Phosphate adsorption by Iron Coated Sand granules as end-of-pipe solution for the purification of drainage water

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Abstract: In this study, a technology based on phosphate adsorption is proposed as a robust technology for phosphate removal from drainage water. This method has some benefits over the typical metal salt precipitation, including its robustness and lower post-processing requirements. The objective was to translate lab scale experience to good practices and optimal working conditions for field applications. Based on this experimental study, a PO_4-P adsorption capacity of 2 to 6 mg PO_4-P/g sorbent can be expected in full-scale phosphate filter applications, when it is assumed that these filters are fed with drainage water containing an average P concentration of 25 mg PO_4-P/L. Also, bench-scale column adsorption experiments were carried out to verify the adsorption capacity and to investigate whether the PO_4-P adsorption capacity could be augmented by changing the operational conditions of the filter, i.e., attempting to achieve an increased adsorption by the use of intermediate rest periods.

Keywords: Phosphate adsorption; Iron coated sand; Drainage water

1. Introduction

The agricultural use of fertilizers has been a major source of nitrate and phosphate pollution in Europe. Remarkably, a correlation between the presence of greenhouses, which often grow soilless crops, in a specific region and the exceedance of the nitrate and phosphate standard in surface water is observed. Both high nitrate and phosphate concentrations are present in the run-off water from agriculture and horticulture, i.e., up to 55 mg NO_3-N/L and 25 mg PO_4-P/L. Hence, this nutrient-rich run-off water becomes detrimental when it will overfertilize aquatic plants and subsequently cause an increased eutrophication. To limit their emission, the EU issued the Nitrates Directive (1991), which has been subsequently been integrated in national legislations by the member states. In response to this Directive, vulnerable zones in Flanders (Belgium) were established, in which the standard of 11.3 mg NO_3-N/L and 0.07-0.14 mg PO_4-P/L (depending on the receiving water body) is exceeded. A way to limit the emission of nitrates and phosphates in the environment is the use of good farming practices to avoid the production of nutrient-rich water. Nowadays, exceedances of phosphate discharge standards are still observed despite the good farming practices, forcing the need to retain phosphate before disposed into the environment.

In this study, an adsorption process, which requires less post-processing compared with a conventional physicochemical phosphate removal process, by using Iron Coated Sand (ICS) grains is proposed as end-of-pipe technology. These iron beads are similar to the commercially available Granular Ferric Hydroxide (GFH) and can be used for the adsorption of a variety of pollutants (e.g., arsenic and phosphate) from wastewater (Sperlich, 2010). The potential of the ICS granules to adsorb phosphate from municipal wastewater on laboratory scale was already demonstrated by Moelants et al. (2010). The main goal of this research is to demonstrate the feasibility

of the phosphate filter to treat nutrient-rich drainage water from horticulture in such a way that the treated water meets the environmental standards and can be discharged in the surface water. Based on batch experiments at lab scale, the influence of granule type (diameter and origin), adsorption kinetics and initial pH was examined. These insights were used to upscale the adsorption columns to a pilot scale application. Special attention is paid to the management and optimal operating parameters of the phosphate filter.

2. Material and Methods

The ICS granules are derived from rapid sand filters used for the deferrization in the production of drinking water from groundwater. The drinking water company PIDPA facilitates drinking water production plants at different locations in Flanders (Belgium), e.g., Balen, Grobbendonk, Herentals and Mol.

The adsorption isotherms and kinetics are determined by batch tests at ambient temperature (20 °C). 10 g of pre-dried granular substrate material is brought in contact with 100 mL synthetic wastewater sample with different PO_4-P concentrations ranging from 10 to 3000 mg PO_4-P/L.

Continuous laboratory-scale column experiments were performed to verify the kinetics and determine the influence of some operational parameters on the breakthrough time of the column. Each column was filled with a predetermined mass of dry iron granules (100 cm^3) and was fed with a phosphate solution with a concentration of 25 mg P-PO_4 /l via a membrane metering pump with adjustable flow rate. By performing the rapid small-scale column tests, the breakthrough time of the adsorption column can be estimated.

3. Results

There was an attempt to achieve an increased adsorption by the use of intermediate rest periods. In this strategy the column was fed 8h per day and in this way the column was left to stand for 16h per day. In Figure 3.1 it can be clearly established that these rest periods cause a significant improvement of the adsorption capacity, making it possible to reach the maximum adsorption capacity, as determined in the batch experiments on lab scale. The underlying cause can be explained by the interparticle diffusion of PO_4-P towards the core of the granules during the rest periods. This will result in fresh and free adsorption sites, leading to a slower saturation of the granules.

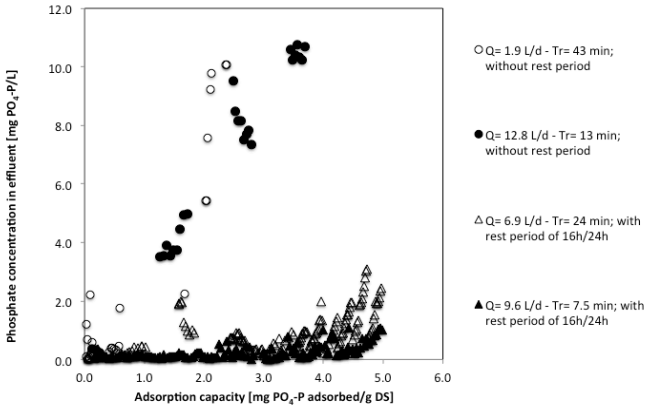

Figure 3.1 Effect of intermediate rest periods on the adsorption capacity of PO_4-P on the iron granules.

REFERENCES

Sperlich, A. 2010 *Phosphate adsorption onto granular ferric hydroxide (GFH) for wastewater reuse.* PhD dissertation, Papierflieger, Berlin.

Moelants, N., Smets, I.Y., Van Impe, J.F. 2011 The potential of an iron rich substrate for phosphorus removal in decentralized wastewater treatment systems. *Sep. Purif. Technol.*, **77**, 40-45.