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Session : Passive treatment

Passive treatment of high-iron acid mine drainage using sulphate reducing bacteria: comparison between eight biofilter mixtures

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2 Outline

- **1- Introduction**
- 2- Materials and methods
- 3- Results and short discussion
- 4- Future works

3 1- Introduction / Acid mine drainage production

- neutral pH : $FeS_2 + 7/2\ O_2 + H_2O$ → $Fe^{2+} + 2\ SO_4^{2-} + 2H^+$
- pH < 4,5 : catalyzed by bacteria

$FeS_2 + 14Fe^{3+} + 8H_2O$ → $15Fe^{2+} + 2SO_4^{2-} + 16H^+$

- For rich pyrite and pyrrhotite base metal mines, iron and sulfates concentrations are often high:

For examples in Québec :

  - Lorraine : [Fe]= 4000 ppm, [SO_4^{2-}]= 9000 ppm (Potvin, 2009)
  - Manitou: [Fe]= 20000 ppm, [SO_4^{2-}]= 110000 ppm (Molson et al., 2008)

4 1- Introduction / Recent works summary

- Recent works by our research group on high iron AMD treatment showed :
  - An anoxic limestone drain followed by a step of aeration and settling pond was not efficient to remove metals (Genty, 2007)
  - Potvin (2009) obtained similar results with a 2000 L dolomite reactor
  - Potvin (2009) and Neculita (2007) showed that sulfate reducing biofilter could treat well AMD with iron concentration of approximately 500 ppm and lower
  - However, Neculita (2007) observed that downflow biofilter columns could clogg mainly with iron precipitates. This phenomenom was not observed by Potvin (2009) who used a horizontal flow in a 2000 L biofilter
- In these studies, SRB biofilters seemed to be the best option to treat AMD.

5 1- Introduction / Sulfate reducing bacteria (SRB) biofilter

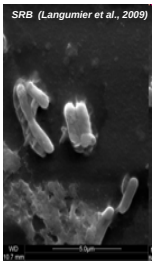
- Degradation of a carbon source and sulfates to produce hydrogen sulfide :

$$2CH_3CHOHCOOH + 3SO_4^{2-} \rightarrow 6HCO_3^- + 3H_2S$$

- Precipitation of metals as metal sulfides :

$$M^{2+} + H_2S \rightarrow MS + 2H^+$$

- Other treatment phenomena can occur in biofilter (Neculita, 2007, Karathanasis et al., 2010, Sheoran et al., 2010):
  - Sorption, hydroxide and carbonate precipitation…
- Important design parameters are :
  - Hydraulic retention time HRT, carbon source



6 1- Introduction / Objectives

- The main objectives of this study are :
  - Evaluate the capacity of SRB biofilter to treat high iron AMD
  - Optimize the biofilter carbon source mixture and the hydraulic retention time
  - Evaluate biofilter clogging
  - Evaluate the effect of AMD iron concentration on the treatment efficiency

7 Outline

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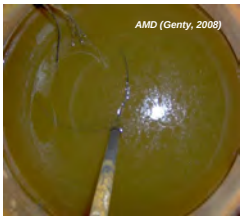
8 2- Materials and Methods / AMD synthetic production

Concentrations	mg/L
Al	1
Cd	0,5
Cr	1
Fe (in AMD)	4000
Fe (in AMD light)	1000
Mg	10
Mn	10
Ni	2
Pb	0,5
SO_4^{2-}	9000
Zn	0,5
pH	3

Two AMD were investigated :

-AMD : Fe = 4000 ppm

-AMD light : Fe = 1000 ppm

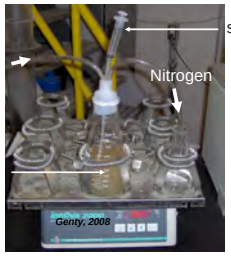


9 2- Materials and Methods / Biofilter mixtures

- **Mixtures summury:**
  - Cellulosic wastes, organic materials, compost, structural agent, inoculum, neutralizing agent, nutriments (more information in the proceedings)
  - #1 : sawdust (20%), wood chips (10%), chicken manure (10%), compost (20%), sand (20%), river sediments (15%), calcium carbonate (2%), urea (3%) (Neculita, 2007).
  - #1, #2, #3, #5 : comparison between 4 organic material sources
  - #6 = #1 without inoculum from sediment
  - #8 = #1 not boost by urea
  - #4, #7 = 50% #1 + 50% sand or calcite sand
- SRB present in compost, sediments, organic materials

10 2- Materials and Methods / Batch tests

- Mixture characterization in batch conditions



- Mesurements : pH, redox potential, metal concentrations, sulfates during 40 days

11 2- Materials and Methods / Column tests

- Three mixtures were selected from batch tests
- 12 L columns
- HRT : 5 and 7 days, upflow
- AMD and AMD light
- The saturated hydraulic conductivity was measured during the experiment to evaluate clogging

12 Outline

- 1- Introduction
- 2- Materials and methods
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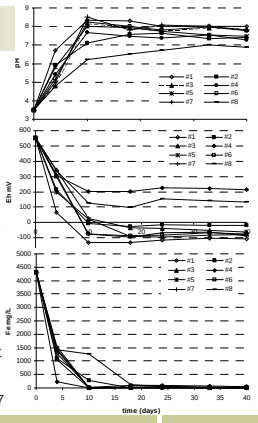
13 3- Results / Batch test results

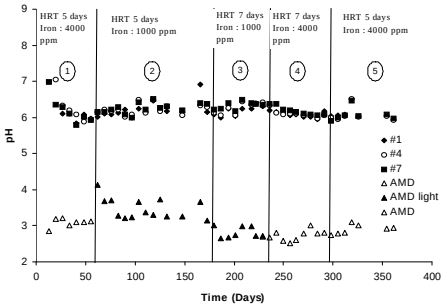
- After 10 days, for most mixtures, pH increased up to 6.5
- Eh decreased below 0 mV for most mixtures and provided reducing conditions
- Metal concentrations reduced around 99%
- Mixture based on chicken, cattle, sheep manures or municipal wastes = similar results
- SRB inoculum coming from sediments was not essential
- Mixtures containing 50% of calcite or sand performed well
- Mixture not boosted by urea was less efficient

➔Three mixtures selected to evaluate hydraulic properties in column test : #1, #4, #7



1-Introduction | 2-Materials and methods | 3-Results and discussion | 4- Future works

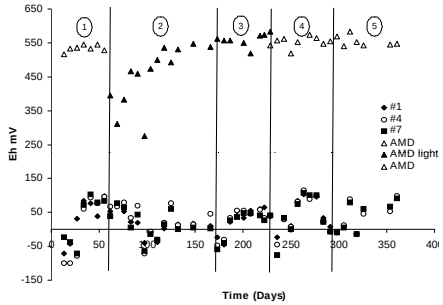
14 3- Results / Column tests / pH



- Neutralization at a pH of approximately 6 whatever the column and conditions

1-Introduction | 2-Materials and methods | 3-Results and discussion | 4- Future works

15 3- Results / Column tests / Eh



- Decrease from 550 mV to 50 mV whatever the column and conditions

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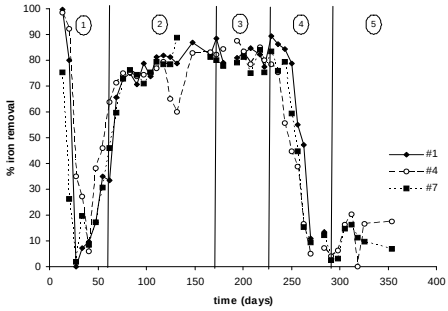
16 3- Results / Column tests / Iron



- Small removal when AMD is treated (20%)
- High removal when AMD light is treated (80%)

No difference with HRT 5 or 7 days

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17 3- Discussion / Column performances

- Al, Cd, Cr, Ni, Zn removal was up to 90%, Pb removal was between 52-80% and Mn removal varied between 1 and 28%. Sulfates removal was 5-20 %. No significant difference between each operational condition.
- Role of biofilter mixture :
  - No signifiant change in terms of iron removal
  - No signifiant change in terms of saturated hydraulic conductivity. Values stayed quite stable around 10^{-3} cm/s for #1 and #4, and 5.10^{-3} cm/s for #7.

    ➔ *SRB biofilter with upflow seemed not clogged (contrary to downflow columns of Neculita, 2007)*
- Role of HRT
  - No signifiant change for iron treatment efficiency for 5 or 7 days
- Role of AMD iron concentration
  - 80% when 1000 ppm, 10-20% when 4000 ppm

1-Introduction | 2-Materials and methods | 3-Results and discussion | 4- Future works

18 Outline

- 1- Introduction
- 2- Materials and methods
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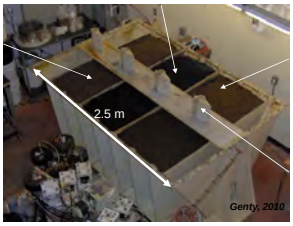
- **4- Future works**

1-Introduction | 2-Materials and methods | 3-Results and discussion | 4- Future works

19 4- Future works

- Single bioreactor improved significantly water quality but did not treat high iron concentrated AMD
- Multi-step treatment systems could be an available option :
  - We are runing a 2000 L reactor (tested previously in columns): wood ash filter (for iron sorption)

SRB biofilter #4 (combination of SRB and ALD)

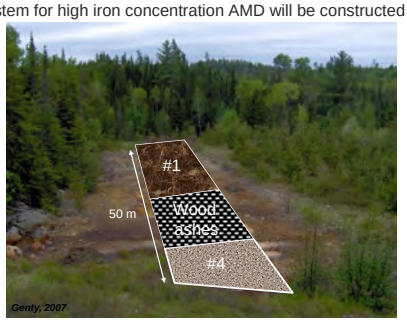


SRB biofilter #1 (polishing step)

sampling port

20 4- Future works

- Next year : based on laboratory results, a field size passive treatment system for high iron concentration AMD will be constructed



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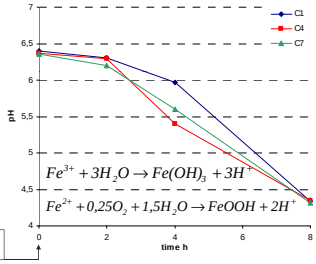
Thank you for your attention

22 Column performances

- Effluent pH decreased related to the high iron concentration of AMD 4000 mg/L:
  - Decrease of pH due to iron hydrolysis and precipitation in effluents

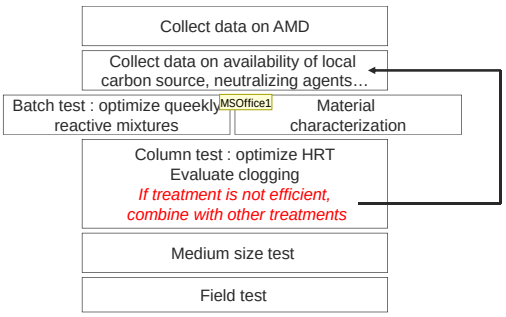


Sampling time

23 Biofilter mixtures

Dry weight %	# 1	# 2	# 3	# 4	# 5	# 6	# 7	# 8
Maple chips	10	10	10	5	10	10	6	10
Maple sawdust	20	20	20	10	20	20	11	20
Chicken manure	10			5		10	8	10
Catle manure		10						
Sheep manure			10					
Compost	20	20	20	10	20	20	12	20
sand	20	20	20	10	20	35	50	20
Sediment	15	15	15	8	15		8	15
Urea	3	3	3	2	3	3	3	
Calcium carbonate	2	2	2		2	2	2	
Calcite sand				50				5
Municipal sludges					10			

24 Methodology



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