Prediction of long term acid generating potential of low sulphur tailings using kinetic tests

B. Bussière, M. Villeneuve, M. Benzaazoua, and M. Aubertin

Industrial NSERC Polytechnique-UQAT Chair on Environment and Mine Waste Management

Presented at:

12th ANNUAL BC/MEND METAL LEACHING/ACID ROCK DRAINAGE WORKSHOP

Content

1. Introduction
2. Materials and Methods
3. Main kinetic test results
4. Long term AMD generation potential
5. Conclusions

1. Introduction

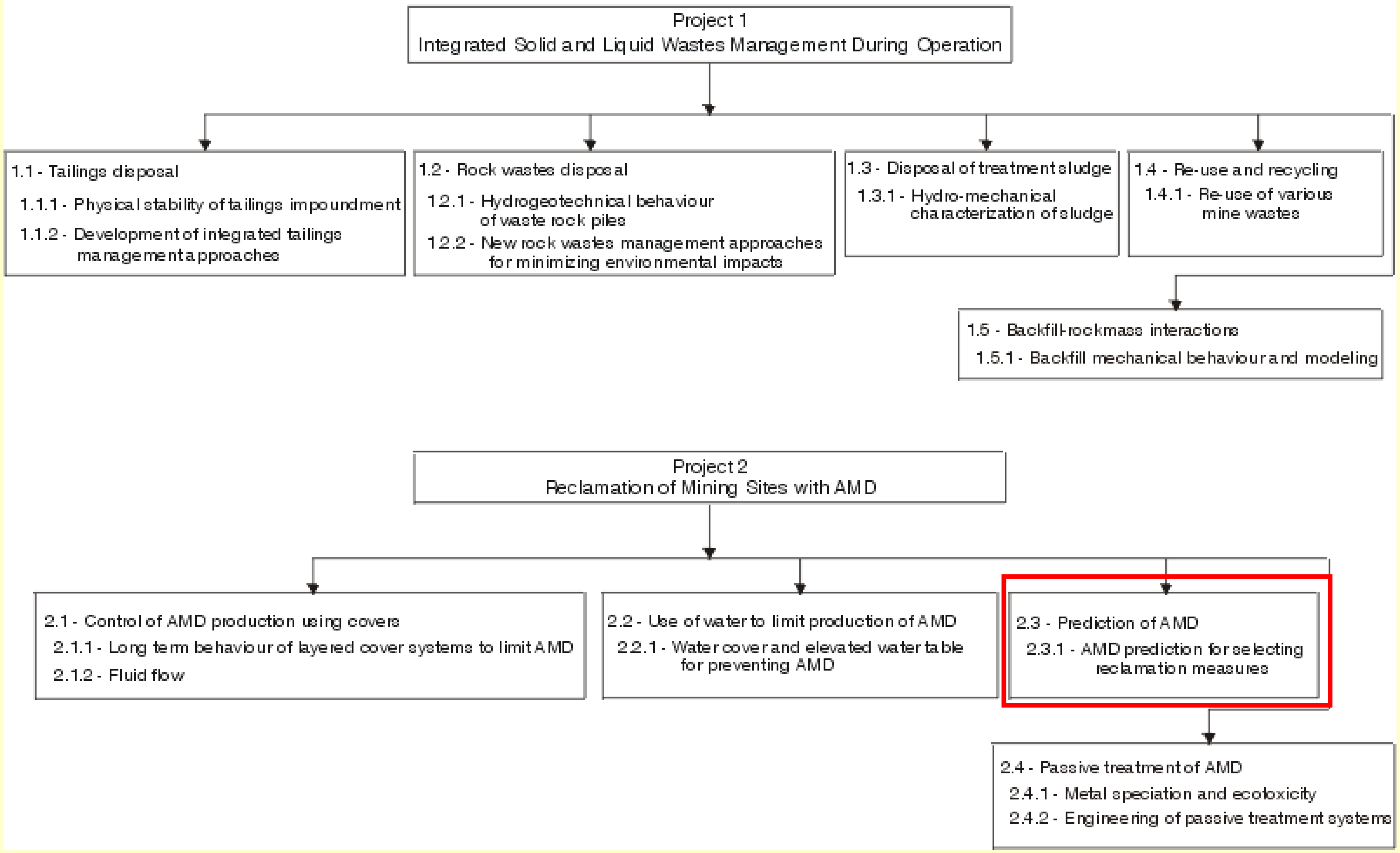
- Costs associated to the rehabilitation of AMD sites are usually greater than for neutral sites.
  - AMD sites : 75 to 250 k$/ha
  - Non AMD sites : 2 to 75 k$/ha
- Important to identify the real geochemical nature of the mining waste
  - Mining companies do not want to spend $ that is not necessary
  - Governments want to be sure that no important environmental problems will appear in the long term
- Static tests have a zone where it is not possible to assess with accuracy the long term acid generating potential
- For these wastes, kinetic tests must be performed and interpreted (no AMD occurs during the test)

1. Introduction

- **The industrial partners of our NSERC Chair have identified the AMD prediction of low sulphide tailings (with low acid generating potential) as a critical issue**
- **Main objective of this study:**
  - Study the geochemical behaviour of mine wastes that contain low sulphide content with different kinetic tests to assess the long term acid generating potential
- **Questions:**
  - Is it possible to accelerate the weathering of minerals without changing significantly the geochemical processes? (see Villeneuve et al. 2003, T&MW'03)
  - Can we evaluate the long term acid generating potential using results from kinetic tests ?

1. Introduction

Projects Organisation Chart
NSERC Polytechnique - UQAT Industrial Chair
Environment and Mine Wastes Management

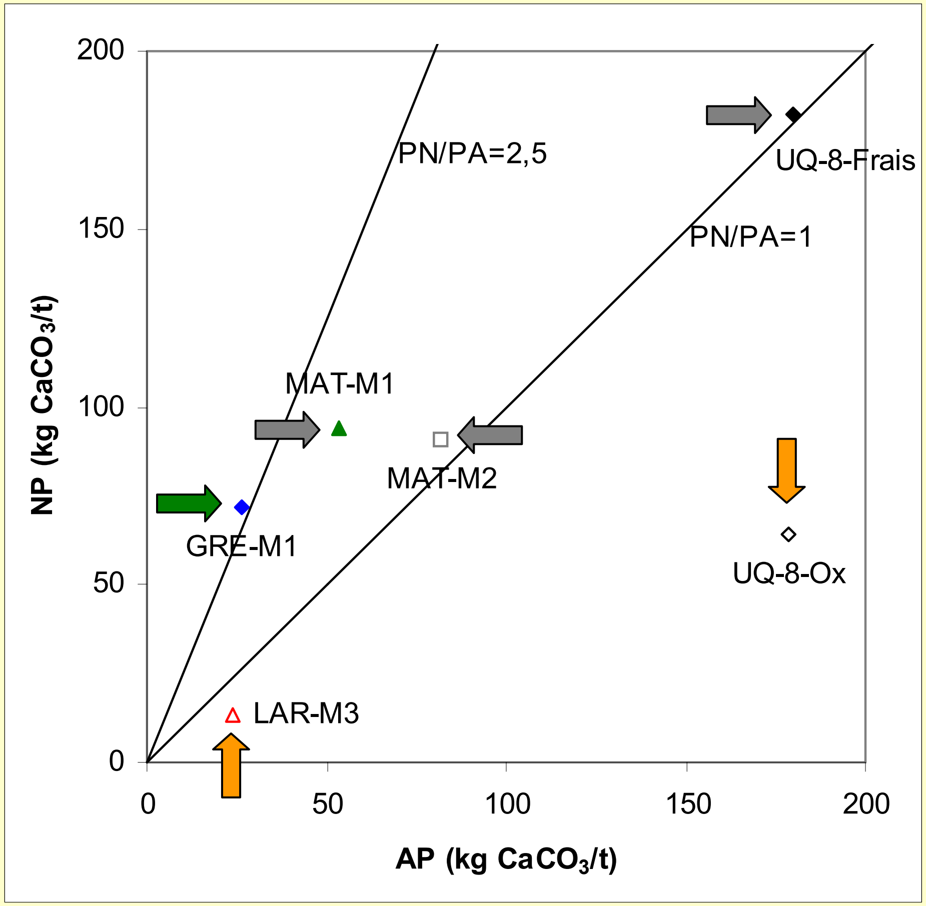


Content

1. Introduction
2. Materials and Methods
3. Main kinetic test results
4. Long term AMD generation potential
5. Conclusions

2. Materials

- 6 tailings with low acid generating potential
- UQ-8-Frais and UQ-8-Ox from an existing tailings impoundment
- GRE-M1, LAR-M3, MAT-M1 et MAT-M2 are desulphurized tailings (by flotation process)
- Static tests results (Modified Sobek test) are usually in or near the `uncertain zone`



2. Materials

- **Tailings properties are typical for hard rock mine tailings (Vick 1990; Aubertin et *al.* 1996, 2002) :**
  - $50 < D_{90} < 105$ µm
  - % < 80 µm between 80 et 95 %
  - % < 2 µm between 5 et 15 %
  - $2{,}78 < D_r < 3{,}07$
- **Sulphur content :**
  - UQ-8-Frais : 5,82 %
  - UQ-8-Ox : 5,72 %
  - MAT-M2 : 2,53 %
  - MAT-M1 : 1,71 %
  - GRE-M1 : 0,85 %
  - LAR-M3 : 0,77 %

Low sulphur in sulphate form (except for UQ-8-Ox,1,37 %$S_{sulphate}$)

2. Materials

Samples mineralogy (Bruker XRD – Rietveld; SEM-EDS)

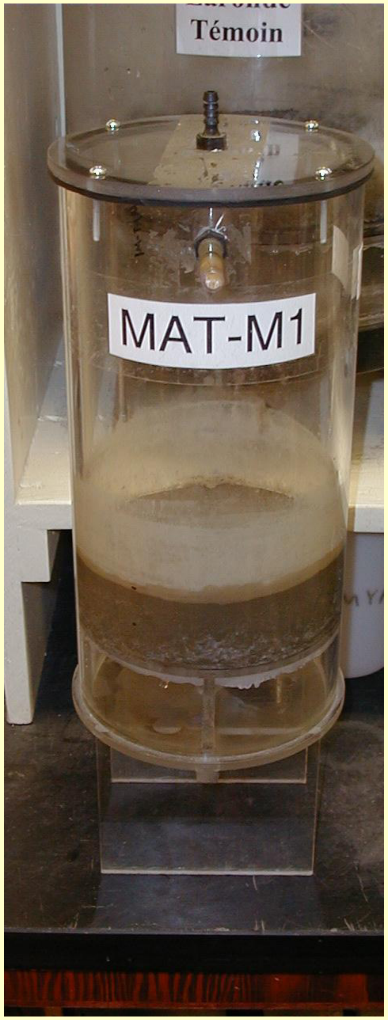
- **Samples mainly composed of silicate minerals (quartz, albite, chlorite)**
  - between 60 and 95 %
- **Acid generating minerals :**
  - Mainly pyrite (between 1 and 12 %)
  - Small amount of chalcopyrite, sphalerite
- **Neutralizing minerals :**
  - Calcite and ankerite (between 3 and 13 %)
  - Also dolomite for UQ-8-Frais and -Ox (5 and 7 % dolomite)
- **UQ-8-Ox also contains gypsum (~ 3 %) → secondary minerals**

2. Methods

- **Column tests:**
  - GRE-M1, LAR-M3, MAT-M1 and MAT-M2 run in 1 m tall by 10 cm diameter Plexiglas columns with 16 kg of material.
  - UQ-8-Frais run in 0.7 m tall by 10 cm diameter Plexiglas column with 8 kg of material.
  - Bottoms consist of porous ceramic plates → water table 2 m below the column.
  - 12 flushes with 2 L of deionized water over a period of 1½ years.

2. Methods

- **Humidity-Cells (Morin & Hutt, 1997):**
  - 14 cm diameter, 30 cm tall Plexiglas cells.
  - 1 kg of tailings.
  - 3 days 1 L/min dry air.
  - 3 days 1 L/min humidity saturated air.
  - On 7th day : flood leaching with 500 mL deionized water, collected after 4 h of soaking.
  - 45 cycles.



2. Methods

- **Mini-Alteration Cells (Cruz et *al*., 2001):**
  - 10 cm diameter Büchner funnel.
  - 67 g of tailings.
  - Leached bi-weekly with 50 mL of deionized water.
  - Water collected by suction after 3 h of contact.
  - Exposition to ambient air between flushes.
  - 40 samplings in 20 weeks.

2. Methods

- **Shake Flasks:**
  - 1 L Erlenmeyer flasks.
  - 50 g of tailings.
  - 500 mL deionized water.
  - Weekly compensated 50 mL sampling by syringe.
  - Weight adjusted before and after every sampling with fresh deionized water.
  - 20 cycles.

2. Methods

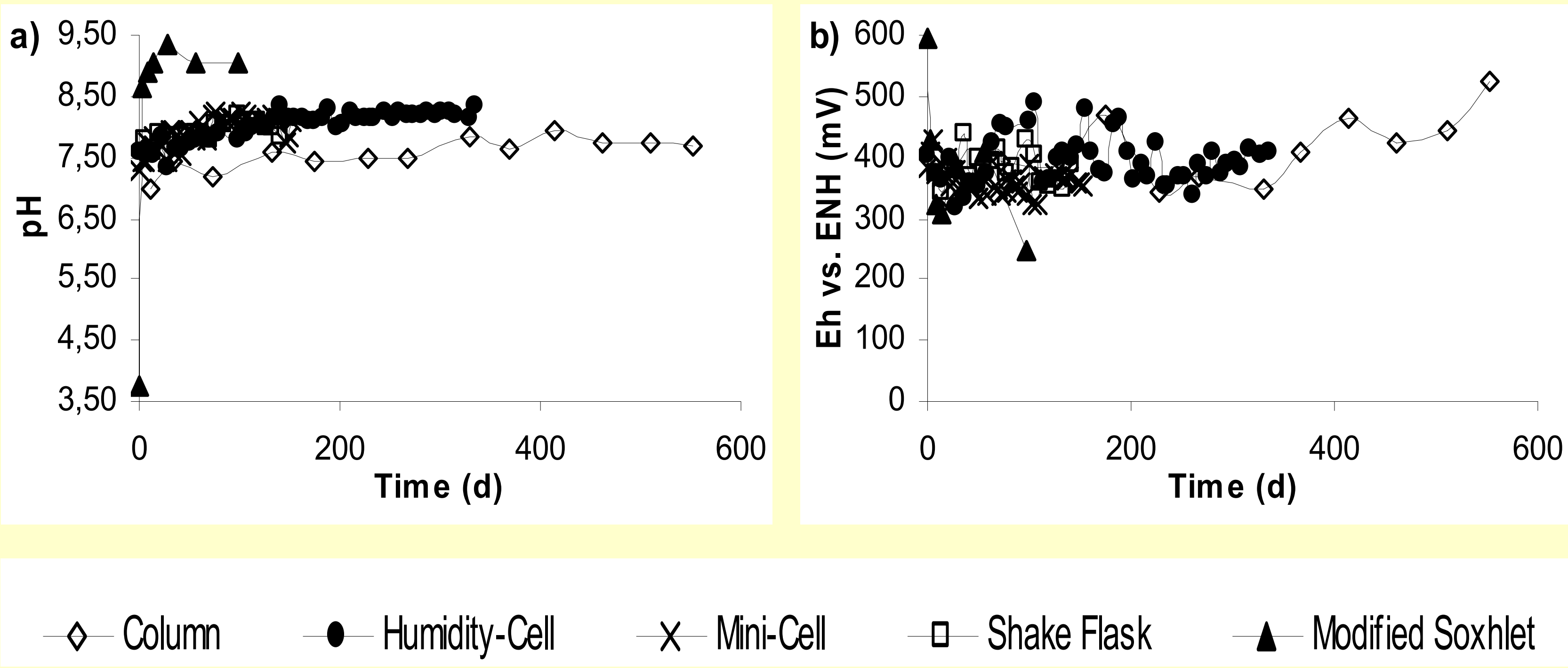
- **Modified Soxhlet extractors:**
  - Sullivan & Sobek (1982) modification : Sample chamber outside the path of rising vapor.
  - Sample temperatures maintained around 20 to 25 °C.
  - 6 g of tailings.
  - 200 mL of deionized water in boiling flask.
  - 50 mL samples collected on days 1, 3, 7 and 14, compensated by fresh deionized water.

Content

1. Introduction
2. Materials and Methods
3. Main kinetic test results
4. Long term AMD generation potential
5. Conclusions

3. Main kinetic test results

- The evolution of different chemical parameters was followed for all materials and each test (pH, Eh, conductivity, Al, As, Ba, Bi, Ca, Cd, Co, Cr, Cu, Fe, K, Mg, Mn, Mo, Na, Ni, Pb, Se, Si, Zn, SO_4^{2-})
- Ex. MAT-M2

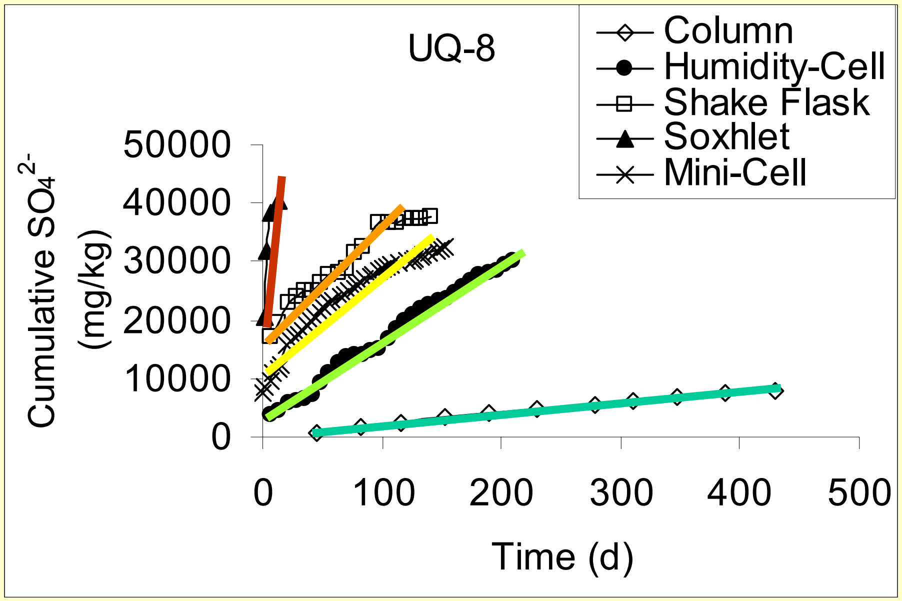


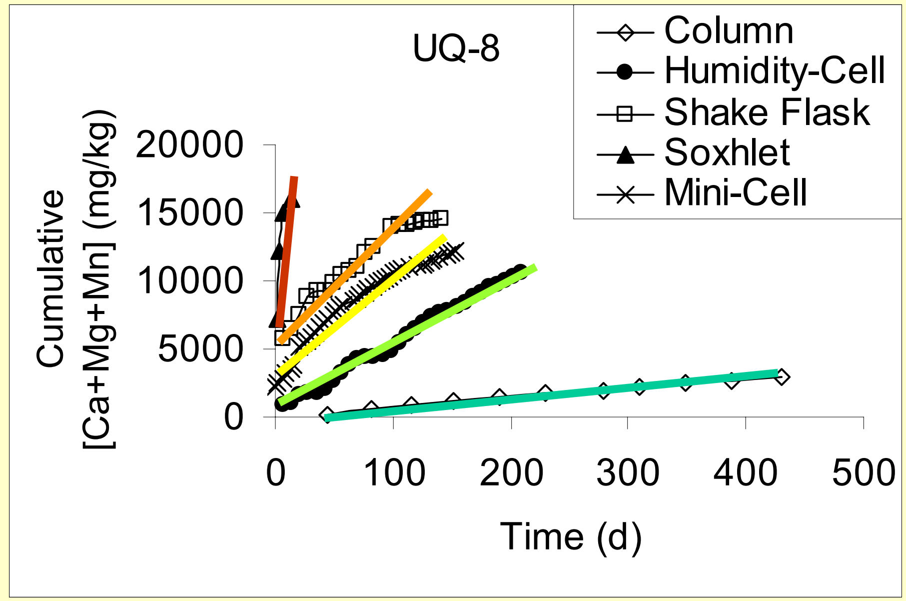
3. Main kinetic test results

- **Water quality of leachates:**
  - pH:
    - High values obtained for all tests on each tailings.
    - Typically between 7 and 9.
  - Eh:
    - Varied between 300 and 500 mV.
    - Soxhlets had a decreasing Eh tendency with time.
  - Cumulative SO_4^{2-}, Ca, Mg and Mn loads:
    - Cumulative SO_4^{2-} loads: products of sulfide oxidation, therefore acidity production.
    - Cumulative Ca, Mg and Mn loads: by-products of acidity neutralization by carbonate minerals.
    - Cumulative loads are normalized per kg of tailings.

4. Results and discussion

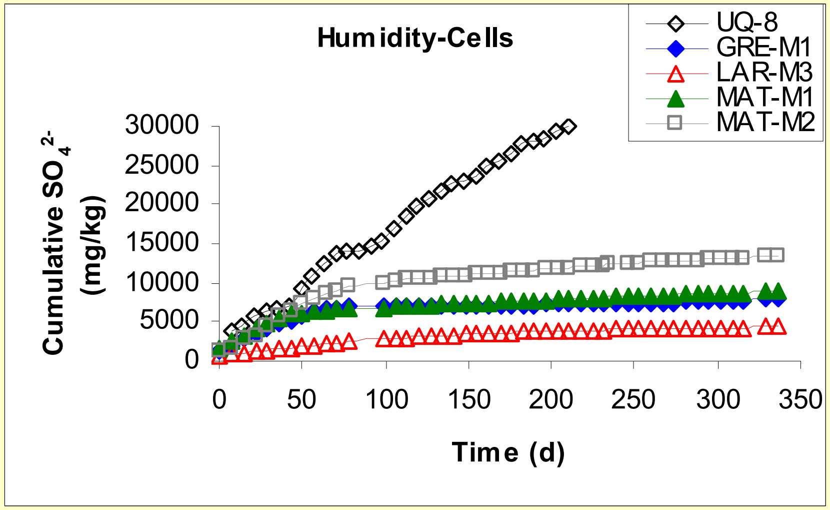
- **Cumulative normalized sulphate and Ca+Mg+Mn:**

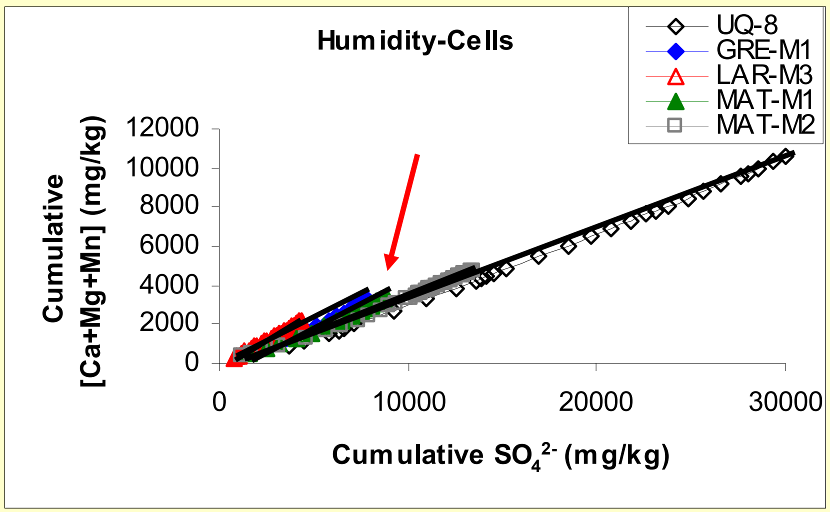




- **Similar evolution of sulphates and Ca+Mg+Mn**

3. Main kinetic test results





- Acidity production rate = a function of sulphide content (as expected)
- Each material has a specific slope [Ca+Mg+Mn] *vs* SO_4^{2-}
- The slope is similar for different samples of a given site (see MAT-M1, M2) even after 15 years of weathering (see UQ-8)

Content

1. Introduction
2. Materials and Methods
3. Main kinetic test results
4. Long term AMD generation potential
5. Conclusions

4. Long term AMD generation potential

- **Qualitative approaches based on the measurements of pH, Eh, cond., sulphates and metals (SRK, 1989; MEND 1.16.1b, 1991); see also Morin and Hutt 1997**
- **The ASTM standard (1998) suggests the approach of White et Jeffers (1994):**
  - Calculations of depletion time for AP (based on sulphate production rate) and for NP (based on Ca and Mg production rates)

$$\text{time to AP depletion} = \frac{[Sulphur]_i}{\overline{\mathrm{R}}_{\mathrm{SO42-}}} \qquad \text{time to NP depletion} = \frac{NP}{\left(\overline{\mathrm{R}}_{\mathrm{Ca}} + \overline{\mathrm{R}}_{\mathrm{Mg}}\right)}$$

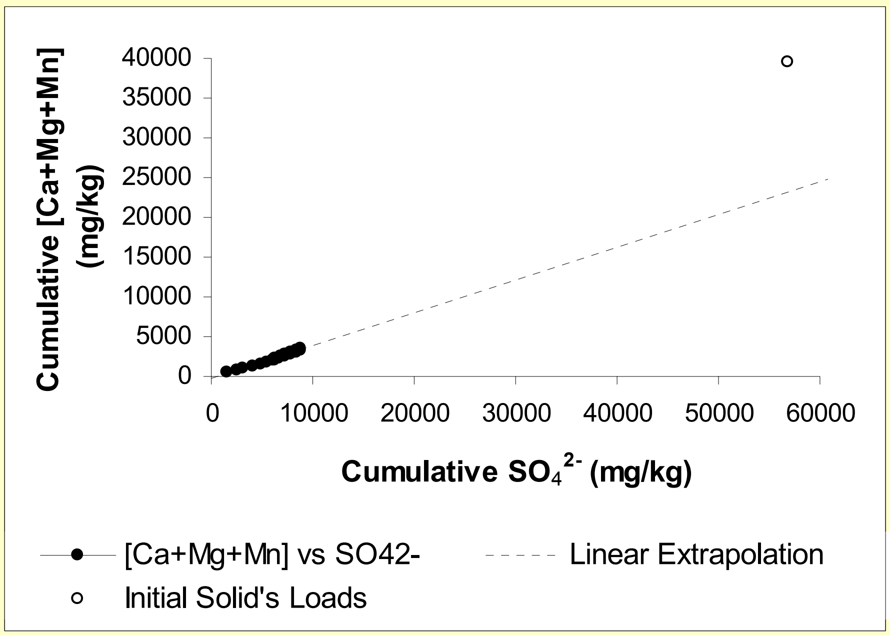
  - Using this approach, verdicts are (red = acid generating; green = non acid generating):

	COL	H-C	M-C
UQ-8-Frais			n/a
UQ-8-Ox	n/a	n/a	
GRE-M1			
LAR-M3			
MAT-M1			
MAT-M2			

4. Long term AMD generation potential

- Benzaazoua et *al.* (2001, 2004) proposed the following approach:
  - X axis : Normalized cumulative sulphate loads (acidity production)
  - Y axis : Normalized cumulative [Ca+Mg+Mn] loads (neutralization products)

Extrapolation



Results

	COL	H-C	M-C
UQ-8-Frais			n/a
UQ-8-Ox	n/a	n/a	
GRE-M1			
LAR-M3			
MAT-M1			
MAT-M2			

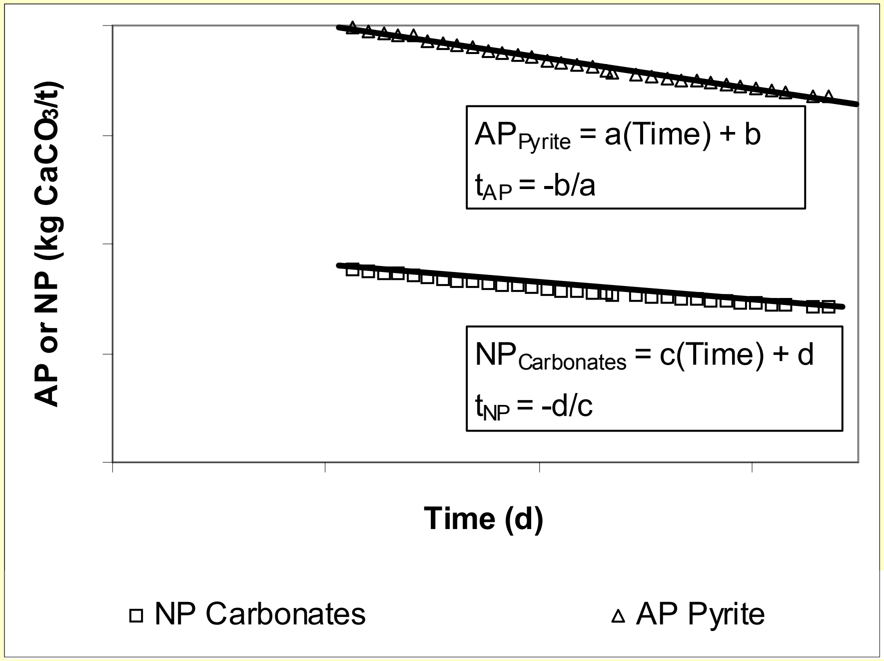
4. Long term AMD generation potential

- **Another approach is based on mineralogical depletion (by the use of elemental tracers):**
  - Zn : sphalerite
  - Cu : chalcopyrite
  - SO_4^{2-} : pyrite
  - Mn : ankerite
  - Mg : dolomite
  - Ca : calcite
- **Mineralogical depletions are converted in $AP_{\underline{Pyrite}}$ and $NP_{Carbonates}$ depletion based on the equations proposed by Paktunc (1999) :**

$$AP_{Pyrite} = 1{,}02 \sum_{i=1}^{k} \frac{n_{M,a} X_i \omega_a 10}{\omega_i} \qquad NP_{Carbonates} = 1{,}02 \sum_{i=1}^{k} \frac{X_i \omega_a 10}{n_{M,i} \omega_i}$$

4. Long term AMD generation potential

- The depletion time of AP_{Pyrite} (t_{AP}) and $NP_{Carbonates}$ (t_{NP}) calculated during the kinetic tests can be extrapolated
- t_{NP}/t_{AP} allows for evaluation of the long term acid generating potential



- Criteria :

  $t_{NP}/t_{AP} < 1$: acid-generating

  $t_{NP}/t_{AP} > 1$: non acid-generating

	COL	H-C	M-C
UQ-8-Frais			n/a
UQ-8-Ox	n/a	n/a	
GRE-M1			
LAR-M3			
MAT-M1			
MAT-M2			

4. Long term AMD generation potential

- White and Jeffers (1994)

	COL	H-C	M-C
UQ-8-Frais			n/a
UQ-8-Ox	n/a	n/a	
GRE-M1			
LAR-M3			
MAT-M1			
MAT-M2			

- Oxidation-neutralisation curves

	COL	H-C	M-C
UQ-8-Frais			n/a
UQ-8-Ox	n/a	n/a	
GRE-M1			
LAR-M3			
MAT-M1			
MAT-M2			

- Mineralogical depletion

	COL	H-C	M-C
UQ-8-Frais			n/a
UQ-8-Ox	n/a	n/a	
GRE-M1			
LAR-M3			
MAT-M1			
MAT-M2			

Content

1. Introduction
2. Materials and Methods
3. Main kinetic test results
4. Long term AMD generation potential
5. Conclusions

5. Conclusions

- The evaluation of the long term acid generating potential of low sulphide tailings is important to select the appropriate rehabilitation scenario
- This study investigated the geochemical behaviour of 5 Canadian low sulphide tailings with 5 kinetic tests
- Closed tests (Shake Flasks and Soxhlets) are difficult to interpret (precipitation)
- For a given tailing: Columns, Humidity-Cells and Mini-Alteration Cells have constant acidity to neutralization ratios (even if concentrations are different between tests)

5. Conclusions

- The long term acid generating potential can be determined using different approaches
- Final results are not always the same, especially with the ASTM approach
- The use of the oxidation-neutralisation curve and the mineralogical depletion to evaluate NP and AP depletion time are interesting approaches (at least for the tailings studied)
- However, all methods are based on hypothesis:
  - Constant reaction rates
  - Carbonates are responsible for the neutralisation in this type of material (pH near neutrality)
  - The depletion of a mineral does not affect reaction rates of the other minerals
  - No significant SO_4^{2-}, Ca, Mg, Mn precipitation occurs
  - Others (see Villeneuve 2004)

Nos partenaires:

BARRICK

AGNICO-EAGLE
DIVISION LARONDE

noranda

DESSAU SOPRIN

Les Ressources Aur inc.
Gestionnaire
Mine Louvicourt

NSERC CRSNG

SNC•LAVALIN Environnement

INMET MINING

Golder Associés

CRDAT
CONSEIL RÉGIONAL DE DÉVELOPPEMENT DE L'ABITIBI-TÉMISCAMINGUE

Environnement Québec

Ressources naturelles Québec

Recherche, Science et Technologie Québec

Commanditaire : ICM CIM

www.polymtl.ca/enviro-geremi