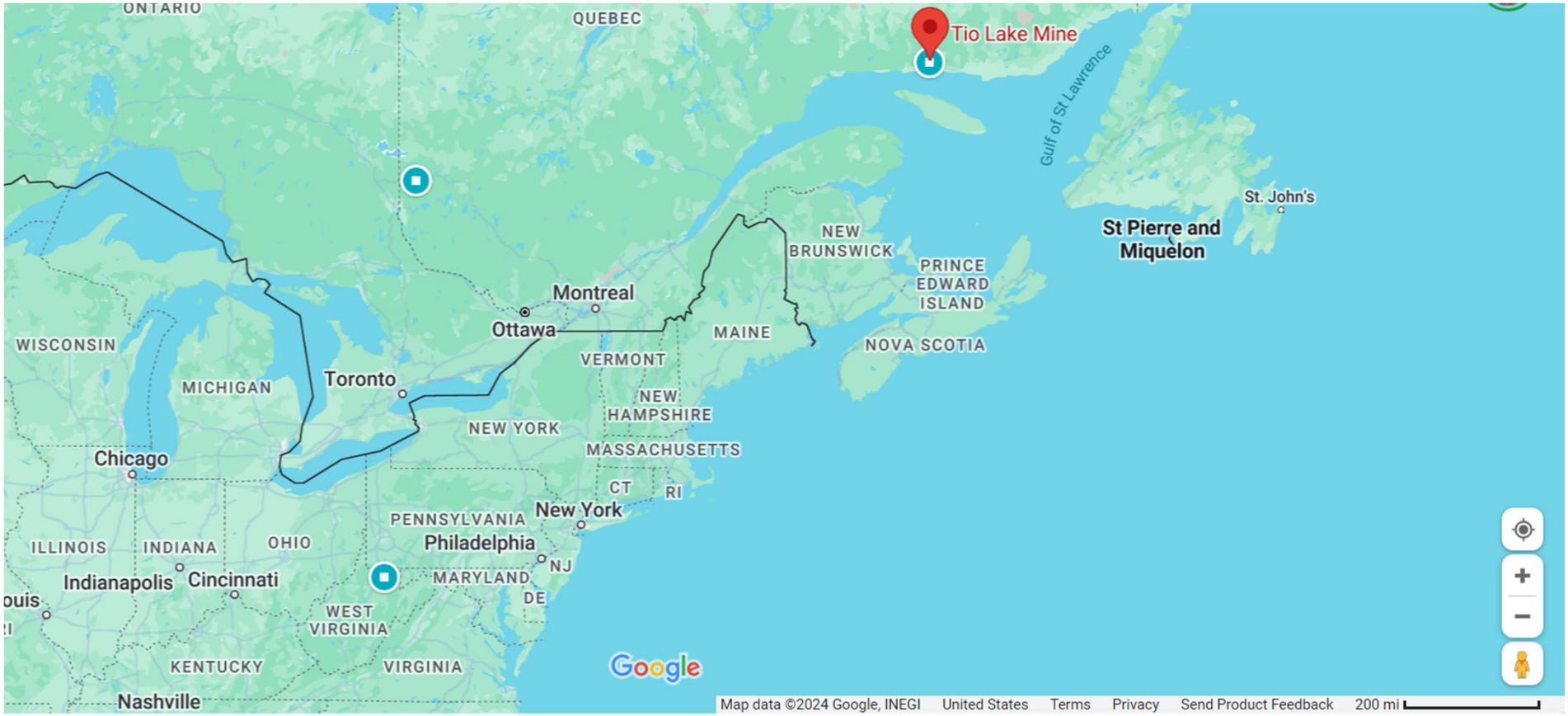
Supervision by Benoît Plante, Isabelle Demers and Mostafa Benzaazoua

Presentation outline

- **Introduction**
- **Methods:**
  - **Initial characterization**
  - **Column experiment**
  - **Use of EDTA**
  - **Batch Sorption tests**
- **Results and interpretations**
- **Conclusions and research perspective**

Introduction (1)



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Introduction (2)

Lac Tio Mine → Largest massive Ilmenite deposit in the world

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Introduction (2)

Acid Mine Drainage =

Sulfide oxidation > Neutralization

(**Acidity** + Metals + Sulfate)

Contaminated Neutral Drainage (Neutral Mine Drainage):

Sulfide oxidation < Neutralization

(Acidity + **Metals** + Sulfate)

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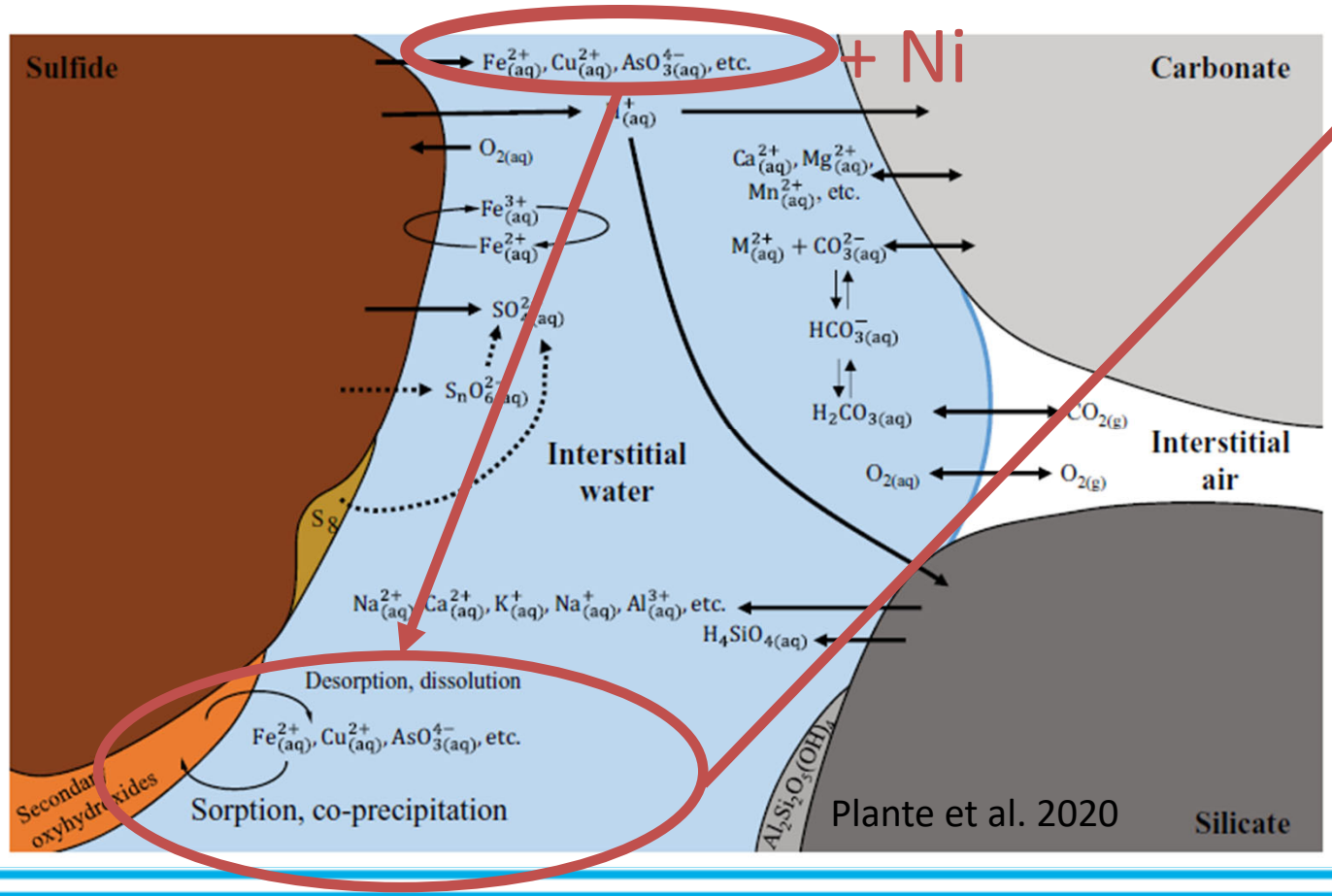
Introduction (3)



Sorption + Precipitation

↓

Immobilization Processes

→∞?

How much time until leaching?

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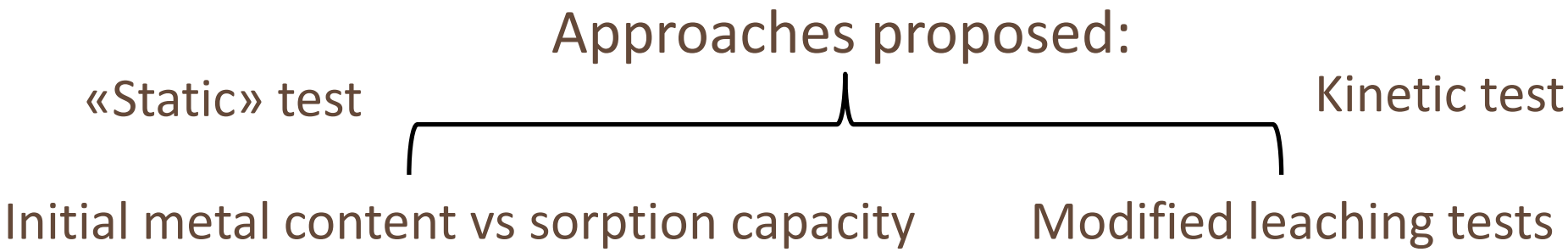
Why use Lac Tio waste rocks?

- Waste rocks from Lac Tio are known for Ni-CND after a few decades of surface storage conditions (caused by sorption mechanisms) (e.g., Pepin, 2009; Plante et al., 2010, 2015, Poaty et al., 2021)
- Mine still operating → “fresh” waste rocks available
- They were the ideal material as “positive control” for CND risk assessment

Why predict CND and how?

- In some case (like Lac Tio mine), classical kinetic tests with deionized water cannot adequately predict CND
  - Consequence: Waste rocks leaches metals after multiple years when sorption sites are saturated



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Method Outlook

Metal concentrations assessment:
4-Acid Digestion + ICP

↓

Deportment of metals:
SEM

Are these metals leachable?

Leachability and rate of metal release:
EDTA leaching

Are the metals readily released?

Capacity of the material to retain the metals:
Sorption experiments

If [Metals] > Sorption capacity
→ High* possibility of CND

If [Metals] = Sorption capacity
→ Moderate* possibility of CND

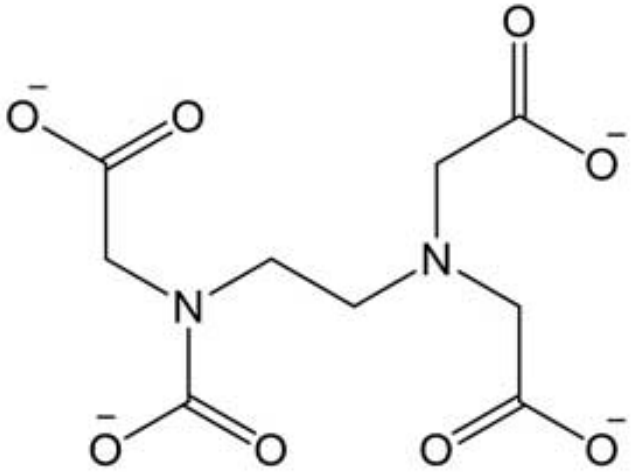
If [Metals] << Sorption capacity
→ Low* possibility of CND

*Thresholds to be determined and interpreted on a case-to-case basis

Initial Characterizations + Microscopy

- Initial Characterizations
  - 4-acid Digestion + ICP-MS
  - Acid Base Accounting AP-NP (potential for AMD)
    - AP= 31.25*%S_{tot}
    - NP → Modified Sobek (Lawrence and Wang, 1996)
- Mineralogy
  - FE-SEM with EDS-SSD
  - General mineralogical assemblage
  - Ni deportment within the minerals

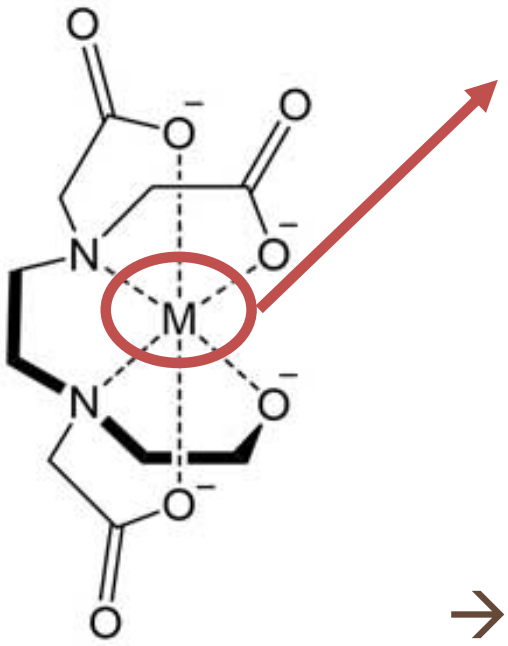
Methods (Column experiments)



Fully deprotonated EDTA

https://pharmafactz.com/wp-content/uploads/2019/01/ch1.jpg

M
M = metal



"Metal-EDTA complex"

Prevent sorption
and precipitation

No immobilization
→ «Real» Metal Leaching

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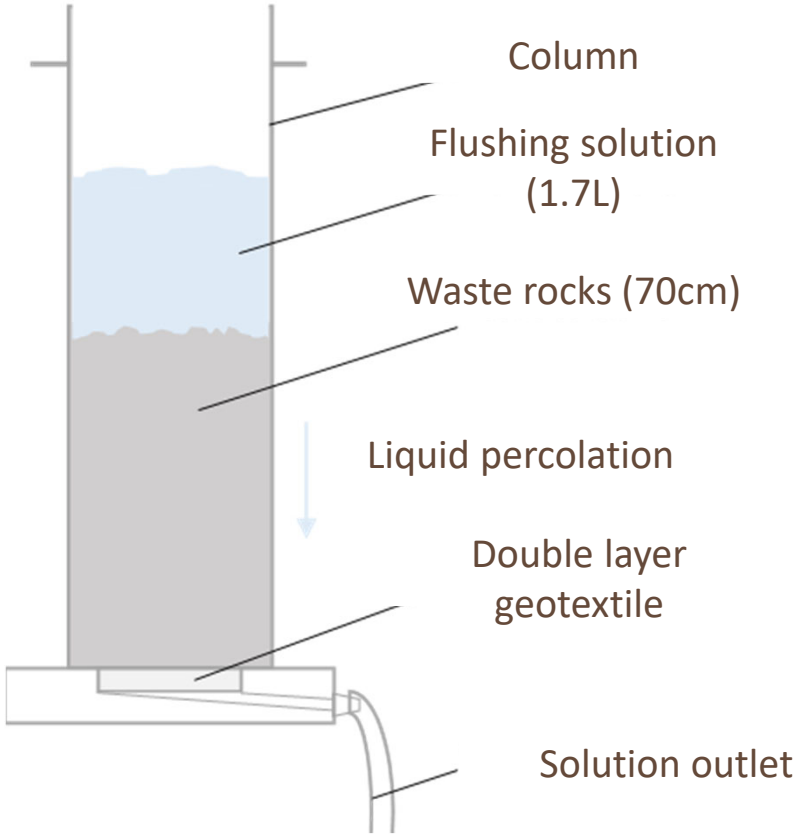
Method (Column experiments)



2 columns (CTRL and EDTA)
Flushed every two weeks
1.7 L of deionized water
1.7 L of EDTA solution (adaptive concentration, buffered to pH 7.5)
183 days in total

Potential for Ni-CND + Ni leaching rates

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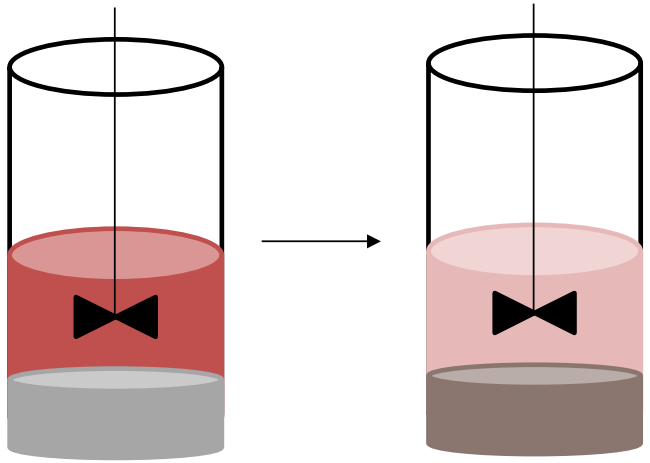
Method (Batch Sorption)

- Batch Sorption Tests
  - 10, 25, 50, 100, 250 mg/L Ni
  - Fixed liquid-solid ratios of 4 and 10
  - Determination of maximal sorption capacity with Langmuir isotherms (q_{max})



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Results

Al	Ca	Fe	Ni	S	Si	Carbon	NNP Sobek	NP/AP
%	%	%	mg/kg	%	%	%	kg $CaCO_3$ /t	(-)
5.2-6.0	2.7-3.0	18–23	270–590	0.17-0.23	14.1-15.4	<0.05	0.1-2.3	1-1.4

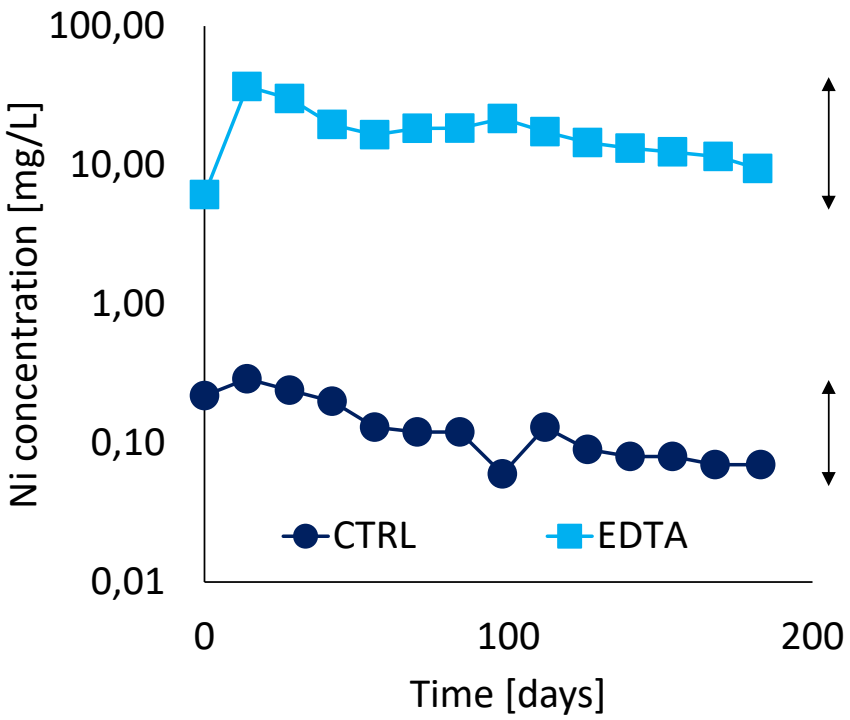
- Ni total concentrations in the waste rocks 270-590 mg/kg of waste rock
- Sobek NNP and NP/AP suggests uncertain acid generation

Mineralogy (Automated SEM)

Ni is mainly associated to pyrite

Mineral	SEM (% wt)
Plagioclase	35.4
Ilmenite	45.3
Pyrite	0.5
Enstatite	9.5
Magnetite	5.4
Other Minerals	3.9

Column leaching (2)



EDTA Ni leaching concentration range: 6-36 mg/L

CTRL Ni leaching concentration range: 0.29-0.06 mg/L

- Increase of Ni concentrations in EDTA – No immobilization mechanisms
- Ni leaching rates:
  - CTRL 0.0007 mg/kg/d
  - EDTA 0.105 mg/kg/d

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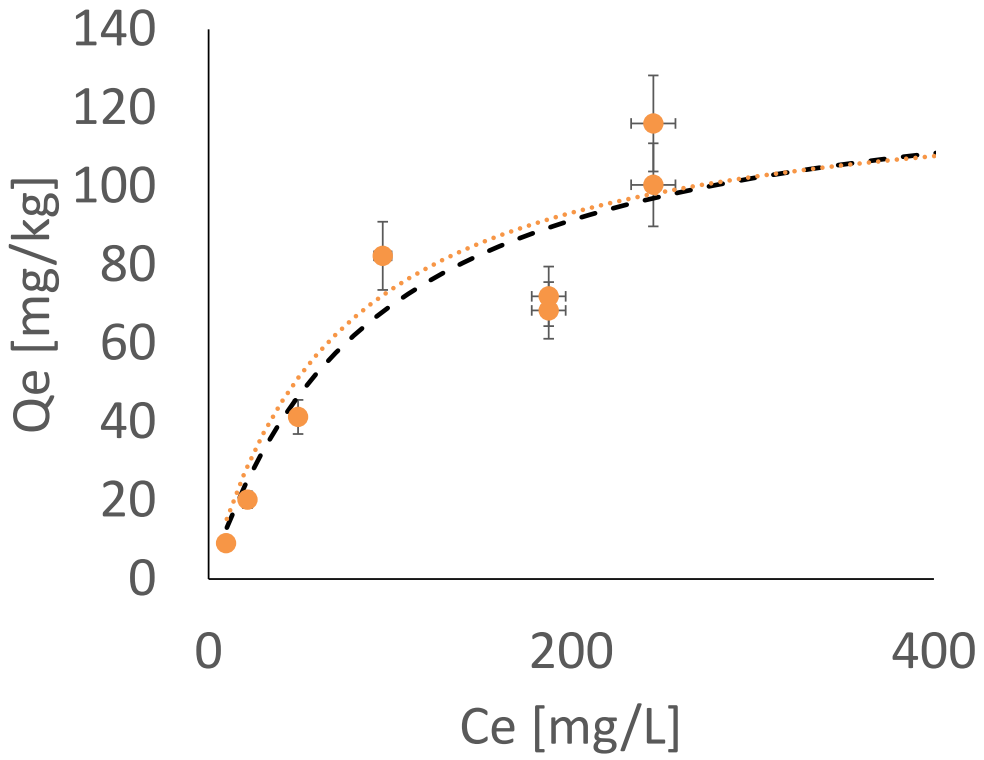
Batch Sorption



Results for fixed L/S =4 (30ml/7.5g) , 0.1 M MES (pH 6.15 buffer)

Langmuir linearized:

q_{max} 133 mg/kg, K_L 0.011 L/mg

Non Linearized Langmuir:

q_{max} 127 mg/kg, K_L 0.014 L/mg

Updated from paper (additional experiments)

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Safe in terms of CND?

Comparison with Plante et al. 2010:

Is known to generate Ni-CND

	This study	Plante et al. 2010 Fresh (Mean)	Plante et al. 2010 Weathered (Mean)
q_{max} Ni [mg/kg]	130 (pH 6.15) Grain size <2 mm	533 (pH 7) Grain size <0.2 mm	233 (pH 7) Grain size <0.2 mm
Total Ni [mg/kg]	270-590	383	336
Ratio Q_{max} Ni vs Total Ni [-]	0.5-0.2	1.4	0.7
Total average Ni+Cu+Co+Zn [mg/kg]	701	1106	996
Ratio Q_{max} Ni vs Metals [-]	**0.2**	**0.5**	**0.2**

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Onset of Ni-CND

- Because [Ni] in the waste rock > Sorption capacity
  - Potential risk for Ni-CND in the long term

- How much time before CND is generated in the column:
  - EDTA leaching rates (no immobilization) 0.105 mg Ni/kg/d
  - Maximal sorption capacity = 130 mg/kg
  - 1238 days → ≈3½ years before sorption site saturation

Updated from paper (additional experiments)

Conclusion and research perspective

- Initial characterizations showed concentrations of Ni between 270-590 mg/kg
- Ni is situated within pyrite grains that oxidize under column conditions
- Kinetic testing suggests material is Ni-generating
- Material sorption capacity around 130 mg/kg Ni at pH 6.15

- **Potential risks of CND** $q_{max} <$ [Ni]
  $q_{max} <<$ [Ni+Co+Cu+Zn]

Perspectives

- How does sorption potential change over time?
- How does the laboratory sorption potential apply to the field?
- How does ions competitivity affect sorption mechanisms?
- Is the modified leaching method applicable to other materials/ions?

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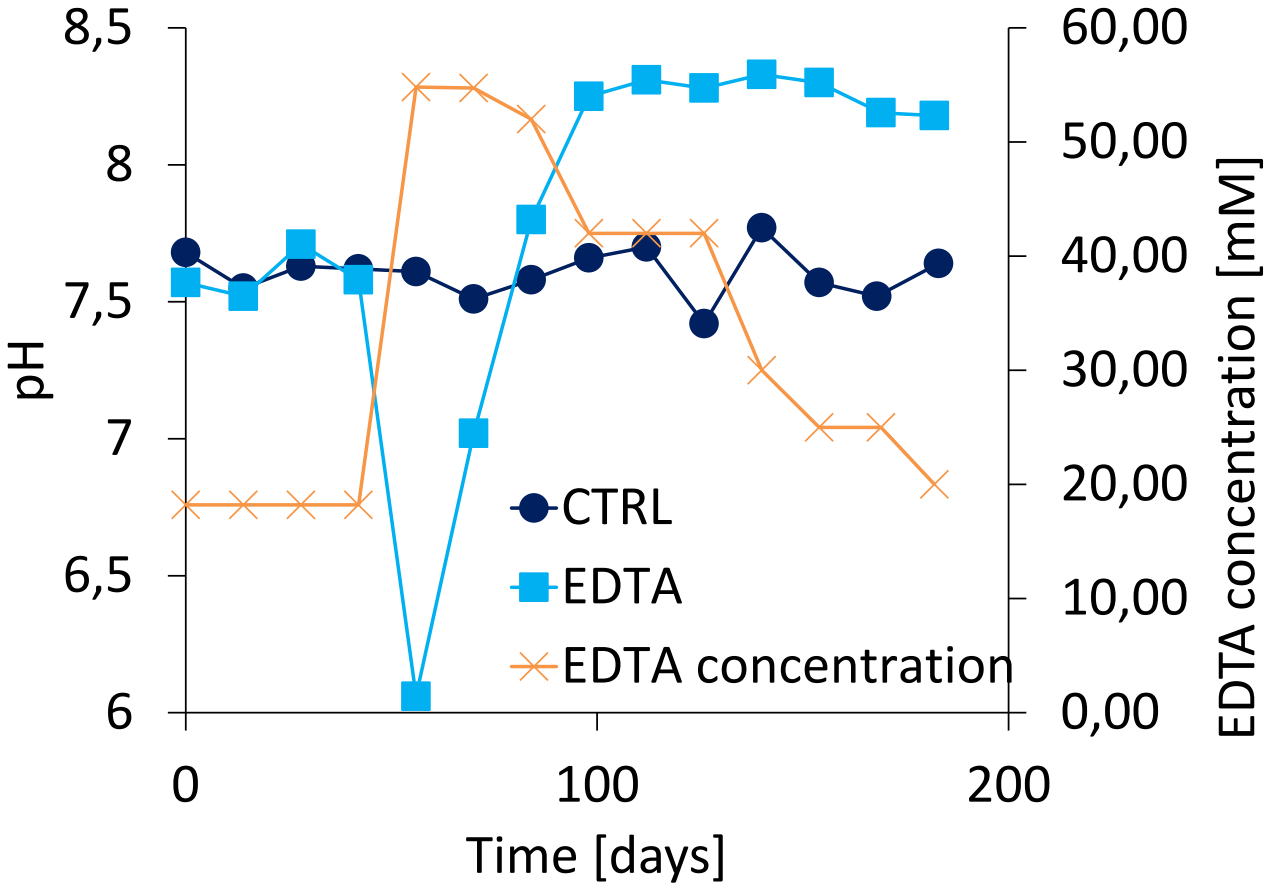
  $q_{max} <<$ [Ni+Co+Cu+Zn]

Annexes

Column Leaching (1)



- CTRL: stable pH
- EDTA: variations of pH with changes in EDTA concentrations

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