Using Phoslock® to control cyanobacteria in a shallow eutrophic Scottish reservoir - assessing its impact on sediment phosphorus pools

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a CEH Edinburgh, b CEH Lancaster, c Cardiff University
I) Lake remediation
   Scientific background
   Knowledge gaps

II) Study site & methods

III) Results Clatto Reservoir

IV) Conclusions
I) Scientific background

-Alternative stable states
-Regime shifts
-Internal load management


Phoslock® as tool:
- intercept internal loading
- regime shift
- forced state change
I) Knowledge gaps

1) *Where* is Phoslock® following a common application?

2) *How* does Phoslock® effect P pools?

3) *When* does Phoslock® alter P pools? Timing of application?
II) Study site & methods

Clatto Reservoir (Dundee, UK)
Area: 9.4 ha
Mean depth: 2.75 m
Max depth: 7 m

Water
depth

Sediment
depth

2 cm slices (0 – 10 cm depth)
Homogenized

Analyses of P pools/fractions
Psenner *et al.*, 1988
modified by Hupfer
*et al.*, 1995

Elemental analyses (ICPOES, ICPMS)
II) Study site & methods

Sampling

05.02.2009 begin monitoring

02.03.2009 pre-application cores
04.03.2009 start application
06.03.2009 end application

03.04.2009 post-application cores

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1) **Where** is Phoslock® following a common application?
Use of lanthanum as ‘tracer’

Variability in horizontal distribution

→ higher lanthanum concentrations in deeper (targeted) areas
III) Where is Phoslock®?

Use of lanthanum as ‘tracer’

- Variability in vertical distribution
  - higher lanthanum concentrations at sediment surface

![Image of sediment sample]

**Average SP 1-4**

Graph showing lanthanum concentration vs. sediment depth.
Potential driver of changes in horizontal and vertical Phoslock® distribution:

- bio-turbation (vertical)
- macrophyte growth (vertical)
- wind induced sediment re-suspension (horizontal)
- sediment ‘focussing’ (horizontal)

Magnitude and combinations of drivers are likely to be highly site specific.
2) *How does Phoslock® effect P pools?*
### III) How does Phoslock® affect P pools?

<table>
<thead>
<tr>
<th>‘Pool’ or ‘Fraction’</th>
<th>Example</th>
<th>P release – driver</th>
<th>P release – seasonality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Labile P</td>
<td>PO₄-P</td>
<td>Diffusion</td>
<td>W S S A</td>
</tr>
<tr>
<td>Reductant soluble P</td>
<td>Predominantly P bound to Fe(III) and Mn(IV) hydroxides</td>
<td>Anoxia</td>
<td>- - S A</td>
</tr>
<tr>
<td>Organic P</td>
<td>Various organic compounds (i.e. algae, microorganism, detritus)</td>
<td>Mineralization (Temperature)</td>
<td>W S S A</td>
</tr>
<tr>
<td>Metal oxide adsorbed P</td>
<td>Predominantly P bound to Al, Fe and other metal oxides</td>
<td>High pH (Photosynthetic activity)</td>
<td>- - S A</td>
</tr>
<tr>
<td>Apatite P</td>
<td>Carbonate bound P</td>
<td>Low pH</td>
<td>- - - -</td>
</tr>
<tr>
<td>Residual P</td>
<td>Various refractory compounds</td>
<td>---</td>
<td>- - - -</td>
</tr>
</tbody>
</table>

**Legend:**
- **W**: winter (December, January, February)
- **S**: spring (March, April, May)
- **A**: summer (June, July, August)
- **S**: autumn (September, October, November)

**Bold letter P release predominantly in this month**
III) How does Phoslock® affect P pools?

- Reductant soluble P pool = largest P pool pre & post application

- Reduction in reductant soluble P pool

- No obvious increase in other P pool
Changes in sediment P concentration

→ potential causes of reduction:

→ hypothesis I: dilution effect
III) How does Phoslock® affect P pools?

Investigation of potential **dilution effect** – *mass balance estimate*

<table>
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<tr>
<th>Elemental analyses</th>
<th>calculated post-application concentration µg P g⁻¹ sed.</th>
<th>measured post-application µg P g⁻¹ sed</th>
<th>difference calculated vs. measured µg P g⁻¹ sed</th>
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<td>2322</td>
<td>2160</td>
<td>163</td>
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<td>2324</td>
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<td>6-8</td>
<td>1232</td>
<td>1253</td>
<td>-21</td>
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<tr>
<td>8-10</td>
<td>1204</td>
<td>1059</td>
<td>145</td>
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</tbody>
</table>

Data from elemental analyses supports dilution theory
III) How does Phoslock® affect P pools?

Investigation of potential **dilution effect** – *mass balance estimate*

<table>
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<th>sediment depth</th>
<th>calculated post-application concentration</th>
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**Psenner analyses**

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<tr>
<td>0-2</td>
<td>758</td>
</tr>
<tr>
<td>2-4</td>
<td>632</td>
</tr>
<tr>
<td>4-6</td>
<td>64</td>
</tr>
<tr>
<td>6-8</td>
<td>-198</td>
</tr>
<tr>
<td>8-10</td>
<td>115</td>
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→ Psenner underestimation of post-application concentrations (=large difference)
→ Larger error using Psenner for absolute concentrations
III) How does Phoslock® affect P pools?

Changes in sediment P pools

→ potential causes of reduction:
  → hypothesis I: dilution effect

→ Reduction in pool resulting from dilution

→ Phoslock® (i.e. lanthanum) does not compete with existing pools
1) *When* does Phoslock® alter P pools?
III) When does Phoslock® alter P pools?

So far…

➔ Phoslock® does not compete with existing pools

Hypothesis…

➔ Phoslock® binds P as soon as it is released from any given pool

➔ Clatto: largest amount of P stored in reductant soluble pool ➔ release in late summer/autumn

Future work…

➔ Analysis of sediment cores from late summer/autumn to verify or reject hypothesis
III) When does Phoslock® alter P pools?

So far…

→ Phoslock® does not compete with existing pools

[Suggested timing of application:]

Trade-off between **maximum instant P binding**

(=application during period when P has been released from major pool, often late summer/autumn)

vs.

Periods of **high biological activity**
IV) Conclusions

• **Spatial Phoslock\textsuperscript{®} distribution:** Phoslock layer varies spatially (horizontally & vertically)
  → additional temporal variation likely in shallow lakes

• **Effect on P pools:** No competition between lanthanum and sediment P pools
  → here: reduction in sediment P concentration dilution effect

• **Timing of effect on P pools:** Hypothesis: Phoslock\textsuperscript{®} (i.e. lanthanum) binds P as soon P is released from pools under natural conditions

• **Sampling & methods:** P content & elemental composition of sediments spatially variable
  → high spatial coverage required
  → complementary analyses required (i.e. check of Psenner vs. EA)