Improved recovery of phosphate through manipulation of iron phosphate chemistry using Mössbauer spectroscopy

Carlo Belloni

carlo.belloni@wetsus.nl

Motivation

Phosphorus (P) is both an essential nutrient for life and a polluting agent. It is involved in vital functions of every living being and it is used in fertilizers. On the other hand, the excess of dissolved phosphate (PO_4^{3-}) in water bodies causes eutrophication and algae bloom. It is generally accepted that P levels below 10 µg/L entail a good ecological status of a water body[1-3]. Moreover, phosphate is also a finite resource, which led the EU to identify it as a critical raw material, demanding for a more circular use of phosphate in the world[4]. Thus, it is very important to remove phosphate from water, as to recover it to allow its reuse.

Compared to the conventional precipitation technique, adsorption is more efficient both in phosphate removal at low concentration and to obtain a purer recovered product. Among all adsorbents, iron oxides represent a low-cost material, which display high affinity to phosphate. However, several iron oxides species exists (Fig. 1), each one displaying different characteristics, both from a structural point of view (oxidation state, degree of crystallinity, etc.) and the chemical point of view (affinity, stability, etc.).

Technological challenge

A further insight into iron oxide structure, as well as adsorption and desorption features, is needed, in order to outline the main parameters affecting the process and to be able to design an ideal, cost-effective adsorbent with higher performances.
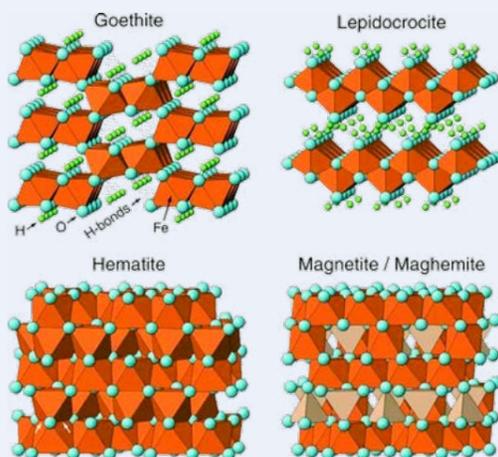
Fig.1 Structure scheme of some different iron oxide species[5].
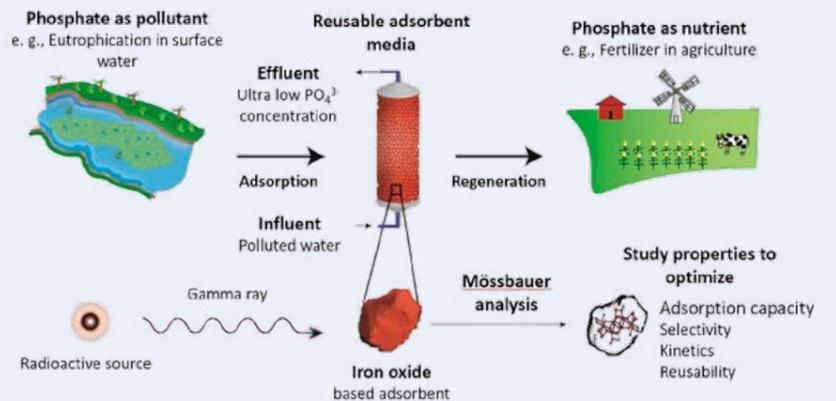
Fig.2 Summary of the project.

The fundamental aspects of the interaction between phosphate and iron oxides will be investigated performing batch and column experiments, involving commercial and synthesized samples. By means of Mössbauer/IR Spectroscopy as an analysis tool (Fig. 2), a better understanding of the binding mechanism, type of adsorbed complexes (Fig. 3), adsorbent affinity, size-effect, structure and its stability during the entire process (involving surface chemistry modification through doping), will be achieved.
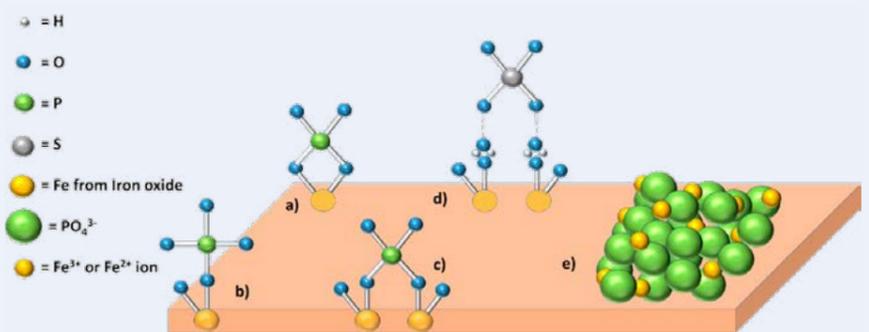
Fig.3 Scheme of the different binding types: a) mononuclear bidentate, b) mononuclear monodentate, c) binuclear bidentate, d) outersphere complex and e) precipitate[6].

Research challenge

In order to be able to design an optimized cost-effective adsorbent for phosphate removal and recovery, the main goals of the research project are:

- to understand the different behavior of the different iron oxide species;
- to understand the binding mechanism and type of complexes;
- to improve the capacity, kinetics and selectivity of the adsorbent;
- to improve the regeneration procedure and the reusability of the adsorbent.

References
[1] EC, 2009. Guidance document on eutrophication assessment. Common implementation strategy for the Water Framework Directive, p. 43;
[2] Schindler, D. W. et al., Reducing Phosphorus to Curb Lake Eutrophication is a Success, Environ. Sci. Technol. 2016, 50(17), 8923-8929;
[3] Carvalho, L. et al., Sustaining recreational quality of European lakes: minimizing the health risks from algal blooms through phosphorus control, J. Appl. Ecol. 2013, 50, 315-323;
[4] EC, 2014. The European Critical Raw Materials Review Memo;
[5] Cornell, R. M., Schwertmann, U., The Iron Oxides: Structure, Properties, Reactions, Occurrences, And Uses, 2nd ed.; Wiley-VCH: Weinheim, 2003.
[6] Wilfert, P., Kumar, P. S. et al., The Relevance of Phosphorus and Iron Chemistry to the Recovery of Phosphorus from Wastewater: A Review. Environ. Sci. Technol. 2015;

C. Belloni, prof.dr. G.J. Witkamp, prof.dr. E. Brück, dr. A.I. Dugulan, ir. L. Korving

NWO Netherlands Organisation for Scientific Research

TUDelft Delft University of Technology