Unsaturated flow and rock characteristics in experimental acid mine drainage rock tanks

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Acknowledgements

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Introduction

- Mining often results in the oxidation of sulfidic minerals such as pyrite (FeS_2) after exposure to water and oxygen; sequences that leads to acid mine drainage (AMD) (Akcil & Koldas, 2006)
- AMD: low pH and high dissolved metal concentrations (Akcil & Koldas, 2006).
- Detrimental

- Several reactions result in the generation of AMD through the oxidation of sulfide minerals (Akcil & Koldas, 2006):

$FeS_2 + 7/2\ O_2 + H_2o \rightarrow Fe^{2+} + 2SO_4^{2-} + 2H^+$ (1)

$Fe^{2+} + 1/4\ O_2 + H^+ \rightarrow Fe^{3+} + ½\ H_2O$ (2)

$Fe\ S_2 + 14\ Fe^{3+} + 8H_2O \rightarrow 15\ Fe_{2+} + 2SO_4^{2-} + 16H^+$ (3)

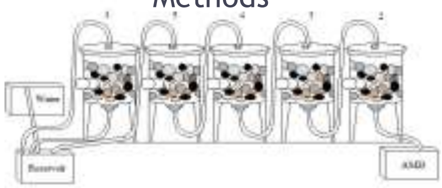
- Reaction 1: dissolved oxygen = electron acceptor in the oxidation of pyrite producing ferrous iron and sulfuric acid.
- Circumneutral pH= pyrite dissolved directly by oxygen.
- pH below 4.5
  - ferric iron generated by iron oxidizing bacteria (reaction 2) becomes the primary oxidant of pyrite (reaction 3; Singer & Stumm, 1970).

- Heterotrophic bacteria exist in small populations (Marchand & Silverstein, 2002).
- **Water flow** (Akcil & Koldas, 2006).
  - controls the transport of nutrients, wastes, and microorganisms throughout media (Schafer *et al.*, 1998).
- Challenging to model subsurface flow (Stockwell *et al.*, 2006).

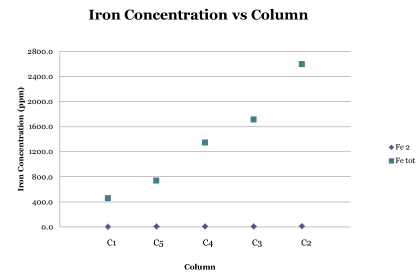
Purpose

- Remediation Strategy: Add organic carbon to experimental rock tanks to stimulate biogeochemical processes that reduce AMD.
- My research purpose: measure factors that determine reaction and transport rates
  - residence times of drainage water in experimental AMD tanks
  - physical characteristics of waste rock (porosity and pore water chemistry).
  - Dispersion coefficient for the columns: reactive transport computational model before trying carbon addition for bioremediation

Methods



- 150 kg rock/column from Leadville, Colorado
- Dimensions: 91 cm long and 45 cm in diameter
- Re-circulating reservoir: tap water added every 24 hours (reservoir turnover is approximately 5 days)
- Measured current conditions of rock tanks (iron, pH, DO, flow rates, humidity)



Methods (Rock Porosity & Saturation)

- 30 rocks from each column at various depths and radial positions

Initial weight → Dry weight

→

→ Dry weight

$$\frac{(\text{sat weight} - \text{final dry weight})}{(\text{sat weight} - \text{buoyant weight})} \times 100 = \text{Porosity}$$

$$\frac{(\text{initial weight} - \text{initial dry weight})}{(\text{saturated weight} - \text{final dry weight})} \times 100 = \text{Saturation}$$

Pore iron concentration

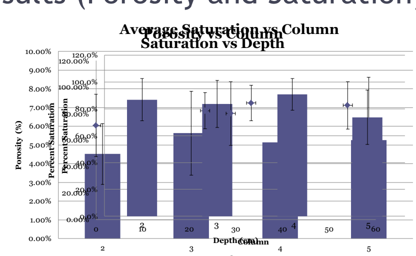
- Six rocks:
  - depth 15 cm and weight between 146.0041 and 164.749 (g)
  - 2 rocks in 400 ml of 20 mg/L benzoic acid acidified to a pH of 1.8.
  - Samples taken periodically for 140 hours and measured for pH and iron.
  - Calculated porosity

$$\frac{(V_p \times C_o)}{[(V_p \times S)+V_{tank}]} = C\infty$$

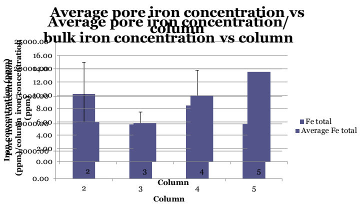
Tracer test

- 2 Molar NaBr
- Prepared standard curves
- 5 min injection
- Recorded readings in Column 2 effluent

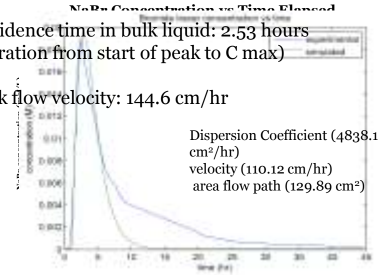
Results (Porosity and Saturation)



Results (Pore Iron Exp.)



Tracer Data (Bromide Test 3)



Residence time in bulk liquid: 2.53 hours (duration from start of peak to C max)

Bulk flow velocity: 144.6 cm/hr

Dispersion Coefficient (4838.1 cm^2/hr)
velocity (110.12 cm/hr)
area flow path (129.89 cm^2)

Conclusions

- Saturations not dependent on depth and pretty similar in each column.
- Pore iron analysis: total iron concentrations 6-13 times higher in pores than the bulk column liquid waste; suggests that the AMD tanks are a dual porosity system.
- The long tail in tracer test indicates dual porosity

Conclusions and future work

- Problems with CDE simulation.
  - Simulation vs experimental
  - CDE test only models the bulk solution: Neglects the dual porosity of the system
- New simulation equation

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Questions?