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## Motivation

Phosphorus (P) is a key nutrient for freshwater eutrophication (Fig. 2) as it usually limits primary production. Therefore, its excess allows the growth of primary producers populations, commonly in the form of algae blooms. Current methods that aim to control P release from the sediment and reduce P concentrations in the water work by adding binding agents which make P unavailable for biological uptake. These methods can have drawbacks such as being vulnerable to environmental conditions, costly, and they do not recover P, only immobilize it. Meanwhile, P is an important macronutrient for life. Unfortunately, it is expected that, over the next few decades, demand for P will surpass its supply [1]. Therefore, it is necessary to find ways to recycle P.

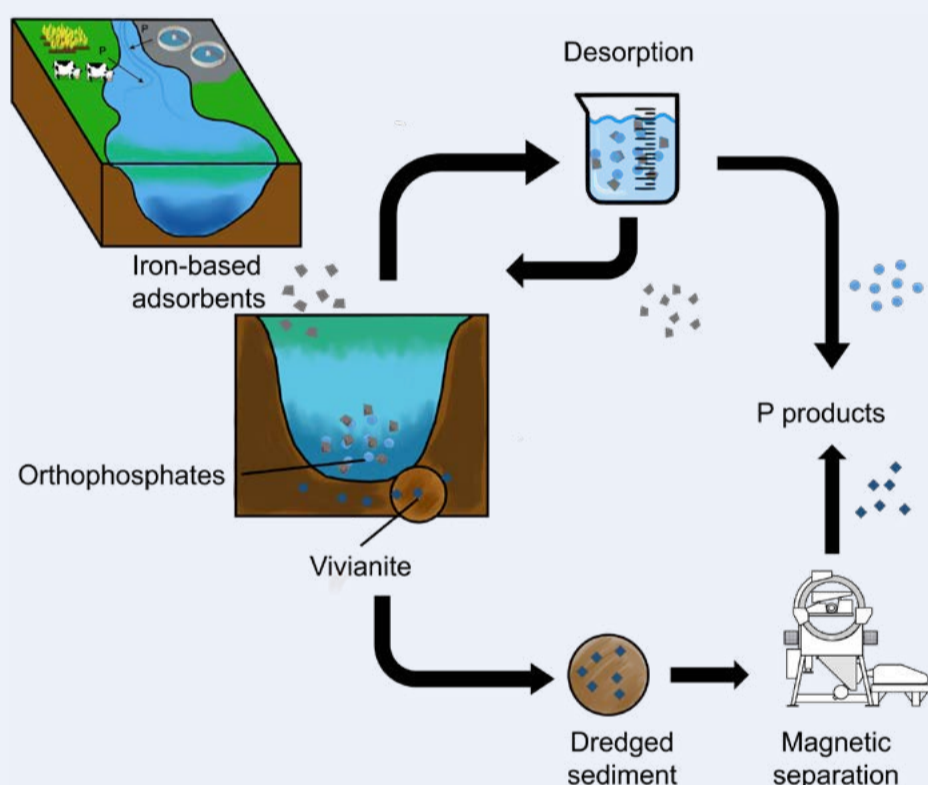


Fig. 1: Schematic representation of a proposed approach for lake restoration through phosphorus recovery.

## Project approach

The strong affinity between iron and P make iron a great candidate to aid P removal and recovery. Thus, this study will use iron-based adsorbents as a lake restoration tool (Fig. 1).

It is believed that vivianite ( $\text{Fe}_3(\text{PO}_4)_2 \cdot 8\text{H}_2\text{O}$ ) authigenesis in lakes is an important phosphorus sink in the right conditions, i.e., reducing environment, high orthophosphate and ferrous iron concentrations, and low presence of sulphides [2]. Thanks to vivianite's paramagnetic properties, the share of P present as this mineral may be removed from sediments using magnetic separation (Fig. 1), as has been shown to work for wastewater sludge [3].

## Technological challenge

Lakes differ from each other in the way they receive nutrient loading, mixing regime, and other variables which may influence P speciation and internal loading. The success of a restoration using iron-based adsorbents is heavily dependent on the P speciation as the material will only adsorb orthophosphate. Therefore, the presence of P in other fractions such as particulate organic P will pose a challenge. In addition, we aim to immobilize P as vivianite (Fig. 3) to an extent that will allow its separation from the sediment, potentially *in situ*. This may be difficult to achieve as concentrations of P in the sediment are not as high as in wastewater sludge. It can also be a challenge to perform magnetic separation within the lakes due to factors such as depth of vivianite formation, potential harm to benthic animals and interference of macrophytes in the sediment.

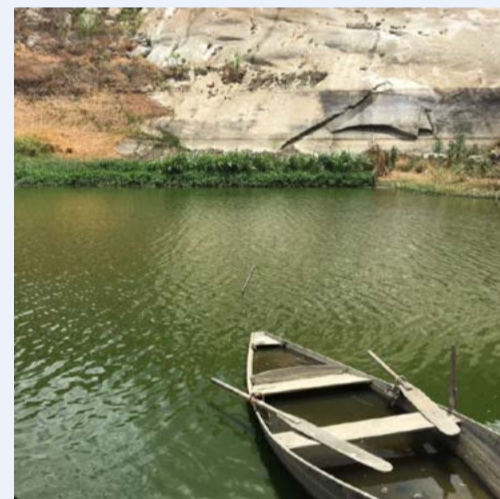


Fig.2: Eutrophic lake.

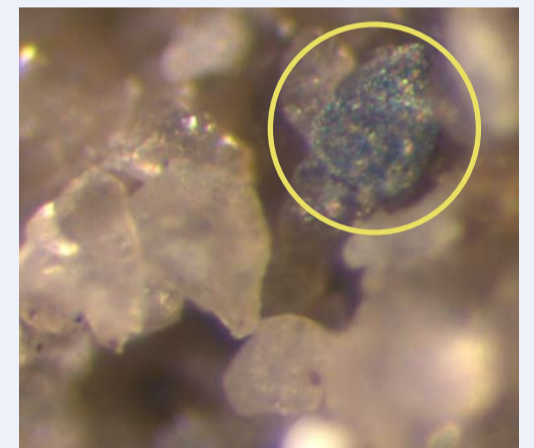


Fig.3: Vivianite in lake sediments. Bouvigne, The Netherlands.

## Research goals

- Investigate the influence of lake characteristics on P speciation, thus its impact on the success of interventions using iron-based adsorbents.
- Develop methods to use iron-based adsorbents to remove P from water bodies that consider site-specific characteristics.
- Further understand the conditions for vivianite formation in lake sediments.
- Investigate the feasibility of P removal from sediments in the form of vivianite through magnetic separation potentially *in situ*.

## References

- [1] Cordell. *et al.* (2009). The Story of Phosphorus: global food security and food for thought. *Global Environmental change*, 19, 292-305.
- [2] Rothe *et al.* (2016). The occurrence, identification and environmental relevance of vivianite in waterlogged soils and aquatic sediments. *Earth-Science Reviews*, 158, 51-64.
- [3] Prot, T. J. F. *et al.* (2019). Magnetic Separation and Characterization of Vivianite from Digested Sewage Sludge. *Separation and Purification Technology*, 224,564-579.