Enhancing Water Quality with Phosphorus Binding Technology

Reducing internal phosphorus loading and associated HABs in Clear Lake

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“Clearlake’s economy has historically been tied to agriculture, tourism, and geothermal power. During the late 1800s/early 1900s, Lake County was considered a resort destination” – City of Clearlake 2040 General Plan
What’s all the Fuss about Phosphorus?

- **High Phosphorus (P) Favors Blue-green algae (BGA)**
  - Many BGA can fix atmospheric nitrogen (N₂ gas)
  - Other algae need dissolved inorganic nitrogen
  - ↑ N:P ratio provides a competitive advantage for other algae

- **BGA don’t get eaten – after death and decay nutrients are released**
  - BGA produce cyanotoxins to deter zooplankton predation
  - Other algae are eaten, transferring nutrients up food web

- **In a perfect world: Enough P to grow beneficial algae, without stimulating BGA**
  - Clear Lake = “Bass Capital of the West”
  - Big fish requires a big food web – algae and zooplankton are vital
Where is Phosphorus Coming From?

UC Davis Research suggests ~60% from sediment release
- Mostly during anoxic conditions
- No/limited release when oxic
- Implicates iron-reduction as main driver

**Annual Internal Load**

<table>
<thead>
<tr>
<th>P-Loading Source</th>
<th>P-Species</th>
<th>Annual Load (MT yr⁻¹)</th>
<th>% Annual SRP load</th>
</tr>
</thead>
<tbody>
<tr>
<td>External</td>
<td>SRP</td>
<td>37.1 - 51.4¹</td>
<td>59-67% 35-43%</td>
</tr>
<tr>
<td>Internal</td>
<td>SRP</td>
<td>25.6</td>
<td>39-41% 57-65%</td>
</tr>
</tbody>
</table>

Phosphorus Release Via Iron-Reduction
Can Phoslock Prevent P-Release?

UC Davis 2020 sediment core incubations suggests it can!

[Graph showing water column P (mg) vs. Sediment Incubation Day for Oaks Arm, with lines for Control 1, Control 2, Phoslock, TDP, and SRP.]

[Bar charts for Clear Lake Oaks and Lower Clear Lake showing Total P Released (mg) for Control and Phoslock, with bars for SRP (mg) and TDP (mg).]
Phoslock Basics

- **LMB is novel phosphorus sequestering geochemical technology**
  - $\text{La}^{3+}$ has a very high binding affinity for $\text{PO}_4$
  - 5% lanthanum by weight, imbedded in clay matrix

- **Developed by Australian government research facility in late 1990s**
  - More than 80 peer reviewed articles
  - 300+ lakes treated globally

- **Often used where Alum is banned**
  - Becoming popular in Europe, China, SE Asia and Oceania
  - More environmentally friendly – low/no ecotoxicity
Phoslock Benefits

• Great at binding PO₄ released from Iron-oxides
  • Forms anoxia/pH stable mineral
  • Permanently removes P from cycle

• Essentially no aquatic ecotoxicity
  • Very high No Observed Effect Concentration (NOEC)
  • > 3,000 mg/L for all fish tested
  • ~ 10 mg/L effective dose

• Allows for Nitrogen release from sediment
  • Enhances N:P ratio to favor beneficial algae

• Reduces sediment OM accumulation
  • Reduces prevalence of anoxia

• Enhances sediment stability/integrity
  • Reduced resuspension from wind/waves

• Can reduce germination rate of dormant cyanobacteria
  • Reduces light and nutrient availability
Phoslock Mechanisms

- Bentonite (Clay, aluminosilicate) with Lanthanum embedded
  - Keeps La\(^{3+}\) in sediment where it can bind released PO\(_4^{3-}\)
  - Essentially eliminates dissolved La\(^{3+}\)

- La\(^{3+}\) has extremely high affinity for PO\(_4^{3-}\)
  - Best binding between pH 6 – 8, good binding pH 5 – 9
  - Clear Lake water pH = 7.5 – 8, sediment likely ~ 7
  - Forms Rhabdophane and Monazite minerals

- In absence of PO\(_4^{3-}\), La\(^{3+}\) reacts with OH\(^{-}\) or CO\(_3^{2-}\) to form insoluble compounds [La(OH)\(_3\) and La\(_2\)(CO\(_3\))\(_3\)]
  - La\(^{3+}\) is only dissolved if complexed with Cl\(^{-}\), SO\(_4^{2-}\), NO\(_3^{-}\), or DOC
  - None of these bonds are thermodynamically favored in Clear Lake (Hardness ~ 100 – 150 mg/L)
Preventing Algal Blooms with Phoslock

Clear Lake

Clear Lake + Phoslock
Redox Stabilization with Phoslock

Clear Lake

- Redox State
  - Aerobic (O₂)
  - Nitrate (NO₃)
  - Iron (Fe³⁺)
  - Sulfate (SO₄)
  - Methanogenic

- Sulfide

Clear Lake + Phoslock

- Redox State
  - Aerobic (O₂)
  - Nitrate (NO₃)
  - Iron (Fe³⁺)
  - Sulfate (SO₄)
  - Methanogenic

- Phoslock
Reducing Dormant BGA germination with Phoslock

Light and SRP exposure = higher germination rate

Light and SRP barrier = lower germination rate

Clear Lake

Clear Lake + Phoslock
Phoslock Success Stories

• Meta-analysis of 18 lakes treated with Phoslock
  • Significant decreases in total/reactive phosphorus and chlorophyll a, as well as a significant increase in Secchi disk depth
  • Published in Water Research “A meta-analysis of water quality and aquatic macrophyte responses in 18 lakes treated with lanthanum modified bentonite (Phoslock)”

• Laguna Nigel Lake, CA
  • 370 acre-ft reservoir in Orange County
  • Phoslock added after aeration system failed to reduce persistence of harmful algal blooms
  • Cyanobacteria abundance dropped by more than 90% following Phoslock application
  • Local home values significantly increased
  • Details available in Scientific journal article: “Operational Evaluation of Phoslock Phosphorus Locking Technology in Laguna Niguel Lake, California”

• Mason Lake, CA
  • Soluble phosphorus reduced from 620 ppb to non-detect, total phosphorus reduced by 50%.
  • Secchi disk depth improved from 0.25 ft to 3.5 ft
  • A major shift in algae community from toxic blue-green to beneficial green algae
  • Resulted published in Land & Water – Lake Management (May, 2011) “A New Tool for Proactive Water Quality Restoration”

• Lake Pampulha, Brazil
  • Water quality and HABs so horrible that drinking water treatment operations ceased
  • Regular Phoslock applications began in 2016
  • Cyanobacteria replace by beneficial algae
  • Water quality continues improve despite intense external loading
  • Results published in 2020 Ecological Indicators journal article: Barcante et al. “Cyanobacteria dynamics and phytoplankton species richness as a measure of waterbody recovery: Response to phosphorus removal treatment in a tropical eutrophic reservoir”.

• Xinyun Lake, China
  • 3,000 tons applied in 2019
  • Results met or exceeded all expectations and 4,000 tons planned for 2020


• Ecotox, 2006a. Toxicity Assessment of Two PhoslockTM Formulations to the Eastern Rainbowfish. ECOTOX Services, Australia.


Phoslock
Notable Articles
Proposed Demonstration Site: Clearlake Keys (Right side)

- Highly populated marinas
- Nearby sewage treatment plant
- Likely low flow due to obstruction
- High cyanobacteria abundance
- Small area for demonstration (~45 acres total)
- Right side treatment, left side control comparison
  - Monitoring by UC Davis TERC team
Potential Funding Source

2021 Nonpoint Source Pollution Control Grant:
*Due December 18, 2020

- "These grant funds can be used to implement projects or programs that will help to reduce NPS pollution. Projects that qualify for funding must be conducted within the state's NPS priority watersheds. Project proposals that address Total Maximum Daily Load implementation and those that address problems in impaired waters are favored in the selection process. In addition, the NPS Grant Program funds projects that implement forest management measures on forest lands to improve water quality. There is also a focus on implementing management activities that lead to reduction and/or prevention of pollutants that threaten or impair surface and ground waters."

- Project Type: Implementation of practices to improve impaired waters:
  - Funding minimum = $250k, maximum = $800k

Key Points:
1. How it addresses the phosphorus problem in Clear Lake (impaired)
2. How it can prevent HABs that threaten the surface water
3. Previous evidence from the UC Davis chamber incubation study
4. Potential to improve tourism and the local economy
5. How it could benefit subsistence fishing and the Pomo community
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The only US Authorized retailer of Phoslock phosphorus locking technology
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Our Water Quality Team

Dedicated to sustainable, effective solutions driven by science.

Supported by a 410-acre Research & Technology Campus with a full-service laboratory.

- **Ajay Jones, PCA**
  - Technical Specialist for CA
  - Projects with C DFA, CDBWW, CA DWR
  - Competent in scientific data modeling
  - M.S in Water Resource Science from University of Minnesota
  - Various publications on aquatic plants and water quality
  - Over 13 years of experience
- **Dr. Byran Fuhrmann, MBA**
  - Aquatic Technology Development Scientist
  - Northern California Director of the California Lake Management Society (CALMS)
  - More than 7 years of experience in water quality
- **Dr. West Bishop, Certified Lake Professional (CLP)**
  - Algae Scientist and Water Quality Research Manager
  - Author of more than 15 publications on water quality and lake management
  - More than 13 years of experience
- **Dr. Mark Heilman**
  - Director of Aquatic Research
  - President of Aquatic Plant Management Society (APMS)
  - Over 35 years of experience
- **Scott Shuler**
  - Regional Sales Manager - West
  - More than 14 years working in the CA Delta
- **Mike Pearce**
  - Water Quality Portfolio Leader
  - Over 14 years experience as Irrigation Manager
Future Technology:
Natural Solid Adsorbent

- Natural material that is modified to preferentially adsorb SRP
  - Will be OMRI (Organic) certified
  - Can be reused as fertilizer – available to plants, but won’t be released in runoff/groundwater

- Material contained in mesh sacks and anchored to sediment
  - Ideally before spring/summer anoxia
  - Could be used with algaecides to bind released SRP
  - Replace when saturated

- ~1 lb P removed per 100 lbs of material
  - 1 lb of P can grow 500 lbs of algae

- Coming 2021 - Stay tuned!
  - We would love to collaborate or hold demonstration project
Summary

- HABs stimulated by excess phosphorus
- Excess phosphorus comes from internal release from sediment
- UC Davis sediment incubation study showed Phoslock dramatically reduces SRP
- Clear Lake Sediment and water chemistry appears perfect for Phoslock
- Phoslock has many benefits, is very safe and approved for drinking water
- Benefits include reduced surface water SRP, stabilized sediment redox, reduced dormant BGA germination, and enhanced sediment stability
- A demonstration in Clear Lake Keys appears to be the perfect next step.

Questions Welcomed!