Interreg
North Sea Region
NuReDrain
European Regional Development Fund

EUROPEAN UNION

FILTER SYSTEMS FOR A SUSTAINABLE AGRICULTURE

FIELD CASE DESCRIPTION

Phosphorus removal from surface water for drinking water production

De Watergroep
WATER. VANDAAG EN MORGEN.

vito

Location

Country: Belgium
City: Diksmuide
Coordinates: 50°59'20.9"N 2°50'11.2"E, 50.989144, 2.836431

Problem description

P concentrations in the surface water are too high (> 0,3 mg/l) due to among others drainage water. These high P-concentrations enable the formation of algal blooms in De Watergroep's water reservoir (Figure 1). The reservoir is used to buffer the surface water and use it to produce drinking water and provide it to an extensive part of West-Flanders. Algal blooms interfere negatively the production of drinking water from surface water. Under the influence of climate change, the frequency and extent of these blooms is increasing significantly. As the largest drinking water company in Flanders, De Watergroep wants to invest in a cost-effective reduction of phosphorus from surface water in problem areas. In addition, the repurposing of drinking water treatment residues, like iron sludge, as filter material for phosphorus sorption can serve as an innovative example of a circular economy solution. The present study aims at developing and demonstrating a cost effective filter technology for full scale application on surface water. Results have shown that filter granules can be produced with iron sludge as a raw material, achieving both a good mechanical stability and a good sorption performance. This pilot aims at validating these results in a field trial on site a large drinking water production facility.

Figure 1 De Blankaart water reservoir covering a surface area of 63 ha with a volume of 5.670.000 m³

Filter description

A self-designed flexible pilot installation was built consisting of three down-flow columns (diameter 40 cm, height 150 cm), which can be either operated in a parallel or serial mode (Figure 2 and Figure 3). The flow is controlled by adapting the height of the water level in the column above the filter materials and can vary between 50 and 1000 L $hour^{-1}$. Online measurements of flow rate, pressure, pH and NTU were performed for continuous monitoring.

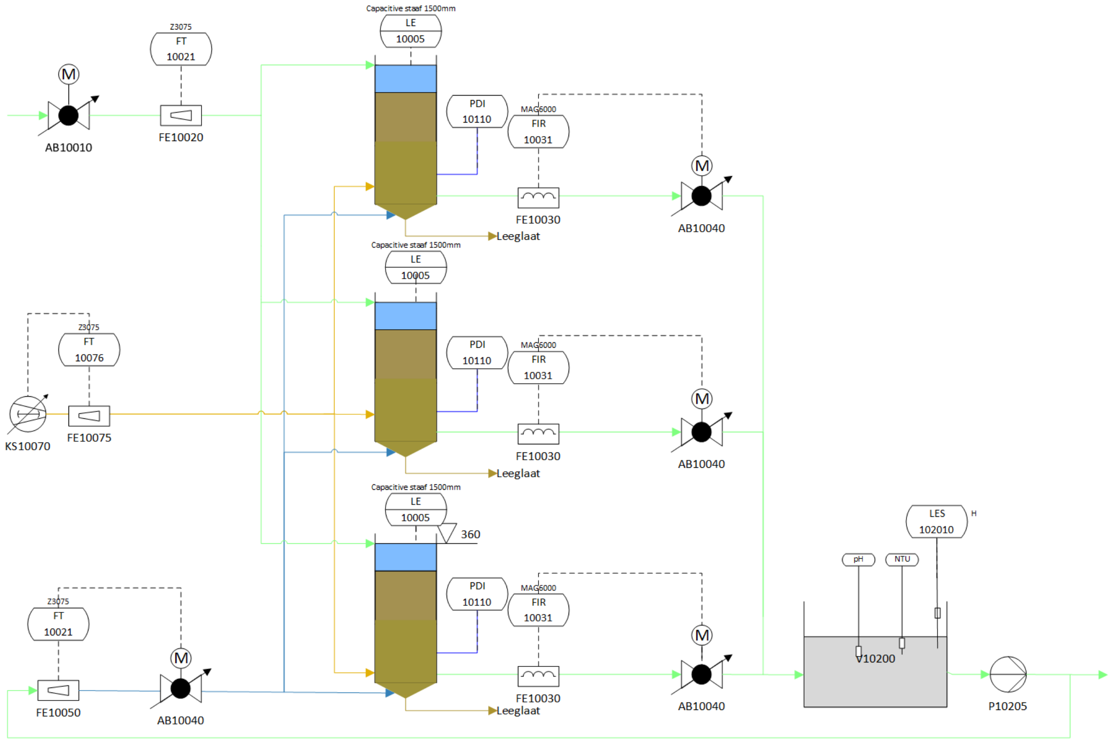

Figure 2 Scheme of the pilot installation

Figure 3 Picture of the pilot installation

As filter material dried alum sludge from the drinking water production centre of Kluizen was reduced in size to below 4 mm using a disc mill. The resulting material was classified and the fraction between 1 and 4 mm was retained. The 1–4 mm fraction was treated in a furnace for 2 h at either 100 °C or 550 °C, obtaining filter materials referred to as ABA-100 and ABA- 550, respectively.

The columns were filled with 32.5 kg of the filter material. A flow of 200 L hour^{1} of unfiltered water was used, resulting in a contact time of approximately 10 min. The experiment was performed on 6 and August 7, 2018 with ABA-100 filter material because water in the basin contained a relatively high P amount of 0.43 mg-P L^{-1} at that time. The water temperature was 24.1 °C. For 24 h, the P concentration of both the influent and the column effluent was sampled once every hour using an automated collection system. The total P concentration of these samples was determined.
The ABA-100 material started to disintegrate after contact with water. As a result, the granules were not visible anymore after a few hours of incubation, and fine ABA-100 material was flushed out of the column.

Figure 4 The column filled with the ABA-100 material, immediately after bringing it in contact with the influent (left), and the same column after 4 hours of treatment at a flow rate of 200 L h-1 (right). In both pictures, the right column is filled with a stable material, which can serve as a reference for the height of the ABA-100 material in the left column.

The use of untreated alum sludge in powder form in this column would likely cause comparable issues. The adsorption column with ABA-550 material showed no problems regarding granule stability, which resulted in a performant percolation throughout the experiment. This clearly illustrated that the stability of the sludge granules throughout a column adsorption treatment is a key factor for application, and that granule stability was warranted by the calcination process. Furthermore, the column with ABA-550 material was able to significantly reduce the P concentration (Figure 5). The P removal efficiency always exceeded 86%, thereby obtaining an average effluent P concentration of 0.035 mg-P L^{-1}. The obtained effluent P concentration was very close to 0.033 mg-P L^{-1}, which is considered the target P concentration for the replenishment of the water basin. The surface water

treatment also slightly affected the pH and the turbidity of the water, although these effects stabilized towards the end of the 24 h-treatment period. During the test, the turbidity of the effluent decreased from 3.3 NTU to minimum 1.6 NTU, which suggested that a fraction of colloidal material in the water could be maintained by the ABA-550 filter. The pH of the treated water increased from 7.6 to maximum 8.1 during the treatment. This slight alkaline effect of ABA- 550 was also obtained in the lab-scale tests with synthetic P solutions of pH 7. With this pilot-scale adsorption experiment, the ABA- 550 material was proven capable of performing in a column system and can therefore be applied in industrial-size adsorption systems in the future.

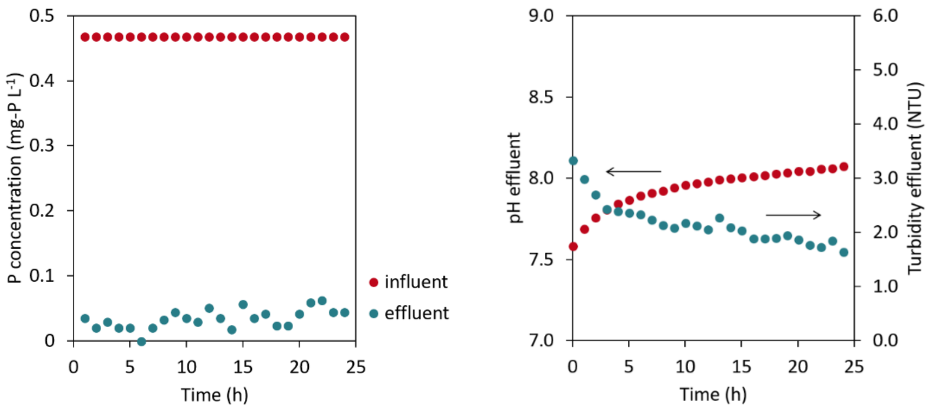

Figure 5 The P concentration at the inlet and the outlet of the pilot-scale adsorption column, measured every hour during 24 hours (left). The pH and the turbidity of the effluent from the pilot-scale adsorption treatment (right).

As shown in Figure 6, good removal efficiencies were obtained at the start for the ABA-500 material. A longer test was done over the course of 10 months on and off operation to have an idea of the different circumstances. Several factors influenced the performance of the P removal as can be seen on the more long-term testing period shown in Figure 6. The filter did remove P (20 – 60%) but both temperature and low P concentration proved challenging:

- At temperatures below 10 °C the removal efficiency dropped to below 20%
- At very low P concentration (< 0.1 %P = 0.3 % phosphate) the contact time of 10 minutes did not suffice to remove more than 80% of the P. Also longer contact times (30 minutes) proved too short.

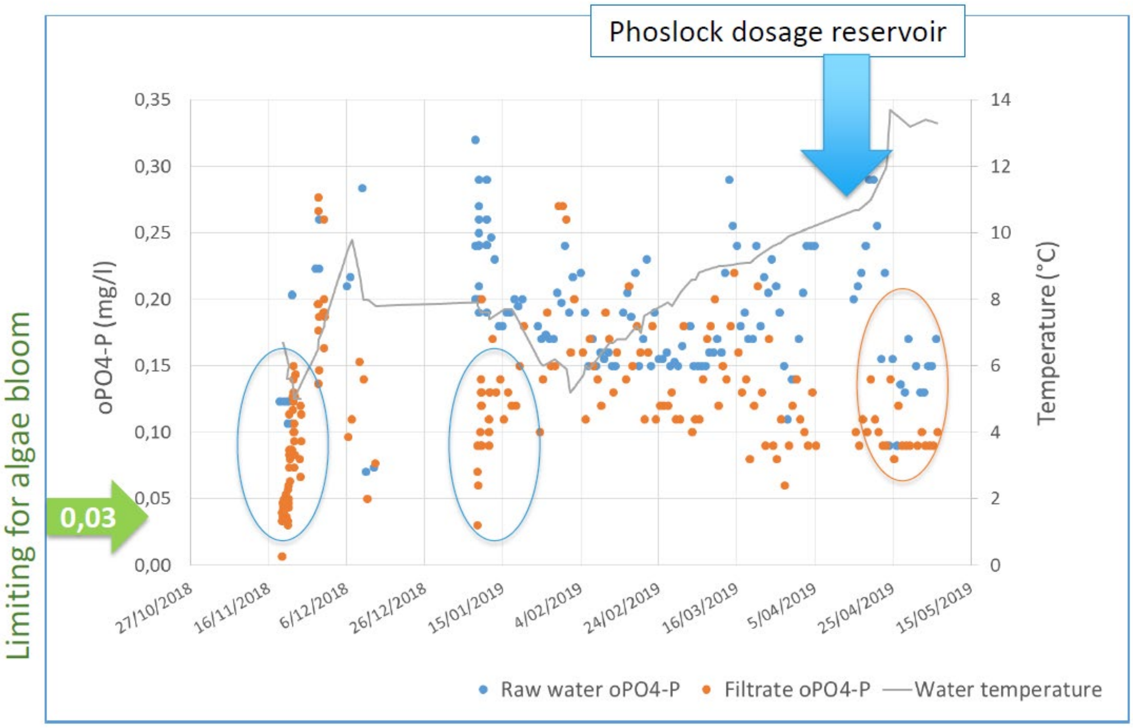

Figure 6 The ortho-phosphate concentration at the inlet and the outlet of the pilot-scale adsorption column, measured at different points between November 2018 and May 2019.

Due to the very low P concentrations in the raw water, it seems to be challenging to remove the P below the limits of algae bloom in the reservoir. The P removal should be done at the more concentrated point sources which feed the reservoir. Samples at different points around the Blankaart basin were taken as indicated on the map below. (Figure 7). For these diffuse sampling points much larger phosphate concentrations of a factor 10-20 compared to the reservoir are observed (Figure 8).

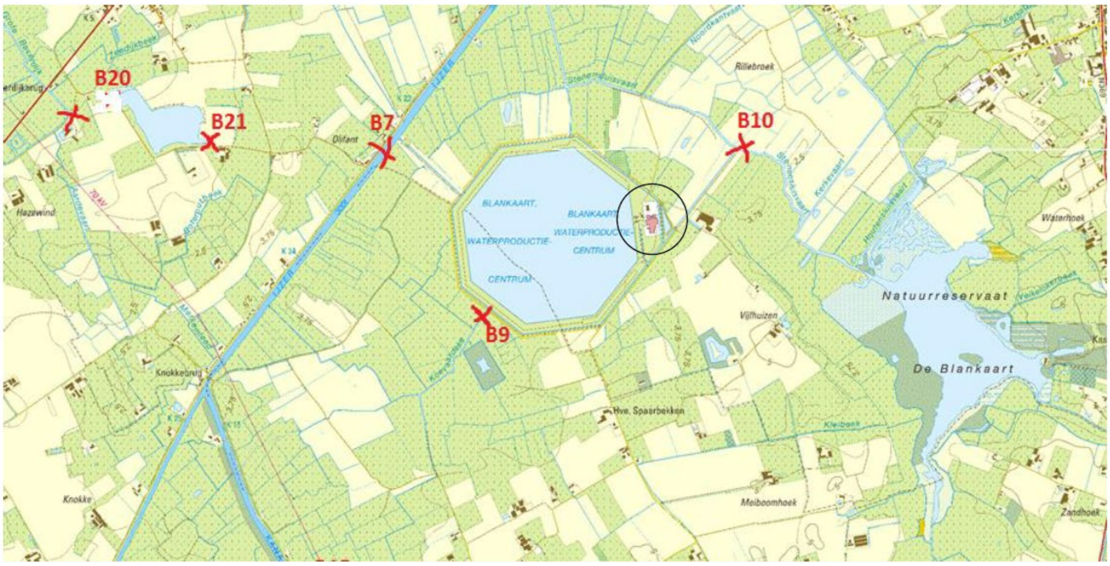

Figure 7 Location of concentrated point sources around the Blankaart reservoir.

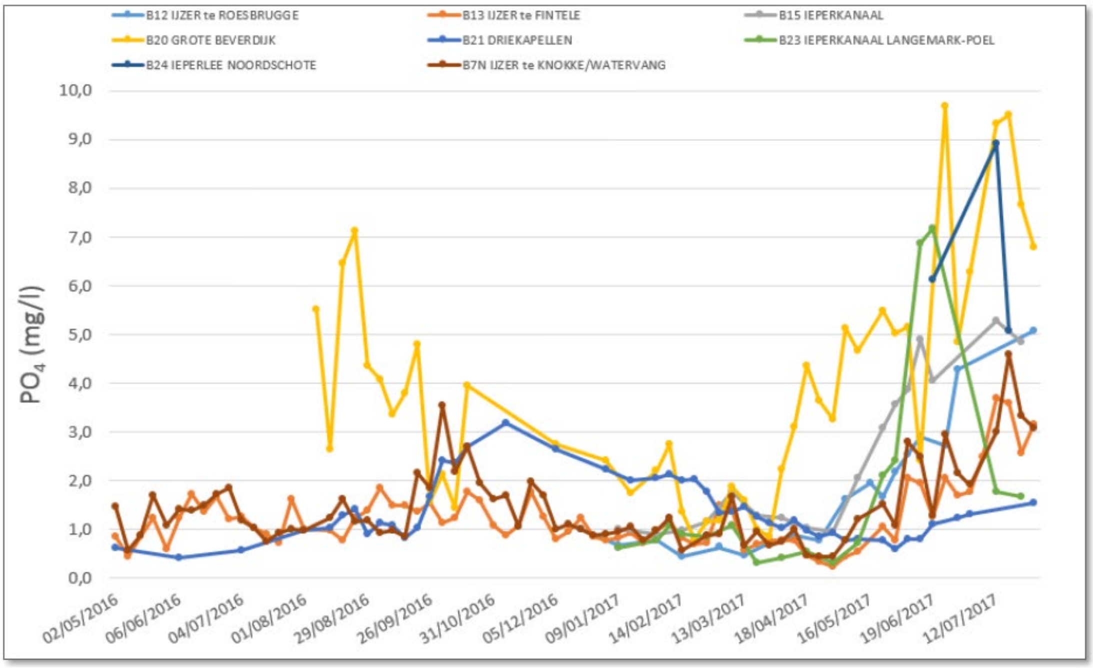

Figure 8 Sample points around the Blankaart basin and their ortho-phosphate concentration over the period of 14 months (sampling 1 point a week).

The feasibility of tackling the P at these more concentrated points was shown by some initial beaker tests were a 70% removal was already shown within the first 8 minutes using only a very small amount of filter material with a S/L of 5 g L^{-1} (Figure 9). However, no filter installation could be build at these point sources to evaluate their feasibility.

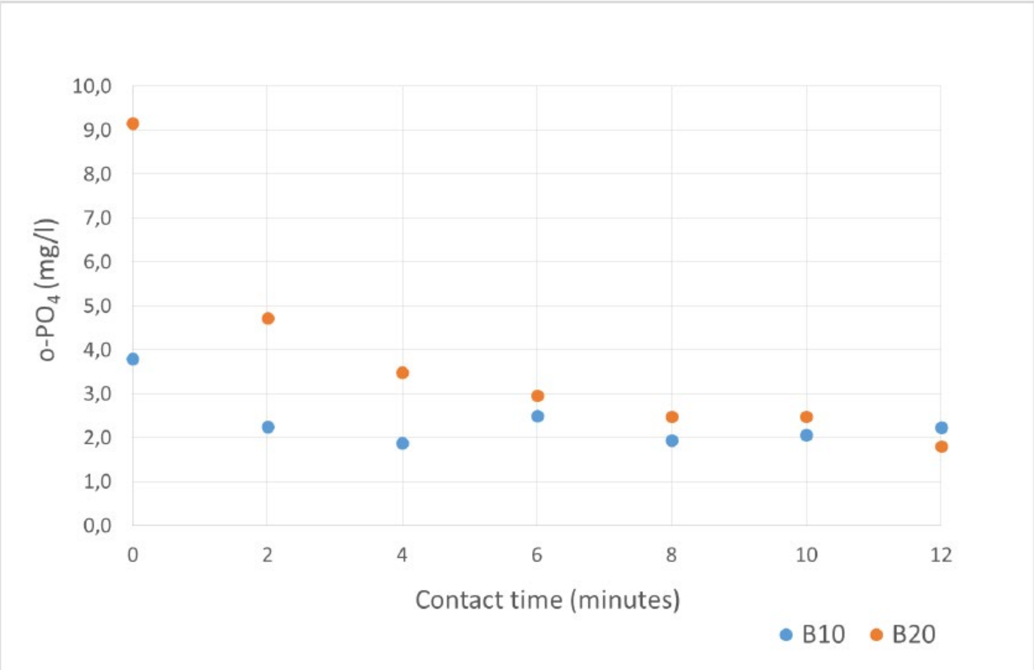

Figure 9 Beaker test for phosphate removal with ABA-500 material on surface water with high P concentration (sampling location B10 and B20).

Furthermore direct filtration of the surface water leads to clogging. During algal blooms the filtration time was severely reduced. The amount of water lost due to backwashing was unacceptable. Thus the filters can be used with water containing low suspend solids however a backwash system remains advisable.

Financial aspect

As removal efficiency dropped fast given the relative low P-concentration in the intake water the filtration system isn't the most efficient solution. As the filter is not suitable to lower the P concentration below 0,033 mg/l, algae blooms cannot be avoided with this technology and the filter is therefore not suitable for this specific application.

Conclusion

P-removal with the tested material is feasible however a higher adsorption capacity at low concentrations is needed for this application or tackling the P removal at the point sources.. Furthermore the pilot showed the need of a backwash system when filtration of water with a high suspended solid concentration is needed.