Preventing Acid Rock Drainage
Can Source Control Really Be Successful?

Paul Eger
Sovereign Consulting
Lakewood, Colorado
Acid Rock Drainage

IN PERPETUITY

Unless we can find practical source control remedies
Role of Bacteria

- Thiobacillus Ferrooxidans
- Gain energy through oxidation of iron sulfide minerals
- Thrive at low pH
- Dramatically increase rate of oxidation
Can we stop them?

• Bactericides
  – Jim Gusek
  – A Pathway to Wak-Away? - 30 Year Old Technology to Suppress Acid Rock Drainage Revisited

• Maintain neutral pH
Guido Sarducci’s 5 Minute University

Mine Waste Management
• “Know Thy Waste”
• Minnesota reclamation rules require all waste be characterized
• Is your waste reactive?
If the waste is reactive, then....

Do not pass go

Do not collect a permit
If you have reactive mine waste, then...

- Modify material
  - Physical characteristics
  - Chemical characteristics
- Modify environment
- Prevent water from contacting material
  - Collect and treat any residual water
Chemical Modification

- If waste is predicted to be acid generating one option is to add neutralizing material
- Work began in late 80’s early 90’s
- Successfully applied in coal industry
- MEND Report (1998) concluded this approach would not be successful in metal mines
Methods Considered

- End Dumping
- Random dumping
- Alternate layers
Is there a better way?
Can we simulate this on a pilot scale?

Practical example of chemical modification

Could it work for mine waste?
• Why should adding fine grained limestone to big rocks be anything but a hare brained scheme?
It's all about reactive surface area

<table>
<thead>
<tr>
<th>Underground Mine</th>
<th>Particle size, in</th>
<th>% passing</th>
<th>Sulfur content %</th>
<th>Specific surface area m²/gm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>12</td>
<td>100</td>
<td>0.6% bulk composition</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>38</td>
<td>0.67%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.0787</td>
<td>3</td>
<td>1.65-1.94%</td>
<td>2.6-4.7</td>
</tr>
<tr>
<td></td>
<td>0.0035</td>
<td>3</td>
<td>0.67%</td>
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</tr>
</tbody>
</table>
• Set up pilot experiment at Minnesota Department of Natural Resources Test Facility, Hibbing MN
• Archean greenstone
• Likely host rock for future metal discoveries in Minnesota
• Soudan Underground Mine
• Characterization
  – Sulfide 0.49%
  – Acid Production Potential = 30.6 lbs CaCO₃ equivalent / ton
  – Neutralization Potential = 12.6 lbs CaCO₃ equivalent / ton
  – NP/AP = 0.33

Laboratory tests with 0.39% to 0.50 % S, had produced acid within 4-12 weeks
Approach

• Add fine grained limestone to increase neutralization potential

• “Manufactured Sand”
   100 % minus 2 mm
   Magnesium rich, dolostone

• Increase NP/ AP ratio
  – 1:1
  – 3:1
Experimental Design

- Three treatments
- Each in duplicate
Rock or rock + limestone

Silica sand

1/2" I.D. slotted PVC pipe covered with geotextile

22 gal. calibrated collection sump
Rock screened to minus 2 inch
Results
<table>
<thead>
<tr>
<th>Treatment</th>
<th>Average Sulfate Concentration, mg/L</th>
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</thead>
<tbody>
<tr>
<td>Control</td>
<td>306</td>
</tr>
<tr>
<td>1:1</td>
<td>250</td>
</tr>
<tr>
<td>3:1</td>
<td>226</td>
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</tbody>
</table>
Another hare brained scheme vindicated!

- Adding fine grained alkaline material prevented acid drainage
- Both ratios worked (1:1, 3:1)
  - Maintained neutral pH
  - Reduced sulfate

Successful treatment for 16 years!

Currently being used at an active gold mine for waste management
Future Work

• Determine effect of treatment on trace metal release
• Mass release calculations
• Estimate lifetimes
Thank You!
It's all about reactive surface area

<table>
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<th>Tank Sample</th>
<th>Underground Mine</th>
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<tbody>
<tr>
<td>Particle size, in</td>
<td>% passing</td>
</tr>
<tr>
<td>12</td>
<td>100</td>
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OUTLINE

- Acid Rock Drainage
- Alkaline Addition
  - Theory
  - Applications
    - Coal
    - Metal
- Case Study
Sulfate vs Time, 2000-2016

- Time: 24-Jul-98 to 22-Sep-17
- Sulfate: 0 to 900
- Graph showing data points for different conditions (Control, 1 to 1, 3 to 1) over time.