Nutrient limitation in freshwater ecosystems – experiences with Phoslock from field studies

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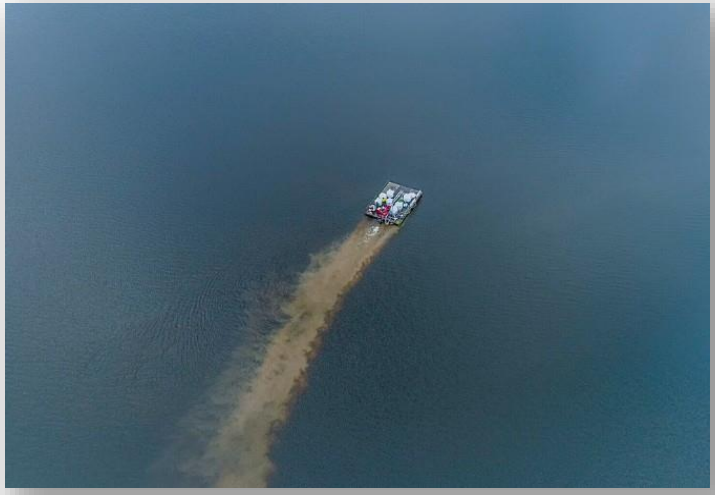
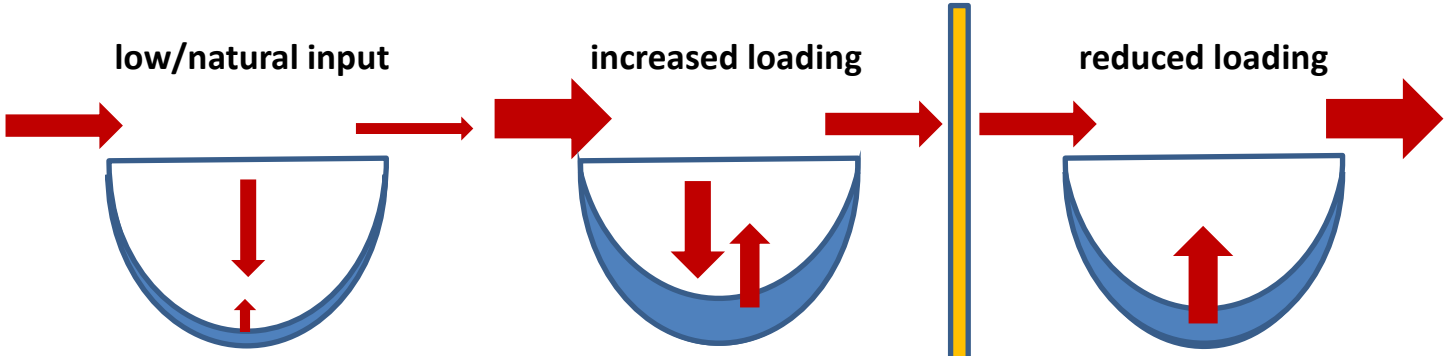
Topics

- 1. Introduction
  - Eutrophication
  - Phoslock
  - Technical characteristics
  - Application techniques
  - Dose calculations
- 2. Examples
  - Multi treatment application
  - Single treatment application
  - (Benthic algae treatment)
- 3. Conclusions and discussion



Eutrophication

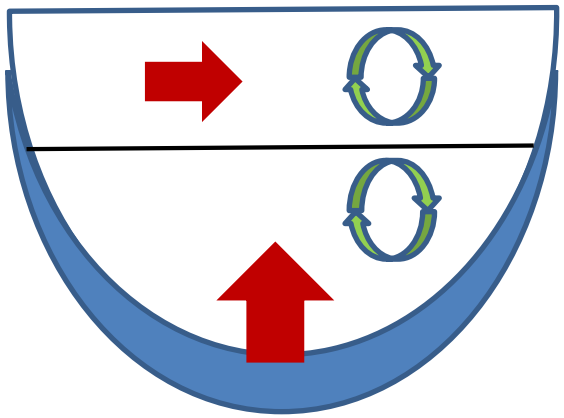


Lakes with low nutrient input: low sedimentation

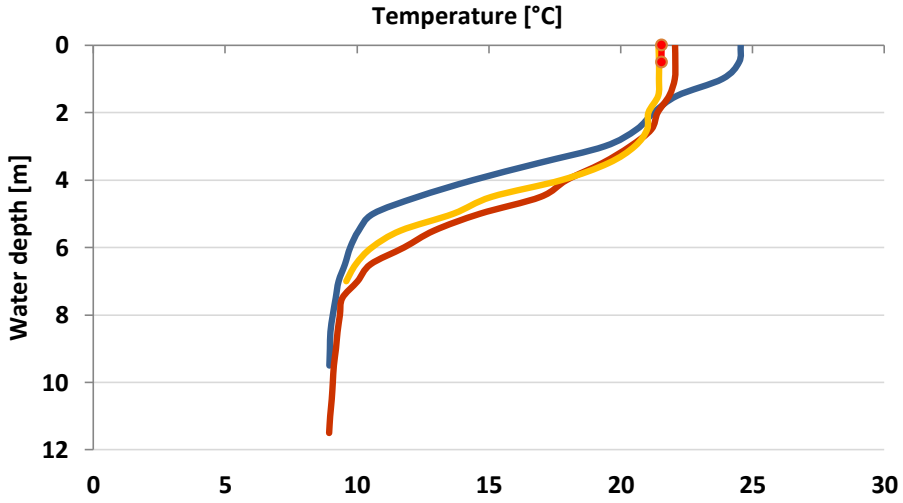
Eutrophication: strong sedimentation = big sediment layer

After reduced external nutrient load: Nutrient release from the sediment = internal fertilization

Stratification

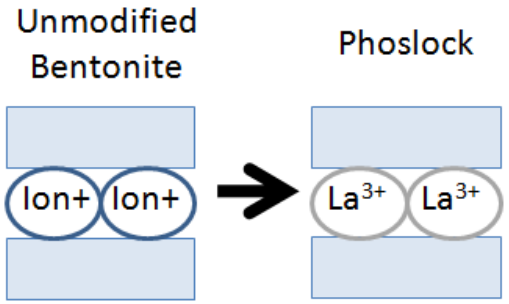


- small flow through layer
- nutrient release from the sediment
- nutrient transport at the boundary layer



Phoslock® - Technical Characteristics

- **Developed by the Australian Government's CSIRO in 1990s**
- **Base Material: Bentonite**
- **Modification: Enriched with lanthanum (La^{3+})**
  - Lanthanum is a Rare Earth Element (REE)
  - But is not rare: 40 mg/kg earth's crust
  - 3 times more abundant than lead



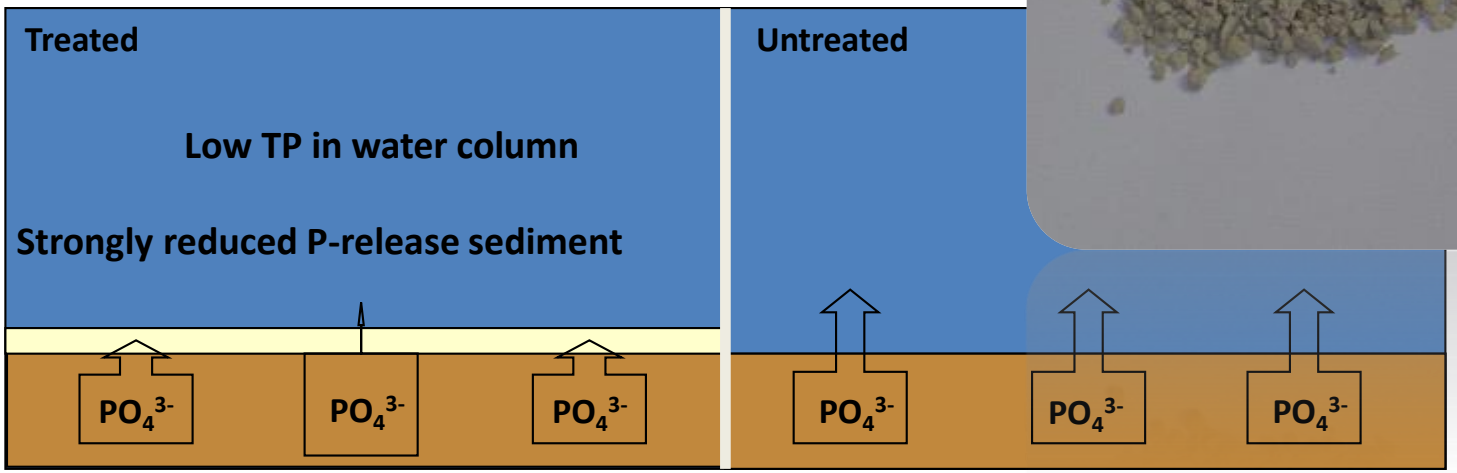
- **Binds Phosphate and other oxyanions**
  - Phosphate is the key nutrient for eutrophication
  - 1 t Phoslock® -> binds 11 kg Phosphorus
  - Full binding capacity between pH 5 and 9
  - Bound as mineral (e.g. Monazite = $LaPO_4$)
  - Once bound, never re-released

$$La^{3+} + PO_4^{3-} \rightarrow LaPO_4$$

Phoslock® - Technical Characteristics

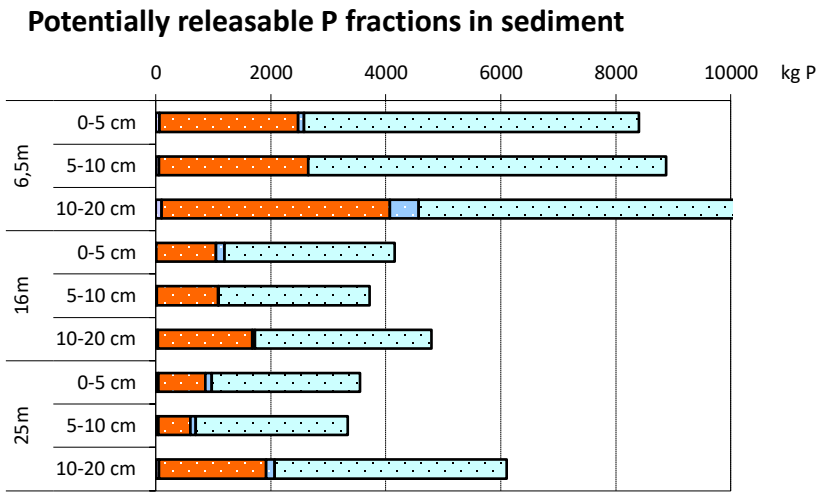
Designed for ‘capping sediments’:

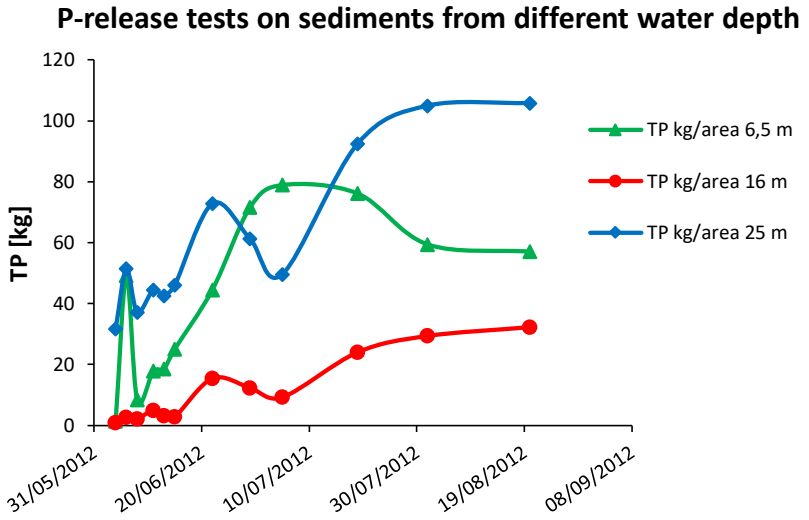
$$La^{3+} + PO_4^{3-} \rightarrow LaPO_4\,(s)$$



P-determination and dose calculation

Psenner analysis and
P-release tests





Phoslock application techniques

Multi treatment: Lake Bärensee

Artificial lake
Recreational lake within biggest camping site in Hessen State in Germany

area	6 ha
volume	156 000 m³
avg. depth	2.6 m
max. depth	3.8 m

External sources:

- ≈220 swimmers / day (220 x 94 mg P/d*)
- groundwater
- run-off

Internal sources:

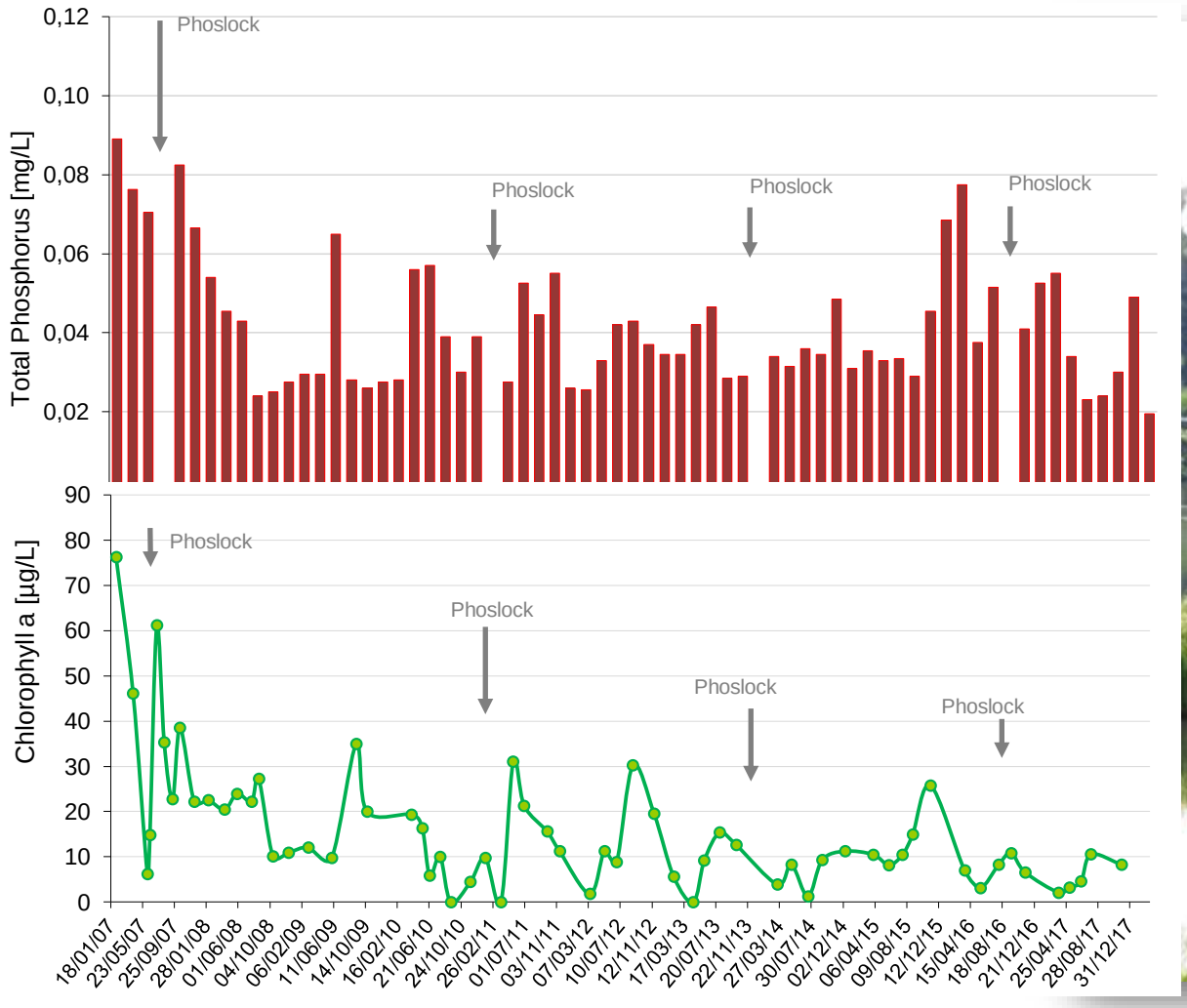
sediment contains:

- 93 kg releasable Phosphorus (<4cm)

Status in 2007 before restoring:
eutrophic: 90 µg TP/l l (14 kg TP)
- cyanobacterial blooms and
- visibility below 50 cm

*SCHULZ, L. 1981: Nutrient input in lakes by bathers
Zentralbl. Bakteriol. Mikrobiol. Hyg. Ser. B Umwelthyg. Krankenhaushyg. Arbeitshyg, Praev. Med. 173:528-548

Results (TP and Chl-a)



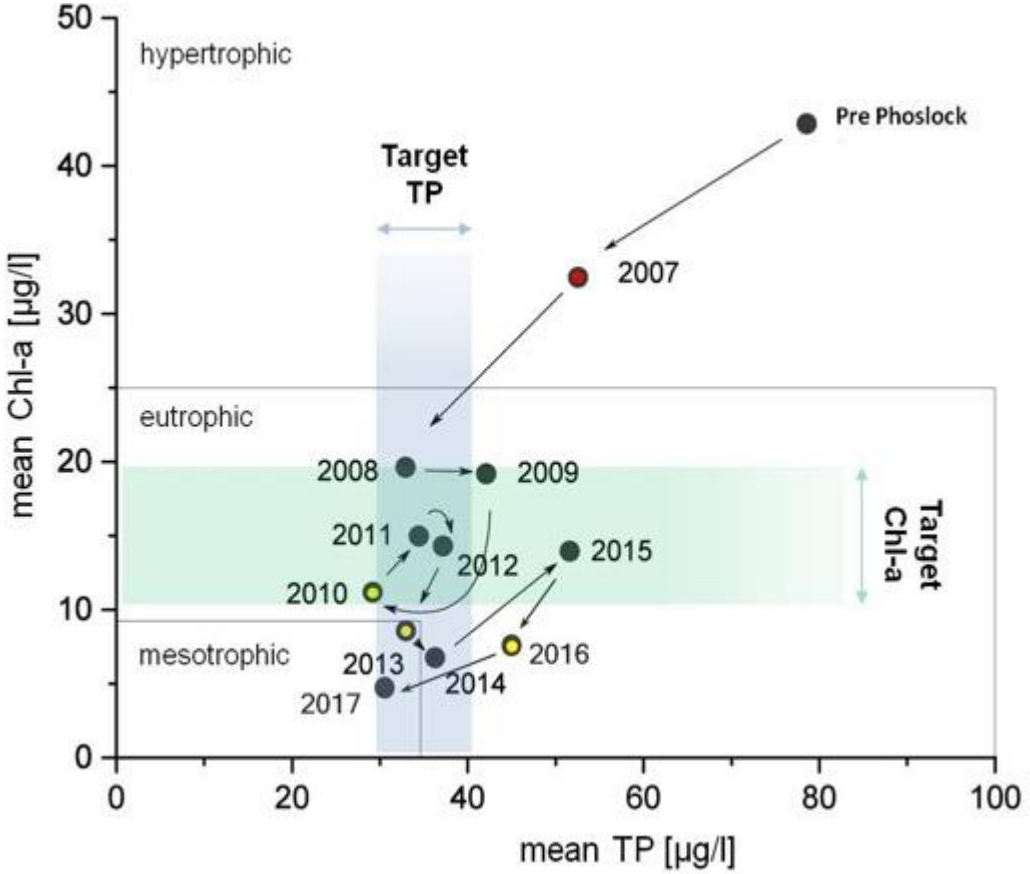
Results*

Chl-a, TP:

- significant changes before and after initial LMB application in 2007
- and re-applications in 2010, 2013 and 2016

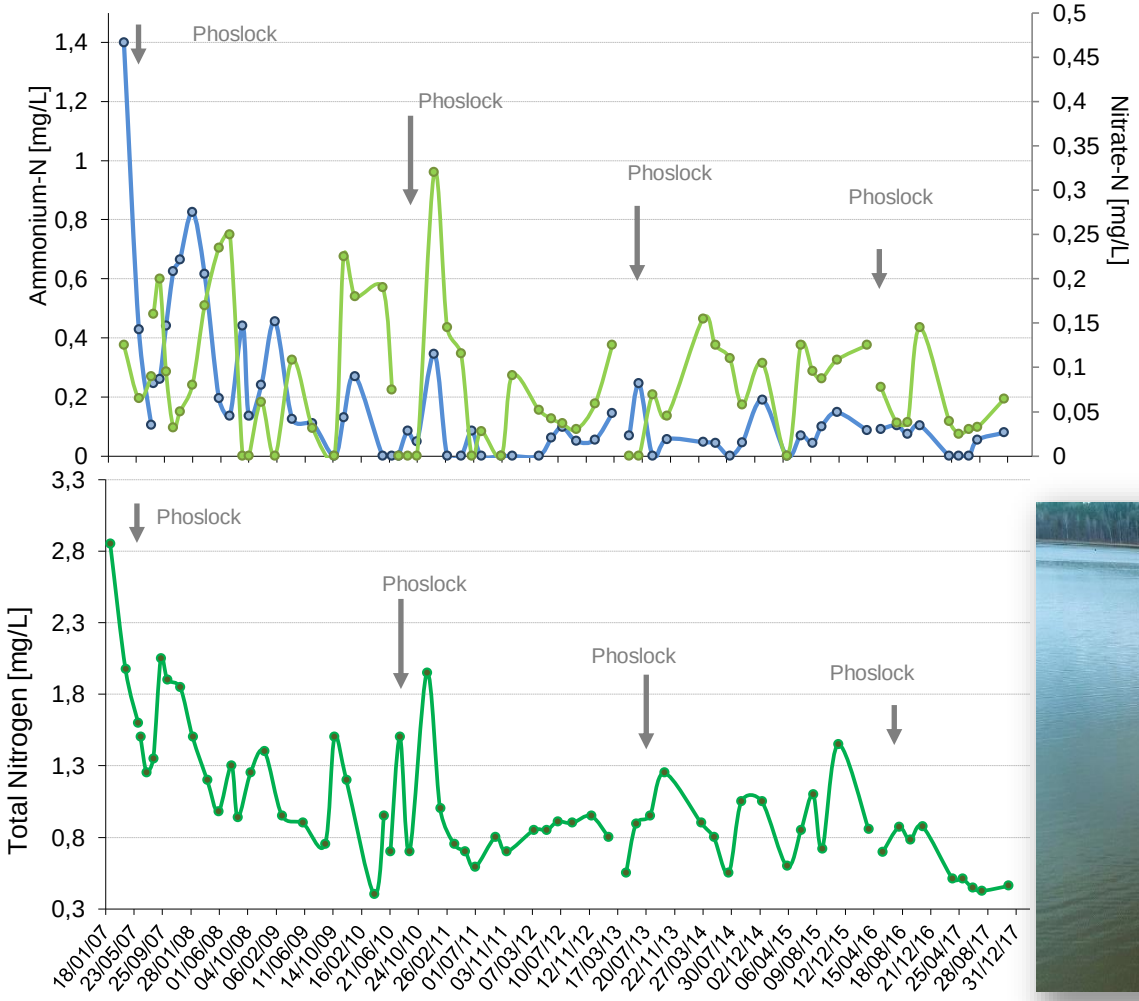
Number of samples:

- 2007 – 2007: n = 9
- 2008 – 2010: n = 14
- 2010 – 2013: n = 16
- 2013 – 2015: n = 14
- 2015 – 2017: n = >10



*Nine years of phosphorus management with lanthanum modified bentonite (Phoslock) in a eutrophic, shallow swimming lake in Germany. T. Epe, K. Finsterle, S. Yasseri 2017, Lake and Reservoir Management, Issue 2, vol. 33, pp 119-129

Results (inorg. N and TN)



Indirect effect:

- Significant reduction of inorganic Nitrogen
- smaller biomass causes lower TN conc.

Single treatment: Behlendorfer See

area	63 ha
volume	3.9M m³
avg. depth	7.5 m
max. depth	16 m

Natural glacial terrain lake

Conservation site and recreational lake

External sources:

- small catchment area
- run-off has been reduced
- groundwater

Internal sources:

sediment < 7 m depth contains:

- 1400 mg P/kg DW
- 1590 kg releasable Phosphorus (<5cm)

Status in 2007 (2 yr before restoring):

320 µg TP/l lake water = 1248 kg TP

- cyanobacterial blooms e.g *Plantothrix*
- low macrophyte growth

Dose calculation

Surface area: 63 ha
Water volume: 3,9 Mio m³

Phosphorus in **water body** (2008): **550** kg

Phosphorus in **sediment**

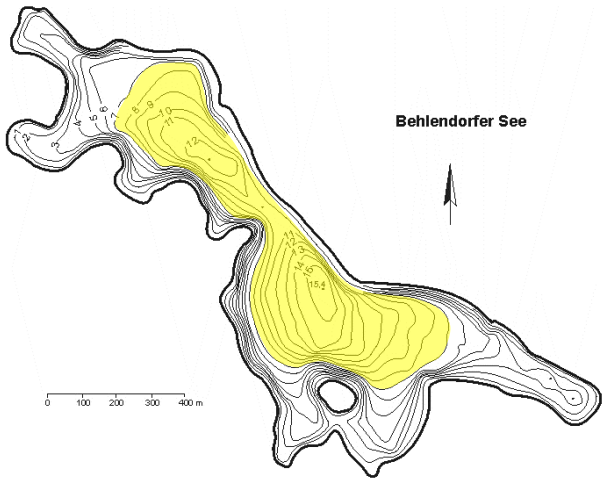
Area < 7 m depth: ~40 ha

Sediment: DW = 9,5 %

$LOI_{550°C}$ = max. 36 %

Yellow application area ~40 ha/5 cm layer:

Available phosphorus = **1590** kg (Psenner-extraction)



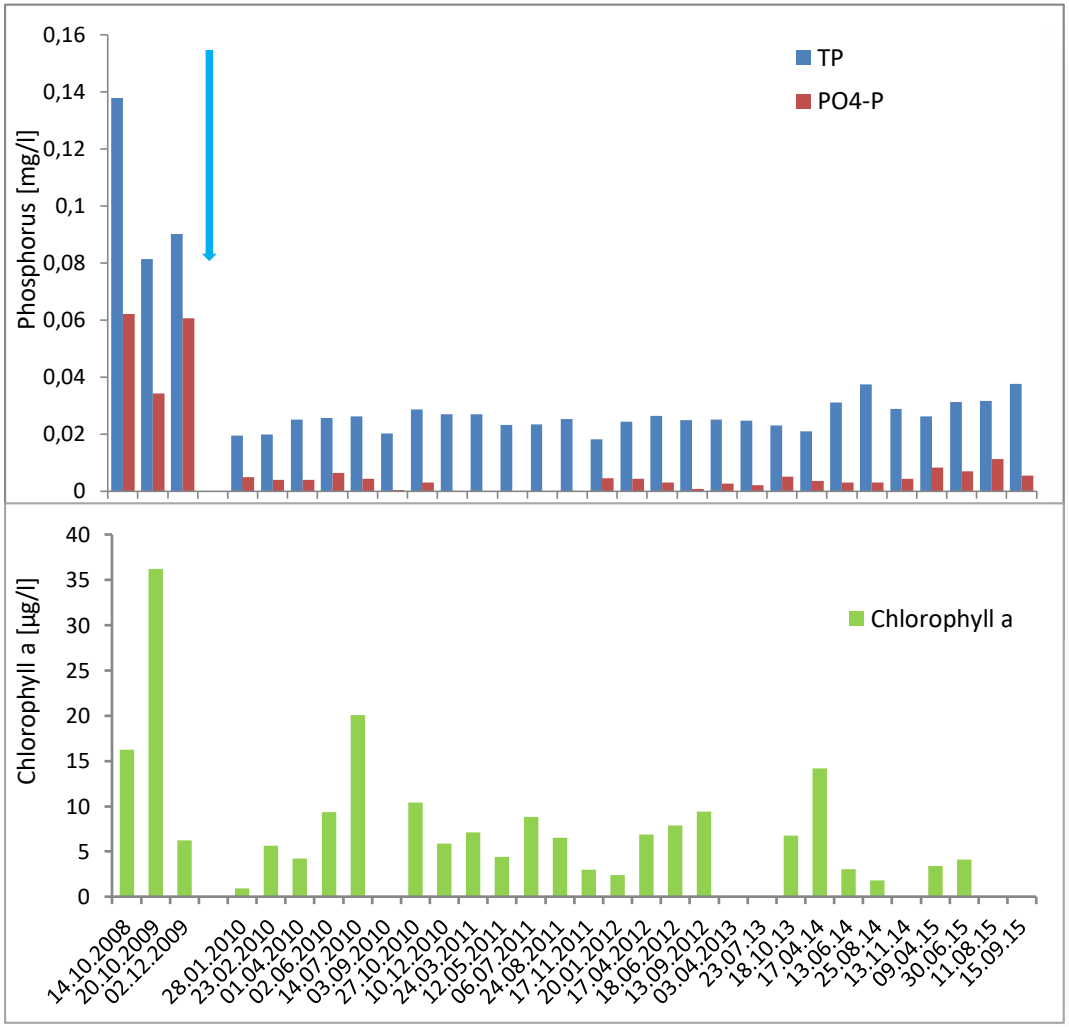
External phosphorus under control (catchment management)

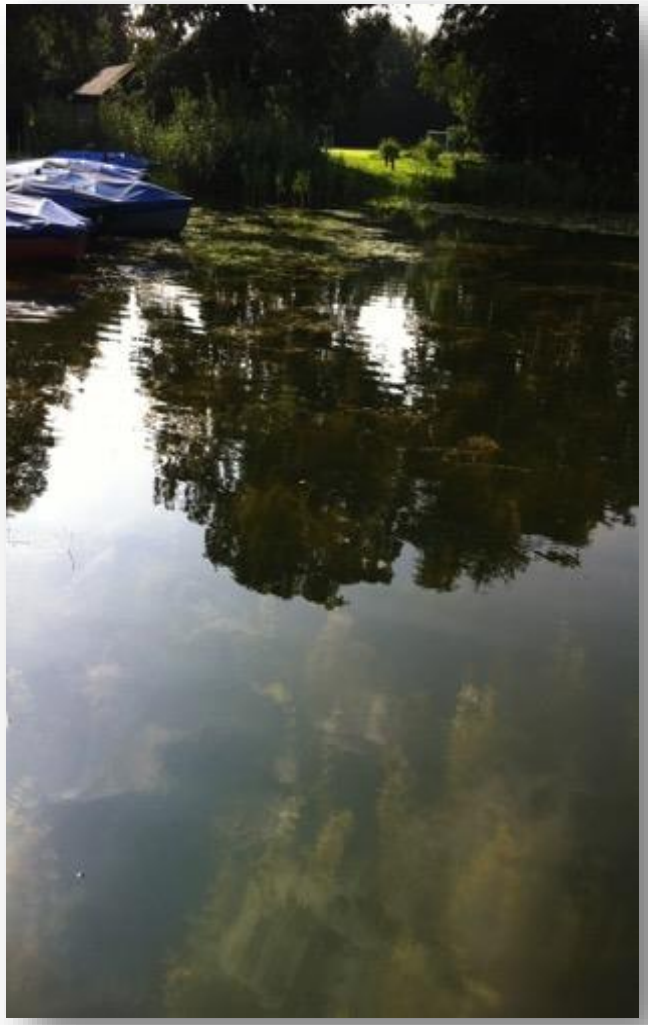
Phosphorus in **water** and **sediment** to bind:

Sum = **2140** kg

Phoslock®- **dose** = **214** tonnes

Results (TP and Chl-a)





Epe, T.S. (2014) Improvement in the ecological condition of a eutrophic lake through hypolimnetic phosphate precipitation. German Society for Limnology (DGL). Extended Abstract from the Annual Conference 2014 (Magdeburg), Hardegsen 2015

Conclusions/Summary

- Targeting the internal P-loading is effective in managing eutrophication
- Reductions in phosphorus concentrations
- Rapid and permanently binding to lanthanum in clay
- Long term P-removal
- No ecotoxicological impact
- Reduced algae growth
- Better water transparency
- Increased macrophyte colonisation depth
- Improving oxygen profile
- Change in the trophic state
- Can easily combined with other techniques

Lake Reith (Alpbach)

Natural karst lake (doline)

but “maintained“

Recreational lake in Tyrol in Austria

area	1.45 ha
volume	67,000 m³
avg. depth	4 m
max. depth	7.7 m

External sources:

- swimmers (94 mg P/d)
- groundwater (main source)
- run-off

Internal sources:

sediment contains:

- 700 mg TP/kg DW
- 30-60 kg releasable Phosphorus

Official trophic status: eutrophic

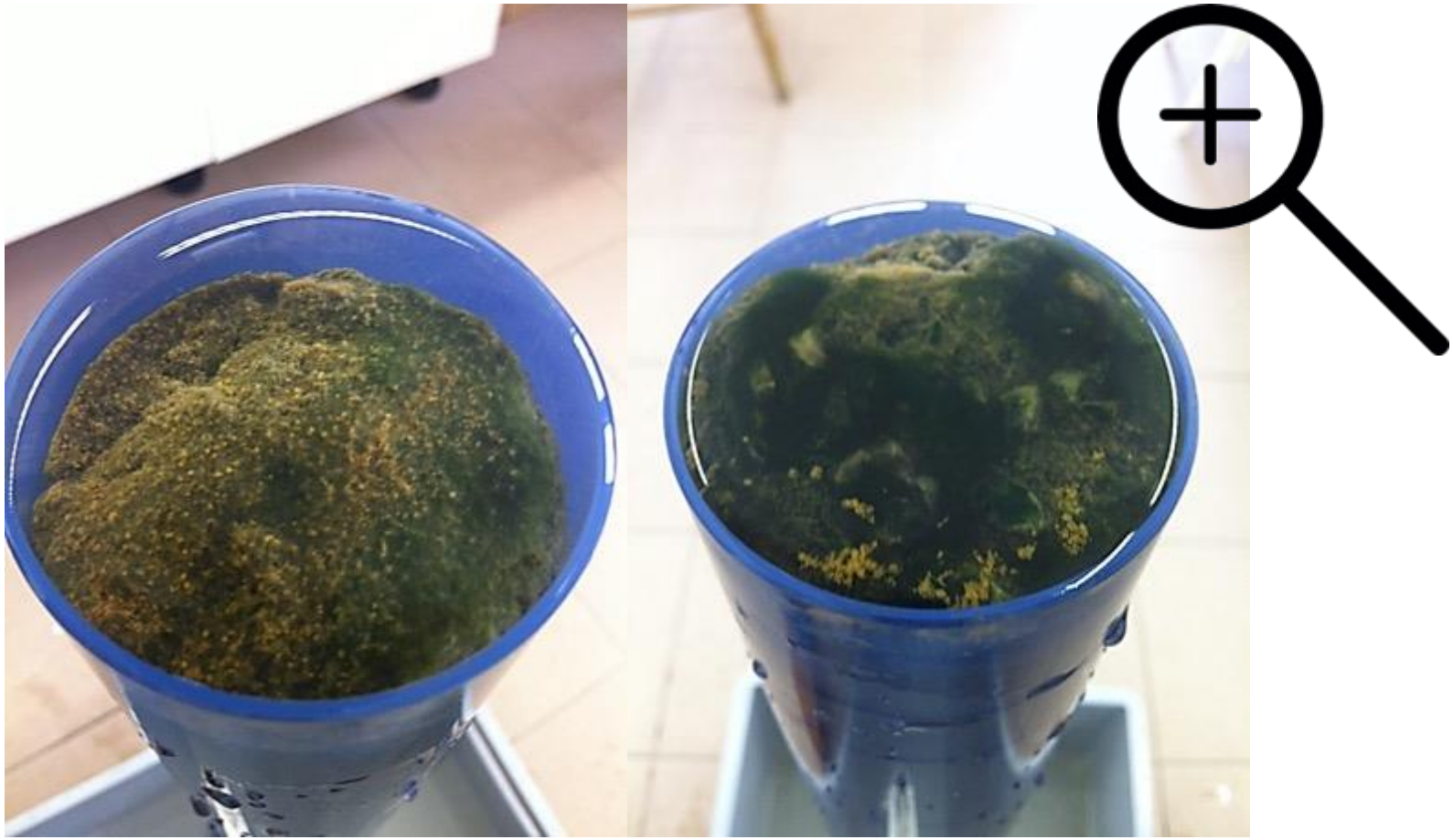
- 11-40 µg TP/l lake water =

“only“ 0.7 – 2.7 kg TP

- Algal mats and visibility below 1.5 m

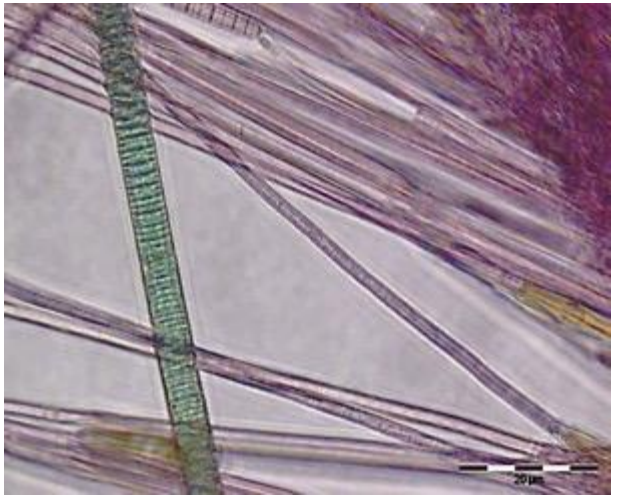
Problem: floating algal mats

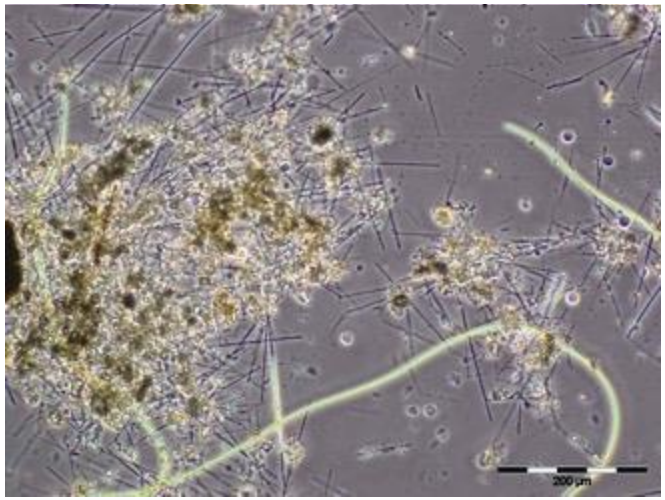
Algal layer



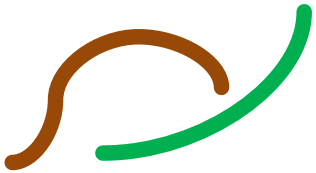
- Sediment cores have been covered with green “fluffy“ layer
- Layer was peppered with yellow structures

Algal layer

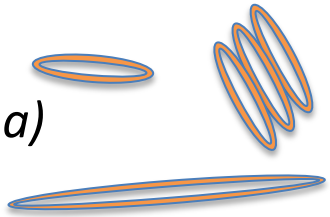




Oscillarioria (limosa)
Planktothrix spec.

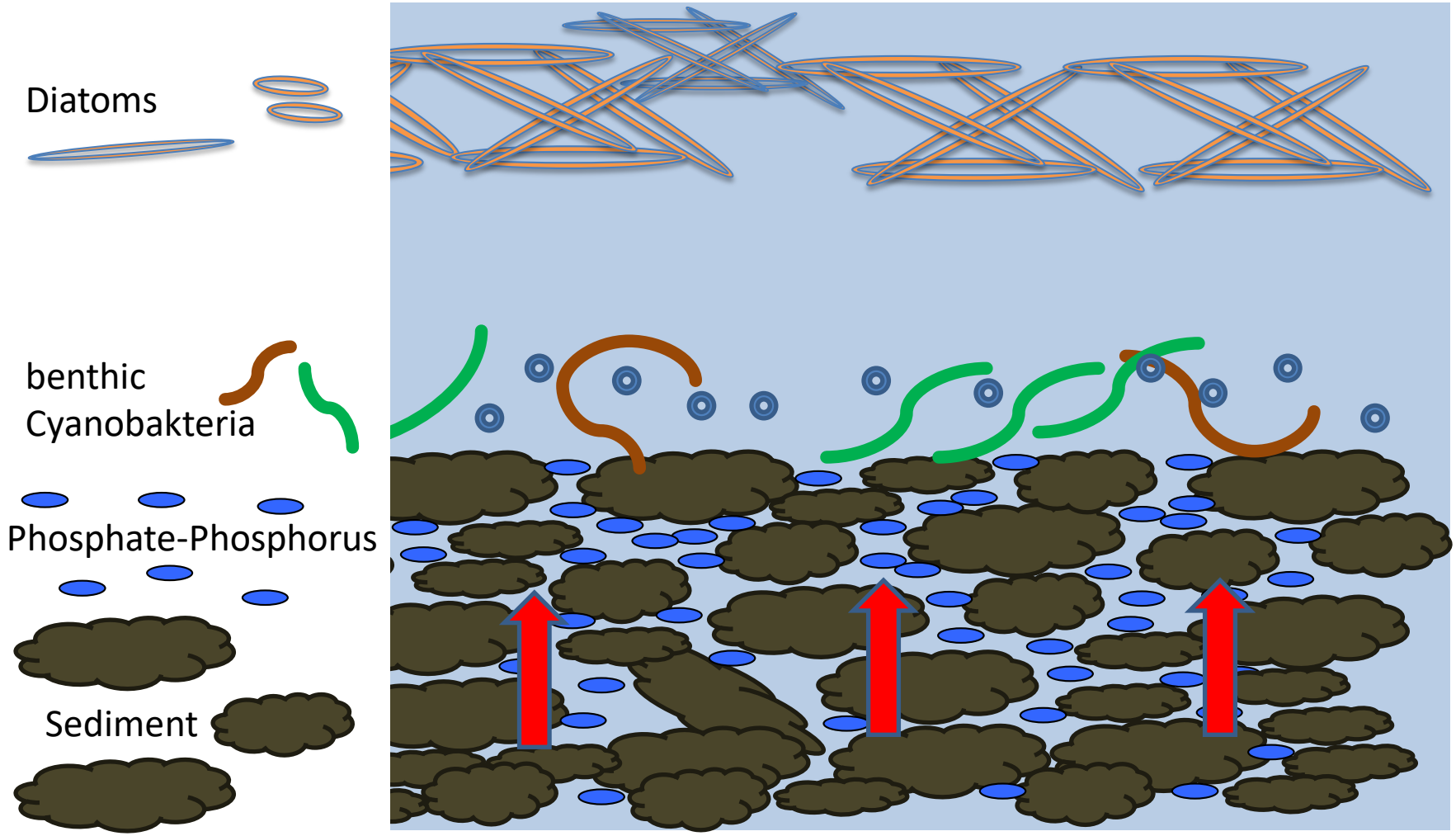


Fragillaria (crotonensis)
Fragillaria ulna (angustissima)



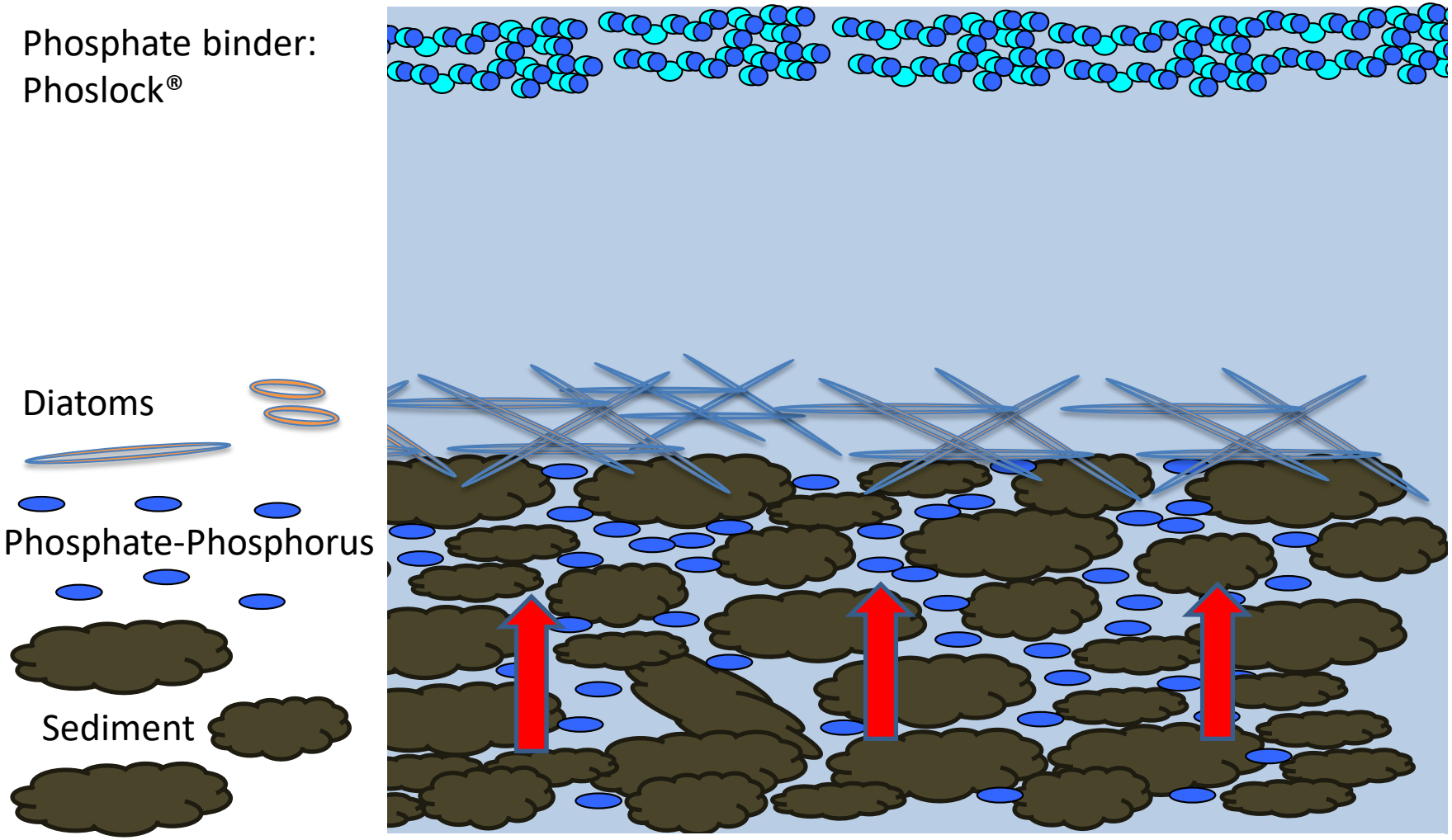
Oxygen
...

Lake Reith - floating mats



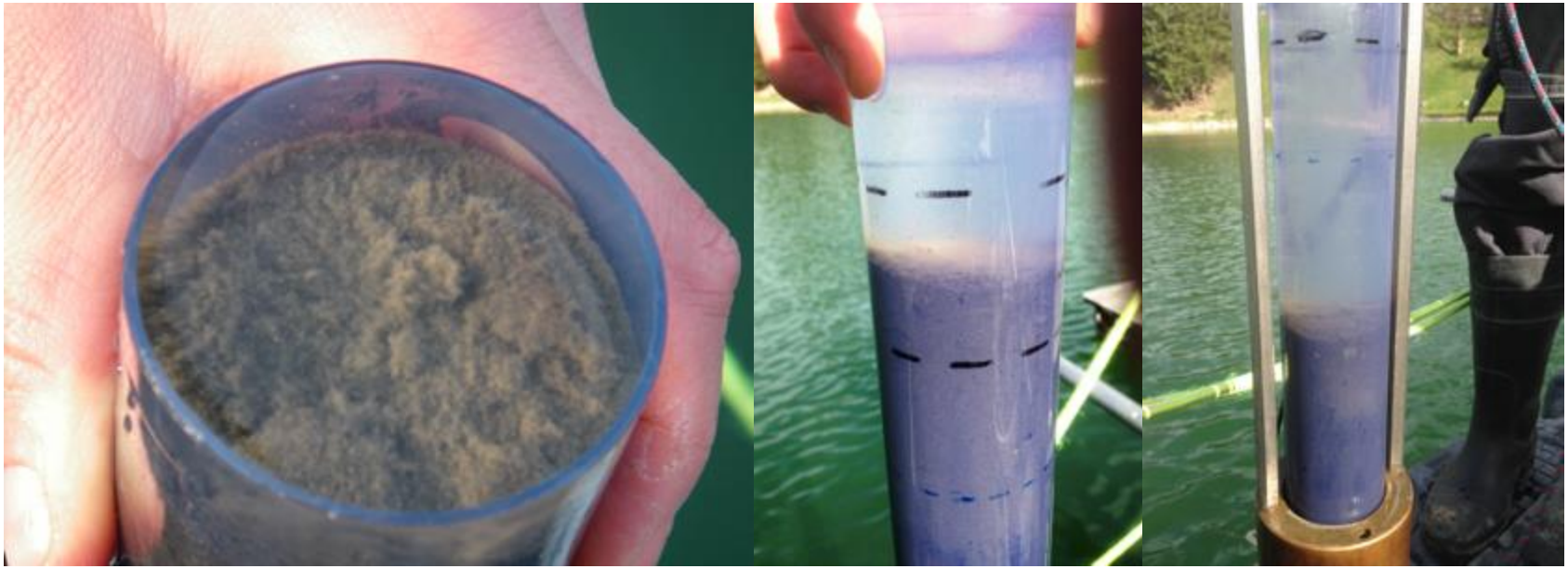
Lake Reith

Phosphate binder:
Phoslock®



- Adding P-binder to compete benthic algal growth

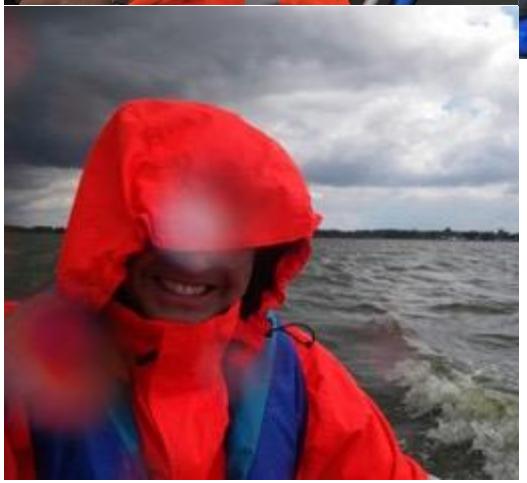
Results



- Reduction in BGA colonization in diatom frustule layer on sediment
- Reduction in algal growth (mats) and Chlorophyll-a concentrations*

*in prep. Tim S. Epe, Said Yasseri, Karin Finsterle, Karin Pall - Binding Phosphorus and establishing charophytes – a successful restoration strategy to control emerging benthic cyanobacteria / diatom mats in an Austrian lake

Thank you for your attention!



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