Aeration of Net Alkaline Mine Drainage to Degas CO2, Increase pH and Iron Oxidation Rates

Carl Kirby, Adam Dennis, Adam Kahler
Objectives

• Aerate Net Alkaline Mine Drainage
  • Degas $CO_2$
  • Increase pH
  • Increase $Fe(II)$ Oxidation Rates
  • Model $Fe(II)$ concentrations, pH, alkalinity, $CO_2$
to predict pond size

• Compare to area required for passive treatment
  (no aeration)
Mine Drainage Chemistry

Formation:

• \( \text{FeS}_2 + \text{H}_2\text{O} + 7/2\text{O}_2 = \text{Fe}^{2+} + 2\text{SO}_4^{2-} + 2\text{H}^+ \)

or

• \( \text{FeS}_2 + 7/2\text{H}_2\text{O} + 15/4\text{O}_2 = \text{Fe(OH)}_{3,s} + 2\text{SO}_4^{2-} + 4\text{H}^+ \)

• \( \text{Fe}^{2+} + 1/4\text{O}_2 + \text{H}^+ = \text{Fe}^{3+} + 1/2\text{H}_2\text{O} \)

• \( \text{Fe}^{3+} + 3\text{H}_2\text{O} = \text{Fe(OH)}_{3,s} + 3\text{H}^+ \)
Net Alkalinity
From Kirby and Cravotta (2005)

• Either
  • If “hot acidity” < 0 (with negative values reported) or
  • measured alkalinity – calculated acidity > 0

  • Where calc. acidity, mg/L CaCO₃
    = 50000(2*Fe/56 + 3*Al/27 + 2*Mn/55 + 10³*10⁻pH)

• In practice, water with metals removed will have pH ≥ 6.3
Increasing pH dramatically increases Fe(II) oxidation rates.

\[
\frac{d[Fe(II)]}{dt} = -k[Fe(II)][O_2][H^+]^2
\]
Study Area Location

Shamokin Creek Watershed, Streams, and Mine Discharges
Field Setting

Photos courtesy of S. Kirby and Jim Koharski.

Figure courtesy USGS 7.5” Shamokin Quad.
Field Setup

Influent from mine drainage

YSI multimeter; logs pH, DO, T

Iron hydroxide “sludge”

Air diffuser stones

Sonde (contains YSI probes)

Outflow for sample collection

Air pump

Metering pump
Fe(II) = 16 mg/L
Al < 0.5 mg/L
pH 5.7
Alk = 117 mg/L CaCO₃

Flow = 2000 L/min
scaled to reactor

Site 21 Field Setup

Fe(II) = 16 mg/L
Al < 0.5 mg/L
pH 6.1
Alk = 170 mg/L CaCO₃

Flow = 17400 L/min

Packer 5 Site
Figure X. Schematic diagram representing the mathematical relationships in Model 2. Arrowheads point to parameter that is a function of the parameter at the initial end.
Compare to Hedin et al. (1994) Estimate - $\left(\frac{20g}{m^2}\right)/\text{day}$

### Winter (5 °C), 1 m deep

<table>
<thead>
<tr>
<th>Site</th>
<th>Acres Hedin</th>
<th>Acres Model 2</th>
<th>HP Model 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site 21</td>
<td>1</td>
<td>0.1</td>
<td>15</td>
</tr>
<tr>
<td>Packer 5</td>
<td>5</td>
<td>0.5</td>
<td>50</td>
</tr>
</tbody>
</table>

### Summer (20 °C), 1 m deep

<table>
<thead>
<tr>
<th>Site</th>
<th>Acres Hedin</th>
<th>Acres Model 2</th>
<th>HP Model 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site 21</td>
<td>1</td>
<td>0.1</td>
<td>8</td>
</tr>
<tr>
<td>Packer 5</td>
<td>5</td>
<td>0.5</td>
<td>25</td>
</tr>
</tbody>
</table>
10X smaller pond with aeration.....

...but what about the settling pond?
Conclusions

- Aeration method very effective for net alkaline, high-CO$_2$ waters
  - pH increase promotes rapid Fe(II) oxidation
- With aeration treatment ponds at least 10x smaller than passive treatment
- Can apply to effluent from ALD’s
- Settling pond of unknown size would need to follow oxidation pond
Future Research

Estimate costs of a building/running a treatment system

Investigate aeration methods

FlexLine™ Nonbuoyant Tubular Fine Bubble Diffuser

Environmental Solutions LLC “Maelstrom Oxidizer”
Future Research

Investigate aeration methods

Aeration Solutions Inc.
Diffuser grid and blower
Future Research

Characterize sediment for pigment quality
Acknowledgments:

Shamokin Creek Restoration Alliance

PA Dept. of Environmental Protection
Growing Greener Program

Dr. Charles A. Cravotta, III

Katherine Mabis McKenna Foundation

Michael Dennis
Questions?