Direct versus Terrestrial Liming for Mitigating Acidity in Streams

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Acid Deposition

• Increased acid content in precipitation
• Caused by anthropogenic emissions of $\text{SO}_2$ and $\text{NO}_2$ gases
Chemistry of Acid Deposition

SO₂ + ·OH → ·SHO₃ (alt. oxidants O₃ or NO₂)

·SHO₃ + O₂ → SO₃ + ·OOH

SO₃ + H₂O → H₂SO₄

SO₂ + H₂O → H₂SO₃ (aq)

H₂SO₃ (aq) + H₂O₂ (aq) → H₂SO₄ + H₂O

N₂ + O₂ + heat → 2NO

NO + O₃ → NO₂ + O₂

NO₂ + ·OH → HNO₃
Effects of Acid Rain on Stream Chemistry

- Weathering of bedrock is the main contribution to ionic composition of stream water
- Charge balance:
  \[ [H^+] + 2[Ca^{2+}] + 2[Mg^{2+}] + [K^+] + [Na^+] = [OH^-] + [Cl^-] + [NO_3^-] + 2[SO_4^{2-}] + [HCO_3^-] \]
- Acid neutralizing capacity (ANC)
  - a.k.a. alkalinity or $[HCO_3^-]$
- 800 USFS stream samples: pH versus observed alkalinity
Little Stony Creek: Annual Average ANC and $\text{SO}_4^{2-}$ Concentration Values

Pyszka, 2017
Acidification and Recovery of Surface Waters

Lawrence et al., 2016
Mitigation Strategies: Liming

• Stream liming
  • Direct introduction of lime material to stream water
  • Targets aquatic system
  • Application method: dump truck, front-end loader or helicopter

• Terrestrial (watershed) liming
  • Application of lime material over a specific area of land
  • Indirect introduction to stream water
  • Targets aquatic and terrestrial systems
  • Application method: helicopter or fixed-wing aircraft

https://www.awapa.org/marketingpromotion
Stream Liming

• Benefits
  • Immediate effects on water chemistry
  • Point application
  • Tailored to stream flow and chemistry
  • Predictable
  • Low relative cost
  • Single treatment within days

• Limitations
  • Does not mitigate the effects of acid rain on soils and terrestrial vegetation
  • Limited treatment duration
  • Treatment occurs downstream of liming site
  • Requires road access
  • Higher cost for helicopter
Dosage Calculations—Little Stony Creek

<table>
<thead>
<tr>
<th>Model</th>
<th>Limestone Dose (tonnes/yr)</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>1996</td>
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<tr>
<td>Deposition</td>
<td>13.50</td>
</tr>
<tr>
<td>“Lost” ANC</td>
<td>6.95</td>
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<tr>
<td>Sulfate equivalence</td>
<td>20.1</td>
</tr>
<tr>
<td>Target ANC/pH</td>
<td>4.05</td>
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</tbody>
</table>

• “Deposition” Model – to offset input of $H^+$ and $NH_4^+$
• “Lost” ANC model – based on late 1980s data
• “Sulfate” Model – the amount equal to sulfate input minus the natural amount present in stream water
• “Target” Model – to achieve pH 6.5 and 25 µeq/L ANC

Pyszka, 2017
Watershed Liming

• Benefits
  • Could supply Ca$^{2+}$ to soils that are base cation-depleted
  • Long-term treatment
  • Can treat entire stream reach
  • Whole ecosystem treatment

• Limitations
  • Relative high cost
  • Does not replace all depleted base cations
  • Difficult to predict mass of limestone needed for treatment
  • Takes time to manifest in stream water chemistry
  • Could be detrimental to plants/animals that prefer acidic habitats (Ex: Swamp Pink)
  • Significant logistical considerations

https://foldedpetals.wordpress.com/2015/02/06/get-to-know-an-endangered-plant-swamp-pink/
Comparison of Direct Stream Liming and Watershed Liming for St. Mary’s Wilderness for a 50-year Treatment Period

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Stream Liming</th>
<th>Watershed Liming</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dosage</td>
<td>25.9 tonnes/yr</td>
<td>6.89 tonnes/ha</td>
</tr>
<tr>
<td>Treatment</td>
<td>182 tonnes</td>
<td>27,900 tonnes</td>
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<tr>
<td>Total Limestone</td>
<td>1,274 tonnes</td>
<td>27,900 tonnes</td>
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<tr>
<td>Treatment Time</td>
<td>1 day (7 days)</td>
<td>155 days</td>
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<tr>
<td>Duration per Treatment</td>
<td>7 years</td>
<td>50 years</td>
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<tr>
<td>Miles treated</td>
<td>10 mi</td>
<td>15 mi</td>
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<tr>
<td>Soils</td>
<td>No</td>
<td>Yes</td>
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<tr>
<td>Vegetation</td>
<td>Aquatic only</td>
<td>Yes</td>
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<tr>
<td>Flora/Fauna Risk</td>
<td>No</td>
<td>Potential</td>
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<tr>
<td>Cost/Labor</td>
<td>High</td>
<td>Very high</td>
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<tr>
<td>Predictable Outcome</td>
<td>Yes</td>
<td>Unproven</td>
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</table>

Driscoll et. al., 1996
Acknowledgements

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References


