Long-Term Ecological Responses to Alum Treatment in Spring Lake, Michigan

Mary E. Ogdahl and Alan D. Steinman

Grand Valley State University
Annis Water Resources Institute
740 W. Shoreline Dr.
Muskegon, MI
Internal vs. External Phosphorus Loads

External Phosphorus Loading:
Phosphorus entering surface waters that originates outside the water body (watershed, atmosphere)

Internal Phosphorus Loading:
Release of P from sediments

1) diffusion of soluble phosphorus from sediments during periods of anoxia

2) resuspension-driven processes whereby soluble P is desorbed from particulate matter or released from the pore water
Sediment-Water Interactions

- SRP bioavailable
- PP particulate
- Uptake
- Release
- Diffusion
- Resuspension
- Precipitation (Fe/Ca)
- Mineraliz’n
- Sedimentation
- Water
- Sediment
- alum
Highly effective P inactivation

- Formation of insoluble precipitate
- AlOH floc adsorbs P

Longevity of treatment varies

- 4-20 years?
- Simultaneous control of external loading is essential
Lake surface area: 5.25 km²
Max. Depth: 13 m
Mean Depth: 6 m
Agriculture 18%
Forested/Undeveloped 57%
Wetlands 6%
Urban 19%
Total Phosphorus: Spring Lake
Objectives:

Experiment 1: 2003-2004
Before field application of alum

- Compare internal vs external P loading rates
- Determine the effectiveness of alum in reducing internal P loading
- Based on lab studies, assess whole-lake alum application
<table>
<thead>
<tr>
<th>Redox</th>
<th>$\text{N}_2$ (anaerobic)</th>
<th>$\text{Alum-N}_2$</th>
<th>$\text{No Alum-N}_2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\text{O}_2$ (aerobic)</td>
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TP Release from Sediment Cores

Steinman et al. 2004
# TP Load Estimates

<table>
<thead>
<tr>
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<th>Estimate</th>
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<tr>
<td><strong>External Load</strong></td>
<td>2.2-4.7 tons yr(^{-1})</td>
</tr>
<tr>
<td><strong>Mean Internal Load</strong></td>
<td>2.7-6.4 tons yr(^{-1})</td>
</tr>
<tr>
<td><strong>Internal:Total Load</strong></td>
<td>55-67%</td>
</tr>
</tbody>
</table>

*Lauber 1999  
**Steinman et al. 2004
Total application: 1.2 million gallons
Treatment area: ~2.4 km² (46%)
Treatment dose: ~80 g Al/m²
Objectives:

Experiment 2: 2006
1 year after alum treatment
• Measure short-term internal P release rates
• Evaluate the short-term ecological effects

Experiment 3: 2010
5 years after alum treatment
• Measure long-term internal P release rates
• Evaluate the long-term ecological effects
## Maximum TP Release Rates (mg P m\(^{-2}\) d\(^{-1}\)) - Anaerobic Cores -

<table>
<thead>
<tr>
<th>Site</th>
<th>Pre-alum*</th>
<th>1 y after**</th>
<th>5 y after</th>
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<tbody>
<tr>
<td>1</td>
<td>29.54</td>
<td></td>
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</tr>
<tr>
<td>2</td>
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</tr>
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* Steinman et al. 2004  
** Steinman and Ogdahl 2008
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* Steinman et al. 2004
** Steinman and Ogdahl 2008
### Maximum TP Release Rates (mg P m$^{-2}$ d$^{-1}$)

- **Anaerobic Cores**

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<td>2.25</td>
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* Steinman et al. 2004
** Steinman and Ogdahl 2008
Total P: Before vs. After Alum

Alum applied

$p<0.001$

Source: Progressive AE
Chlorophyll a: Before vs. After Alum

Alum applied

$p=0.056$
Invertebrate Density: Before vs. After Alum

$p<0.005$
Invertebrate Community Composition

Mean (+SE) Invertebrate Density (Organisms/m²)

- Chironomidae
- Chaoboridae
- Oligochaeta
- Ceratopogonidae

Before 1 Year 5 Years
Conclusions

• The invertebrate community has recovered from the decline observed 1 year after treatment

• Alum continues to be highly effective at reducing sediment P release rates, but its efficacy is beginning to decline

• Water column P remains sufficiently high to fuel algal biomass at or above eutrophic levels

• Control of external sources of P is essential for further improvements in the lake and continued success of the alum treatment
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- Gail Smythe
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- Eric Nemeth
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- Pam Tyning – Progressive AE
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