Acidic Mine Drainage in Sulfate-Reducing Bioreactors: Inside the SRB Cell.

Tracy Branam, Matt Reeder and Denver Harper
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• Participants
  – IGS Professional: Jack Haddan, Ron Smith, Margaret Ennis
  – **IU DOGS: Dr. Greg Olyphant**
  – IU Student Hourly: Sara Bergfeld, Jared Olyphant, Sashi Challa, Elizabeth Gawthrop, Janelle Steffen, Alex Gore, Elizabeth Bockstiege, Scott Breeden
Remediation Strategies

FeS_2 + 3.5O_2 + H_2O → Fe^{2+} + 2SO_4^{2-} + 2H^+

- prevention
  - Large Scale = Anaerobic Wetlands
  - Small Scale = Sulfate Reducing Bioreactors

- treatment
  - precipitate iron
  - remove sulfate
  - neutralize acidity
  - apply alkalinity

Utilize bacteria
Sulfate-Reducing Bioreactor Cell (SRBC)

Acid neutralization boundary
Redox boundary

AMD Inflow

Limestone buffered organic substrate (LBOS)
Perforated pipe drainage system

\[
\text{CaCO}_3 + 2\text{H}^+ \rightarrow \text{Ca}^{+2} + \text{H}_2\text{CO}_3
\]

acid neutralization

\[
\text{CH}_2\text{O} + \text{O}_2 \rightarrow \text{H}_2\text{CO}_3 \Leftrightarrow \text{HCO}_3^- + \text{H}^+
\]

aerobic bacteria removal of oxygen

\[
\text{SO}_4^{-2} + 2\text{CH}_2\text{O} \rightarrow \text{H}_2\text{S} + \text{HCO}_3^-
\]

anaerobic bacterial sulfate reduction

\[
\text{H}_2\text{CO}_3 + \text{CaCO}_3 \rightarrow \text{Ca}^{+2} + 2\text{HCO}_3^-
\]

alkalinity generation

\[
\text{H}_2\text{S} + \text{HCO}_3^- \Leftrightarrow \text{HS}^- + \text{H}_2\text{CO}_3
\]

pH buffered hydrogen sulfide dissociation

\[
\text{Fe}^{+2} + \text{HS}^- \Leftrightarrow \text{FeS} + \text{H}^+
\]

ferrous iron sulfide precipitated
Fermenters, sulfate reducers and methanogens will starve and the bioreactor cease to function if the more complex organic molecules are not broken down to simpler molecules. Rate of complex molecule decomposition is unknown but an important component for developing predictive model
Average values obtained from 12+ months monitoring

<table>
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<tr>
<th>Sample ID</th>
<th>Temp</th>
<th>SpCond</th>
<th>pH</th>
<th>Eh</th>
<th>Acidity</th>
<th>Alkalinity</th>
<th>SO4</th>
<th>Fe(II)</th>
<th>Al</th>
<th>Mn</th>
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<td>Lacy South seep</td>
<td>13.4</td>
<td>2883</td>
<td>2.5</td>
<td>612</td>
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<td>2265</td>
<td>6.2</td>
<td>91</td>
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<td>3363</td>
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<td>407</td>
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<td>7</td>
<td>2179</td>
<td>525</td>
<td>47</td>
<td>7</td>
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<td>1829</td>
<td>6.3</td>
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<td>162</td>
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<td>666</td>
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</table>
Lacy SRBC Design

Plan View

Short dimension cross sectional view

Long dimension cross sectional view
Pipe level sampler

Floating sampler

Pipe level sampler in place

Deploying floating samplers
Sampling ports
Peristaltic pump
Flow thru chamber
Multiparameter sonde
Filtration unit
Peristaltic pump
Sampling ports
Ferrous Iron concentration range

Sulfate concentration range
Spring 2010

Sulfate mg/L
- 200
- 600
- 1000
- 1500
- 2000
- 3000

Ferrous Iron mg/L
- 50
- 100
- 200
- 300
- 500
- 700
Bromide tracer introduced on 6/28/2010
Detected at Outlet on 6/30/2010 at conc. of 19 mg/L

Bromide values 7/2/2010

Bromide values 7/7/2010
Conclusions

- Internal 3-D monitoring system enhances performance evaluation
  - Monitoring frequency of internal ports reveals changing extent of reducing zone and migration of acid neutralization front.
  - Reveals magnitude of chemical reactions and development of preferred flow paths
  - Residence time, critical for developing microbial-catalyzed reactions, can be determined for all monitored areas of cell from tracer injections
Questions to be answered by continued research

• Is preferential flow path development a result of precipitate buildup?
  – Iron and aluminum oxides at neutralization front
  – Gypsum in oxygen depletion zone
  – Iron sulfides in sulfate-reducing zone
  – Determined from examination of multiple cores

• Can sulfate reducing bacteria be rejuvenated throughout neutralized zone of cell?
  – Adding simple organic compounds through sampling ports (alcohols, sugars, organic acids)
  – Summer season best time when bacterial activity is increasing as flow decreases