Biobarriers in Fractured Bedrock: Effects of Gasohol on Biofilm Structure

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Outline

1. The Biobarrier Concept
   • From Laboratory Testing to Field Demonstration
   • Our Goal

2. What can the microscale tell us?
   • The Tools
   • The Responses

3. Future Work and Application
   • @ microscale
   • @ macroscale
The Biobarrier Concept
@ Microscopic and Macroscopic Scales

Bacteria

+ Exopolymeric substances (EPS)

= Biofilm

Stimulation of a biofilm growth

Development of a biobarrier

Groundwater Flow

Injection wells:
- nutrients
- electron acceptors

Reactive wall: biodegradation zone

biofilms

Confinement wall
Highlights of the Development of the BiobARRIER Concept

- **On Bioclogging:**
  - Biofilm thickness of 1100 μm
  - Decrease in K of 99.99%
  
  (Ross et al. 2001. Wat. Res. 35:8)

- **On Monitoring Tools:**
  - Eh and planktonic bacteria as indicators
  - Tracer experiments to develop mathematical models
  
  (Ross et al. 2005, JEES, Submitted)

- **On Field Demonstrating:**
  - After 15d of biostimulation: up to 20-fold ↓ GW velocity and 40% aperture reduction

  (Ross, N., Bickerton, G., Remediation.12:5-21, 2002)
Fractured Bedrock can be Effectively Clogged. How Does Contamination Affect the Biobarrier?

Our Goal:
To observe the effects at the microscale of the addition of gasohol to a biofilm

The Objectives are to Measure the:
1- Effects of Gasohol on Hydrogeological Parameters
2- Removal of Gasohol by a Biofilm
3- Effects of Gasohol on the Biofilm Structure
Obj. 1 & 2: Hydrogeological Parameters and Gasohol Removal

Two species culture

4-Day feeding in “Recycle mode”

7-Day fresh continuous feed

Tracer tests

Increasing concentrations of gasohol

Measurements of hydraulic conductivity and gasohol removal
Obj. 3- Effects of Gasohol on the Biofilm Structure

- Input
- Output
- Biofilm without BTEX
- Biofilm with BTEX

Flow Diagram:
- Medium
- Pump
- Flow breaker
- Capillary flow cells
- Microscope
- Waste

Parameters:
- BTEX: 0.42 mL/min, 40 ppm
- BTEX: 8.9 ppm
- Linear velocity: 1.0 cm/s
- Media: 1.46 mL/min

RemTech 2005
Obj. 3 - Effects of Gasohol on the Biofilm Structure
Obj. 3- Effects of Gasohol on the Biofilm Structure

- **Areal Porosity**: Ratio of void area to total area
- **Biovolume**: Total biomass volume in the biofilm. It is calculated by summing number of cluster pixels in the image set.
- **Fractal Dimension**: Rate of change in the perimeter of an object. The rougher the biofilm boundary, the higher the fractal dimension.
- **Biofilm Roughness**: Describes the courseness of the biofilm
Exposure to an Increasing Concentration of Gasohol led to a Two-fold Increase in K
Biofilm was Effective to Remove BTEX up to 40 ppm

The graph shows the percentage gasohol removal for different BTEX components (Benzene, Toluene, Ethyl Benzene, m-Xylene) at various concentrations (20 PPM, 40 PPM, 80 PPM, 100 PPM). The biofilm proved effective in removing BTEX up to 40 ppm.
Increasing Concentration of Gasohol Decreased the Biofilm Area

Control

20 ppm

40 ppm

100 ppm
Biofilm Slightly more Porous; However Significantly less Clustery

% Increase in Porosity

% Decrease in Biovolume

Gasohol Concentration (ppm)
Biofilm Slightly more Heterogeneous; However, Significantly Rougher
Conclusions

1. At high concentrations, over 80 ppm gasohol in this study, an increase in $K$ of a couple of folds is expected in a bioclogged media;

2. In the conditions tested, higher removal were measured at gasohol concentrations around and below 40 ppm;

3. The microstructure of biofilm is significantly affected by the presence of gasohol at concentration higher than 40 ppm.
Future Work

1. Correlate changes in biofilm structure with bacterial activity and viability when exposed to gasohol;

2. Explore mathematical models on contaminant diffusivity to measure the effect of biofilm on transport in fractured rock;

3. Gain information at macroscale from a bioclogging of a complex fracture network at field demonstration scale.
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