Mitigating Acid Rock Drainage with Land-Applied BCR Effluent

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- ARD Tetrahedron Refresher
- Biochemical Reactor Refresher
- Heap Leach Technology Refresher
- Vaccination versus Medication?
- Vaccination and Medication Concepts
- Medication Case Studies
- Cost Model
- Sequatchie Test 2014
Acid Rock Drainage

UNLESS WE CAN FIND PRACTICAL SOURCE CONTROL REMEDIES
Acid Rock Drainage Tetrahedron

Water

Oxidizer
(Air, Fe$^{+3}$)

Bacteria

Pyrite
Acid Rock Drainage Tetrahedron

Water

Oxidizer
(Air, Fe$^{+3}$)

Pyrite

Good Bacteria

“PROBIOTIC” PATHWAY TO WALK-AWAY
**Biochemical Reactor Refresher**

\[ \text{SO}_4^{2-} + 2 \text{CH}_2\text{O} \rightarrow \text{HS}^- + 2\text{HCO}_3^- + \text{H}^+ \]  
* (Sulfate reduction and neutralization by bacteria)

\[ \text{Zn}^{+2} + \text{HS}^- \rightarrow \text{ZnS} (s) + \text{H}^+ \]  
* (Sulfide precipitation)

\[ \text{H}^+ + \text{CaCO}_3 \rightarrow \text{Ca}^{+2} + \text{HCO}_3^- \]  
* (Limestone dissolution)

**REDUCING/ANAEROBIC CONDITIONS**
Anaerobic Biochemical Reactors (BCRs)

AKA
Vertical Flow Reactors or
Sulfate Reducing Bioreactors (SRBRs)

Aluminum and heavy metal removal, selenium removal, de-nitrification, pH adjustment, alkalinity & hardness addition
Anaerobic Biochemical Reactors (BCRs)

PLANTS ARE NOT REQUIRED FOR A BCR
BCR Effluent Characteristics

- Dissolved organic carbon (measured as BOD or total organic carbon [TOC])
- Bicarbonate alkalinity
- Reducing oxidation reduction potential (ORP) of – 100 mv or less
- Low dissolved oxygen [DO] (<1 mg/L)
- Dissolved sulfide ion, and
- Dissolved manganese
Barren Solution Delivery

- Drip Emitters
- Wobbler Sprinklers
- Reciprocating Sprinklers
- High Rate Evaporative Sprinklers

Images courtesy of Reddit.com, gtghydroponics.com, ebay, & bradshawsupply.com
Heap Leach Plumbing Layout

Courtesy of Senninger.com
Known Bactericidies

- Sodium lauryl sulfate (SLS)
- Slow release commercial products
  - ProMac (*no longer available*)
- Alkyl-benzene sulfonate (laundry detergent is cheaper than SLS)
- Sodium Thiocyanate (NaSCN)
- Bi-Polar Lipids (patented)
Vaccination versus Medication?
Bactericides for Suppressing *Acidithiobacillus Ferrooxidans*

- Vaccination
- Medication
- Sequential Application or Cocktail?
Vaccination & Medication Scenarios

- Heap Leach Pads/Dump Leach Site
- Tailings Storage Facilities
- Waste Rock Repositories
- Pit Walls

Has any of these been done before?
Medication Case History #1

• Fisher Coal Mine, PA – 1995

- Geophysics targets 3 ARD–generating zones; seep pH was 5.5; iron 17 mg/L and higher.
- Multiple injection boreholes on a tight spacing
- Injection of 20% NaOH solution simultaneously into 12 shallow (3 m deep) boreholes with packers
- Injection of 2% sodium lauryl sulfate bactericide
- Seepage continues to be net alkaline 19 years later, bond release is reportedly imminent

Ref: Plocus & Rastogi, 1997
Medication Case History #1

- Fisher Coal Mine, PA – 1995

“A ton of prevention is worth an acre of passive treatment”
FIGURE - 6
Raw Seep Manganese Concentration

SI: Subsurface Injection
CTD: Chemical Treatment Discontinued

mg/L

Date of Sampling


Raw Manganese (Mn) DEP Limit

CTD: 07/26/95
SI: 06/19/95 INJECTION
CTD: 02/19/96
TR: 12/27/95

Plocus & Rastogi, 1997
FIGURE - 7
Raw Seep Iron Concentration

SI: Subsurface Injection
CTD: Chemical Treatment
Discontinued

mg/L

Date of Sampling

SI: 06/19/95
INJECTION
TR: 12/27/95
CTD: 02/19/96
CTD: 07/26/95

Plocus & Rastogi, 1997
FIGURE - 8
Raw Seep Alkalinity & Acidity

S1: Subsurface Injection
CTD: Chemical Treatment Discontinued
TR: Treatment Restarted

CTD: 02/19/96
CTD: 07/26/95
S1: 06/19/95 INJECTION
TR: 12/27/95

mg/L

Date of Sampling


Raw Acidity

--- Raw Alkalinity

Plocus & Rastogi, 1997
WHY DOES IT STILL WORK – 19 YEARS LATER?

1) The initial “flooding” injection of caustic neutralized the residual acidity in the mine waste so that the subsequent application of bactericide was “protected” from chemical attack;

2) The bactericide solution (2% sodium lauryl sulfate) would have followed the preferential pathways established during the stage 1 injection of caustic to inhibit the activity of the acidophilic community; and

3) The well-established revegetated surface of the site provided a steady supply of bacteria inhibiting organic acids (and continues to do so) which appears to have suppressed the “reinfection” of the site that would have otherwise occurred.
Sequatchie Coal Mine, TN – 2007
Western Research Institute

- Geophysics used to target ARD
- Two doses - drip application of waste milk and biosolids (as inoculant)
- Seepage reportedly net alkaline after seven years.
- Patent issued January, 2012
- Check out ITRC website
- Plans to conduct follow up research (summer 2014).

Ref: Jin et al., 2007

http://www.itrcweb.org/miningwaste-guidance/cs31_sequatchie.htm
Medication Case History #2

- Sequatchie Coal Mine, TN – 2007
Sequatchie Site Medication Case History #2

WHY DOES IT STILL WORK – 7 YEARS LATER?

1) No formal “bactericide” in the mixture, just milk?
2) Casein in the waste milk curdles when it encounters pH <4.6 conditions
3) This might create a “heat-seeking missile” effect that is pyrite-surface selective
4) Curdled milk is a protein, which is slow to degrade and would provide a long-term electron donor source for heterotrophic bacteria
5) Revegetated surface of the site provides a steady (sustainable) supply of acidophile-inhibiting organic acids. (Similar to Fisher Site)
Similarities and Differences

BCR Effluent would behave more like waste milk than the sequential approach by Plocus & Rastogi at the Fisher Mine

BCR effluent may oxidize more quickly when it encounters acidic conditions on a pyrite grain surface to form a biofilm

BCR effluent-derived biofilm wouldn’t contain much long-lived protein

BCR effluent will probably contain manganese, which should form abiotic coatings (over any surface) deeper in the mine waste column
Application Concept: Mine Dumps

Figure 1. Gravity segregation and resulting interbedded structure in waste rock dumps.

After G.W. Wilson, 2008
Preliminary “Medication” Cost Model

- Waste Rock Repository – 100 acres divided into 20-acre application zones
- Add 60 inches (152 cm) of BCR effluent for a year (34 m³/day)
- 8 hrs/day yields about 24 gpm
- Drip row spacing of 3 ft (1 meter)
Preliminary “Medication” Cost Model

- Capital cost $14,500 converts to fixed cost of $7,200/yr.
- Operating cost $19,000/yr.
- Total drip irrigation cost: $26,000/yr. for 20 acres
- BCR effluent $0.31/m³ or $4,000/yr.

Total cost of $30,000/annum or $1,500/acre treated ($3,700/ha)
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In Addition to Geochemical & Physical Controls...

- Good Bacteria fed with Organic Matter
- "PROBIOTIC" PATHWAY TO WALK-AWAY

GO FORTH & IRRIGATE
Thank You

Questions?

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