# LANTHANUM-MODIFIED BENTONITE AS A TECHNOLOGY FOR EUTROPHIC LAKES: ENVIRONMENTAL FACTORS THAT INFLUENCE ITS REMEDIATION EFFICIENCY

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## INTRODUCTION

**Lanthanum-modified bentonite** (LMB) is the current most widespread technique for P-pollution in lakes (Spears et al., 2014). The main LMB commercial product used is **Phoslock®**, and after its application to the water column's surface, the La ions sorbed to the clay mineral are released by exchange with other cations present in the water, and then react with **soluble reactive phosphorus** (SRP) to rapidly form a highly stable insoluble mineral known as **rhabdophane** ($LaPO_4 \cdot n H_2O$) (Yamada-Ferraz et al, 2015). After settling on the sediment surface, rhabdophane can form a thin adsorptive layer, and as long as La binding sites are still available, the product will continually adsorb new P (Ross et al., 2008), blocking phosphorus release from the sediment (Spears et al., 2013). Recent observations show that Phoslock® rarely binds SRP in the expected ratio of **100:1** (100 g Phoslock® remove 1 g P), indicating interference in the rhabdophane formation, possibly by water parameters such as pH, alkalinity, and dissolved organic carbon (DOC) (Lürling et al., 2014).

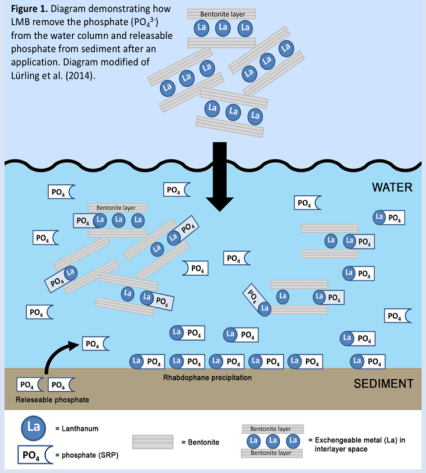


**Figure 1.** Diagram demonstrating how LMB remove the phosphate ($PO_4^{3-}$) from the water column and releasable phosphate from sediment after an application. Diagram modified of Lürling et al. (2014).

## OBJECTIVES

1. Investigate the efficacy of Phoslock® on the P reduction in the available literature.
2. Assess the main physicochemical and environmental factors influencing driving Phoslock® efficacy.

The study was carried out at **laboratory** and on a **field scale**

## Laboratory studies assessment

### METHODS

**15 papers** assessed, containing **98 experiments** P removal efficacy was tested with **SRP**

1. A **general meta-analysis** was carried out with 98 experiments to assess the % of reduction in SRP concentration after the application of Phoslock®
2. Other meta-analyses were performed to test the influence of multiply **environmental variables** on P reduction efficiency
3. As an alternative approach, a **Principal Component Analysis (PCA)** was performed to explore the most influential factors on Phoslock® efficiency

### RESULTS AND DISCUSSION

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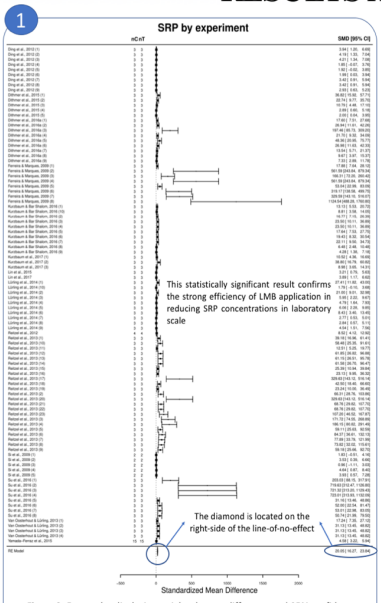


**Figure 2.** Forest plot displaying weighted mean difference and 95% confidence intervals of 98 laboratory Phoslock® experiments. Fail-Safe N test = 32394.

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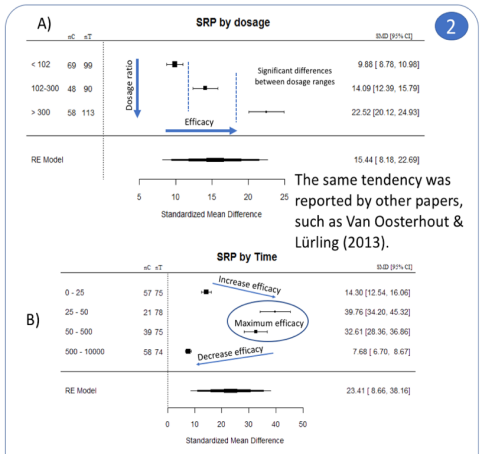
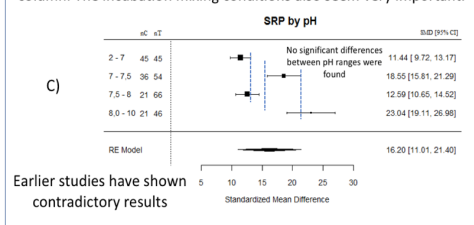



The same tendency was reported by other papers, such as Van Oosterhout & Lürling (2013).

Lürling et al. (2014) demonstrated that SRP removal efficiency is highly dependent on reaction time Phoslock® particles in the water column. The incubation mixing conditions also seem very important.




Earlier studies have shown contradictory results

**Figure 4.** Forest plot displaying weighted mean difference and 95% confidence intervals of: (A) three ranges of Phoslock® dosage/ initial SRP); (B) four time during experiment ranges (in hours): and (C) four pH ranges. Fail-Safe N test using = (A): 1004; (B): 1337; and (C): 940.

3

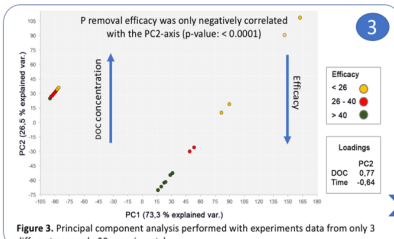



**Figure 3.** Principal component analysis performed with experiments data from only 3 different papers (= 20 experiments).

The interference by DOC has been already reported by several authors: DOC cause the LMB to be less effective through the humic complexation (chelation) with La and LMB.

## Field scale assessment

### METHODS

**17 papers** and **15 technical reports** performed by LMB distributors / manufacturers assessed, containing information from **31 lakes**.

Phoslock® efficacy was tested with **total phosphorus (TP)**, calculated according to the equation:

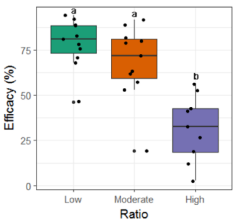
$$\text{P removal efficacy (\%)} = (TP_{pre} - TP_{post}) / (TP_{pre} \times 100)$$

VS

1. LMB dosage ratio
2. Lake volume
3. Mean depth lake
4. Lake surface area
5. Amount of LMB applied

### RESULTS AND DISCUSSION

The dosage ratio (the LMP applied compared to the initial TP) showed a significant influence (Fig. 5; $p < 0.001$) on P removal efficacy.




TP reduction under the three ratio ranges

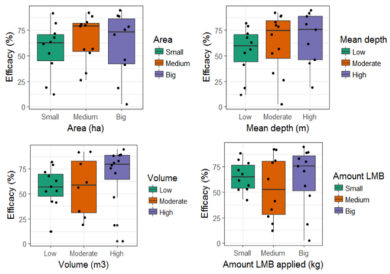
↑ LMB dosage ratio ↓ Efficacy

Adding higher dosages do not result in a more effective P control. This result agrees with Spears et al. (2016).

**Figure 5.** Efficacy vs dosage ratio ([LMB]/TP initial. Low ratio (0 – 400:1); moderate ratio (400 – 1500:1); high ratio (1500 – 5000:1).

The lack of agreement between the field and the laboratory experiments is probably related to:

1. The high variability in chemical composition of waters and sediments.
2. The difficulties in the estimation of the required LMB dosages at the field scale.
3. The remobilisation of P from the sediment.




No significant influence were found between P removal efficacy and lake area, mean depth lake, total amount of LMB applied and lake volume (Fig. 5).

**Figure 6.** Changes in P removal efficacy (%) by different lake variables: lake surface area, lake volume, mean depth lake and amount of LMB applied.

## CONCLUSIONS

- The positive effect of Phoslock® in soluble P remediation of waters was demonstrated under laboratory and field conditions, although less effective in whole-lake applications.
- The dosage of LMB is the main factor determining P removal efficacy. Higher dosage ratios increase P reduction in laboratory experiments, while higher amounts of LMB applied at field scale do not result in more P reduction. Remobilisation of P from sediments could be an explanation to this trend.
- The time spent since the application and DOC seem to cause a significant interference in P sequestration in laboratory experiments, while pH does not.
- At the field scale, lake area, amount of LMB applied, mean depth and lake volume were not factors that influence Phoslock® efficiency.

## REFERENCES

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