Interreg
North Sea Region
NuReDrain
European Regional Development Fund

EUROPEAN UNION

FILTER SYSTEMS FOR A SUSTAINABLE AGRICULTURE

FIELD CASE DESCRIPTION

Phosphorus filters for drain water from horticulture

PCS
proefcentrum voor sierteelt

Locations

Location 1

Country: Belgium
City: Destelbergen
Coordinates: N 51,07039 - E 3,81565 (PCS)

Location 2

Country: Belgium
City: Nevele
Coordinates: N 51.03476 - E 3.52911 (Floristry Meuninck)

Problem description

Applying chemical fertilizers to soils already saturated with phosphates and spreading excessive amounts of manure on land causes phosphates to run off during heavy rainfall and pollute nearby water sources. Greenhouses reuse their drain water as much as possible, but 5-10% of the water cannot be reused and contains high amounts of P. When the amount of total phosphorous exceeds 100 parts per billion (ppb) in streams or 50 ppb in lakes, eutrophication -- the effect of algal blooms -is a danger.
Phosphorus removal from wastewater can be achieved by the adsorption onto filter materials.

Filter description

Waste products of drinking water companies can be used as filter material for P removal. During the production of drinking water, drinking water companies apply biological and adsorptive deferrization because groundwater often contains high iron concentrations (> 15 mg/l). In addition to biologically formed iron sludge, there is also iron adsorption on sand grains. In this fast sand filtration process, ICS (= Iron Coated Sand) is formed by the adsorption of iron on the sand cores. Due to the deposition of iron on the grain surface, the iron grain grows steadily and part of the grain must be removed from the sand bed periodically. It is this waste material (ICS) that can be used for another adsorption processes including the removal of phosphate (Photo 1).
In case the iron removal from groundwater results in solid iron sludge, this sludge can be pelletized and the phosphate removal takes place via the same process (Photo 1).

At location 1, 2 types of filters to remove P were compared: 2 IBC tanks of 1 m³ were filled for 80% with iron-ridge sludge pellets or ICS grains (Photo 2).
At location 2, 2 filters filled with ICS grains were installed in series and the tanks were filled for 80% with ICS grains. Wastewater passed through both filters (Photo 3).

	
Iron Coated Sand granules (ICS)	Pellets made from iron-ridge sludge

Photo 1 Iron Coated Sand granules (ICS) (left) and pellets made from iron-ridge sludge (right) at the start of the trial

Photo 2 Two P filters at PCS (in parallel)

Photo 3 Two P filters at Floristry Meuninck (in series)

Results (follow up of several seasons)

Location 1

Drain water, collected in a tank after removing N, flowed through the filters from bottom to top (to prevent clogging).
The efficacy for removing P was excellent.
In 2017, 18 times a day for 1 minute, water was pumped through the P filter with ICS grains or pellets. In 2018, the capacity was increased to 18 times a day for 2 minutes: 0,8 m³ per day was pumped through both filters.
The results for 2017 and 2018 are shown in Figure 1 and Figure 2. At the end of 2018, the P content in the drain water after the P filter was higher than 1 mg/l P. This indicated that the filter might be saturated.

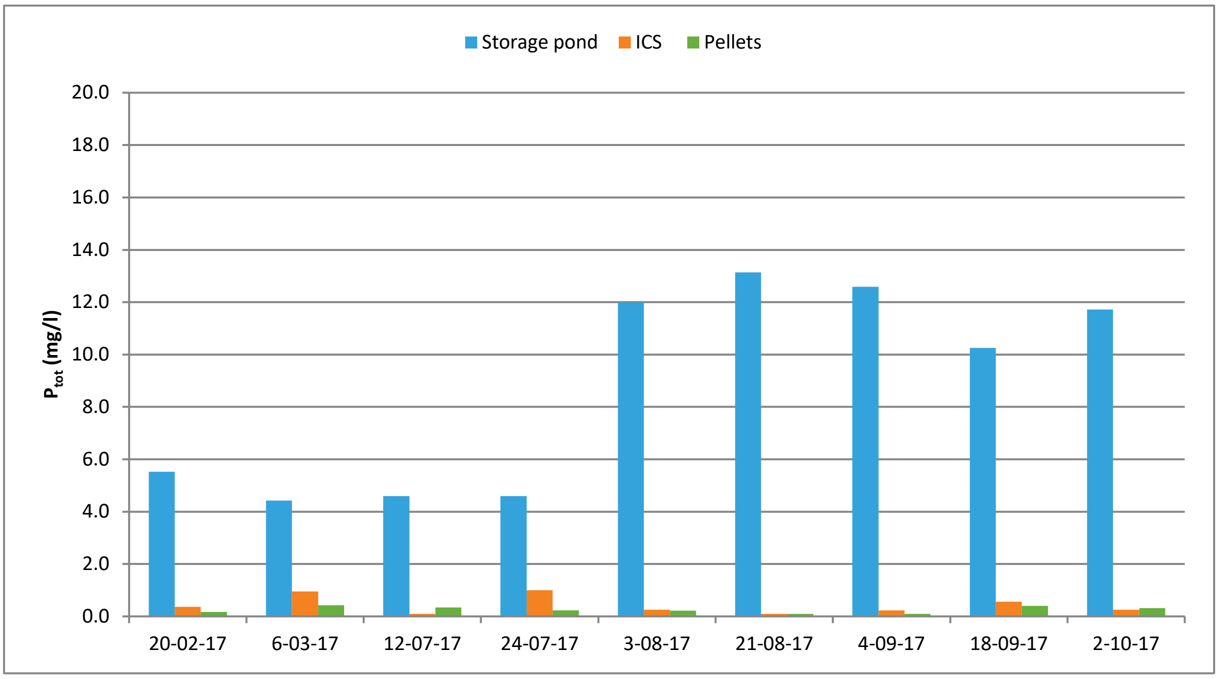

Figure 1 Results for P filters at PCS during summer 2017

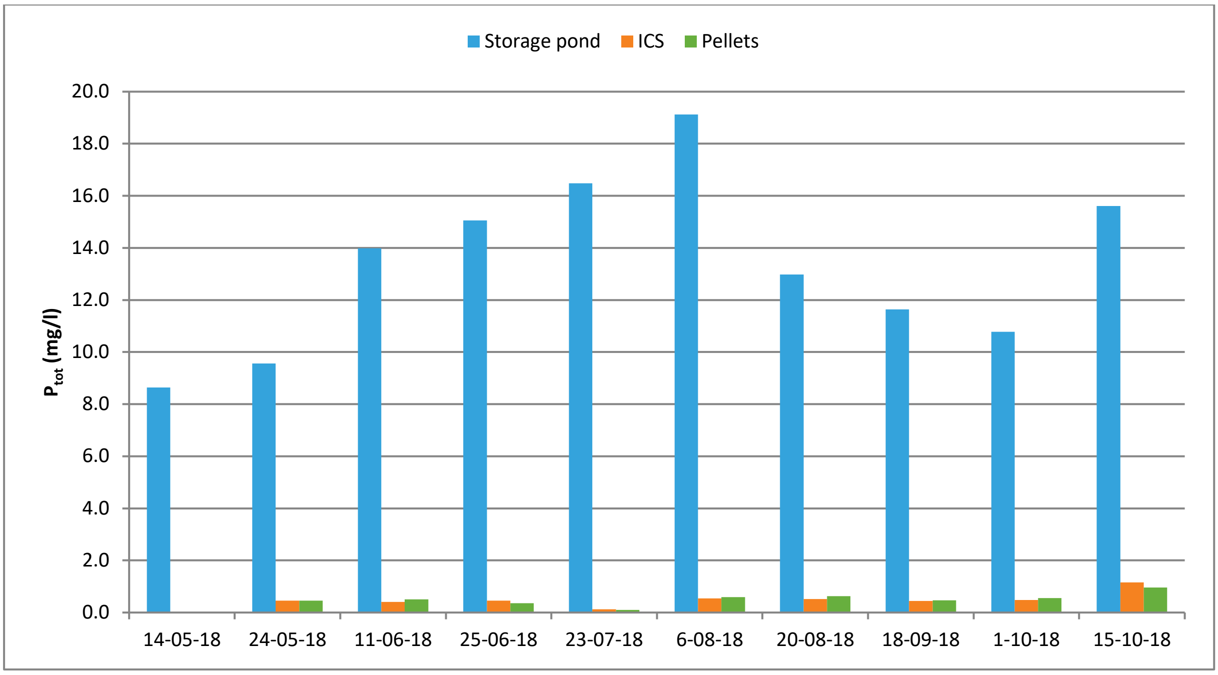

Figure 2 Results for P filters at PCS during summer 2018

Because of some months of inactivity in winter, saturation was avoided and in 2019, the efficacy of the P filters was excellent again without replacing ICS granules (Figure 3). In 2019, all P in the water of the storage pond was adsorbed onto the filter materials. Till the end of September, 1,3 m³ per day was pumped through both filters. Also the effluent of the MBBR passed through both P filters which resulted in higher filtered volumes. At the end of September, the pump capacity was increased: 18 times a day, 120 liter water was pumped through each P filter which means 2,2 m³/day through each filter.

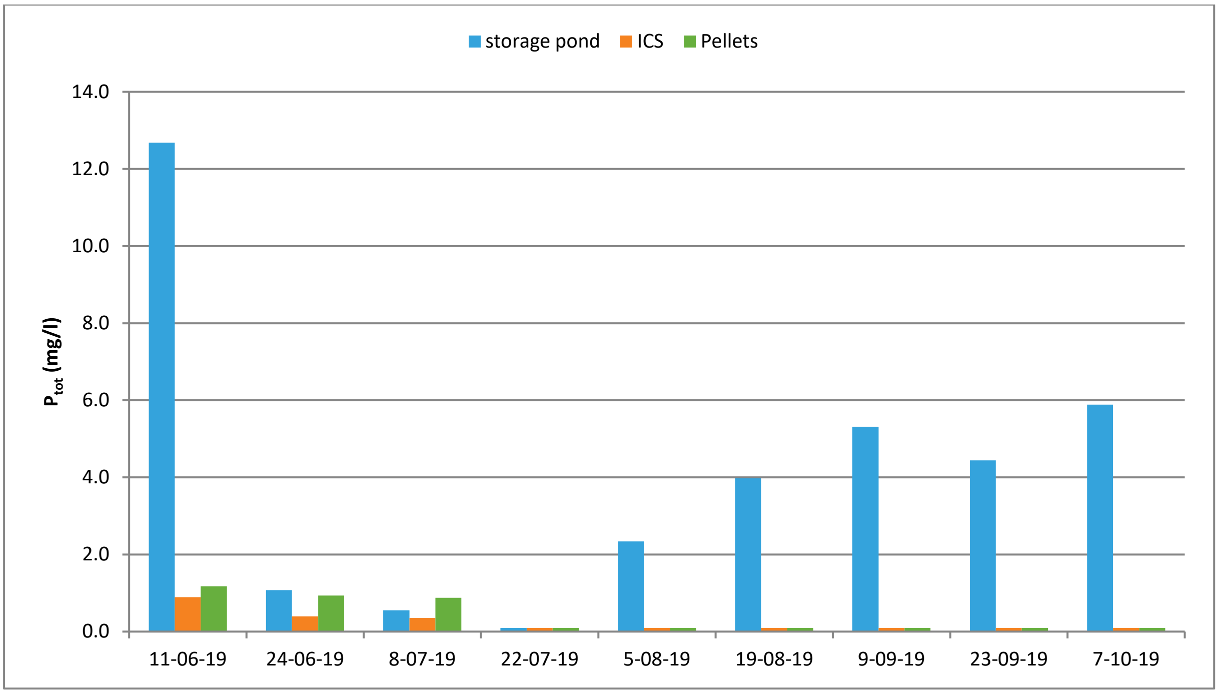

Figure 3 Results for P filters at PCS during summer 2019

In 2020, the amounts of P in the storage pond were higher than 12 mg/l. The filters worked well but not perfect (Figure 4). Each day, 0,75 m³ water passed through each filter. There was a serious reduction in P, but concentrations remained from July on between 2 and 4 mg/l P. Filters may be saturated, therefore, samples were taken to be analyzed by KULeuven.

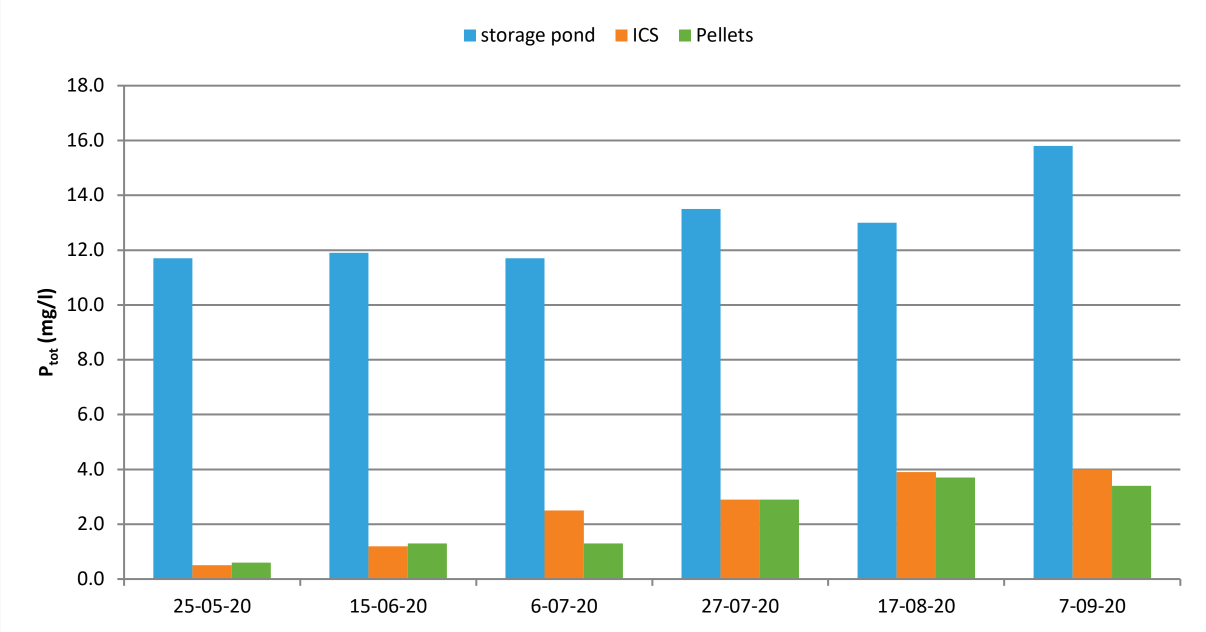

Figure 4 Results for P filters at PCS during summer 2020

In September 2017, September 2018 and November 2019, the level of adsorbed P on the grains and on pellets were determined by the KULeuven (Table 1). There was still more than sufficient capacity for the granules and pellets to adsorb P. Lab grains were already saturated after 4,40 mg P/g DW, but we could determine that in practice, levels up to 16 mg P/g DW are possible. This is due to the fact that P can migrate deeper into the grains, especially in times of rest (discontinuous flow). In this way, new adsorption places are available at the outside layer. This explains why it was not necessary in 2019 to replace the material. This was also confirmed by Figure 3, were we could see that in 2019, P was removed from drain water for both filter materials.

	September 2017	September 2018	November 2019
Pellets	4,40 mg P/g DW	7,46 mg P/g DW	10,2 mg P/g DW
ICS	4,27 mg P/g DW	13,66 mg P/g DW	Result not available

Table 1 Adsorbed P on the grains and pellets in mg P per g dry weight in September 2017, September 2018 and November 2019 (PCS)

After 4 years in operation, the structure of the ICS granules and pellets at PCS were not changed. Both materials conserved their structure (Photo 4).

	
Iron Coated Sand granules (ICS)	Pellets made from iron-ridge sludge

Photo 4 Structure of the ICS granules (left) and pellets (right) from the P filters at PCS after 4 years in operation

Location 2

The filter systems for removing P at Floristry Meuninck worked perfect in 2016 (Figure 5). All P was removed from the drain water. In March 2017, the grower pumped during 70h 80 m³ drain water through the filter (all captured water during winter) which is very harmful for the filter. In 2017, P filters were saturated and ICS granules had to be replaced. There was even 26,06 mg P/g DW absorbed on the ICS from filter 1 and 18,38 mg P/g DW on the ICS from filter 2, which are very high amounts.
On 17/04/18, ICS-grains from filter 1 were replaced. Because of this, P content of the drain water decreased after passing through the P filters but not all P was adsorbed; this was because ICS-grains of filter 2 were also saturated and needed replacement. This was carried out on 19/09/18. P filters also remove in small amounts some Ca and Mg from the drain water (Figure 6 and Figure 7). The Ca and Mg content in the buffer tank was always higher than the content in the drain water after the P filters.
In 2019, all drain water was collected in the buffer tank till the beginning of August. The results for the P filters are shown in Figure 8. More than 90% of the P in the buffer tank was removed from the drain water.
Also in 2020, P filters worked very well (Figure 9). Almost all P was removed from the drain water.

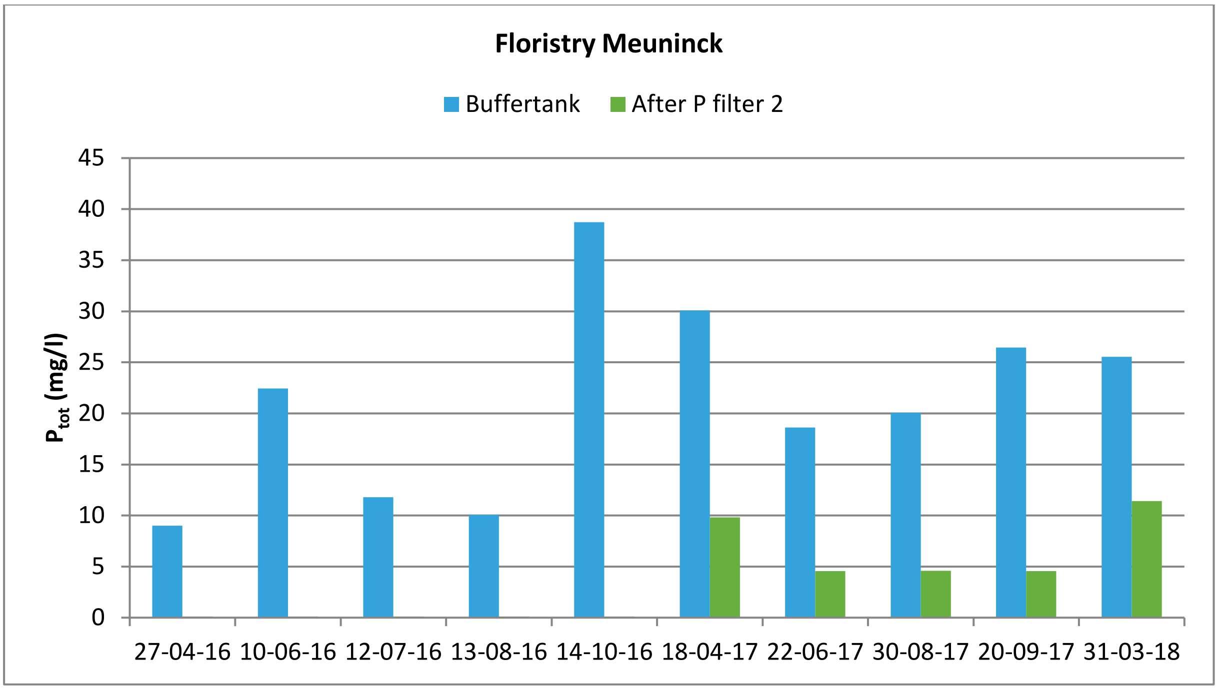

Figure 5 Results of P removal for P filters at Floristry Meuninck during the period 2016-2017

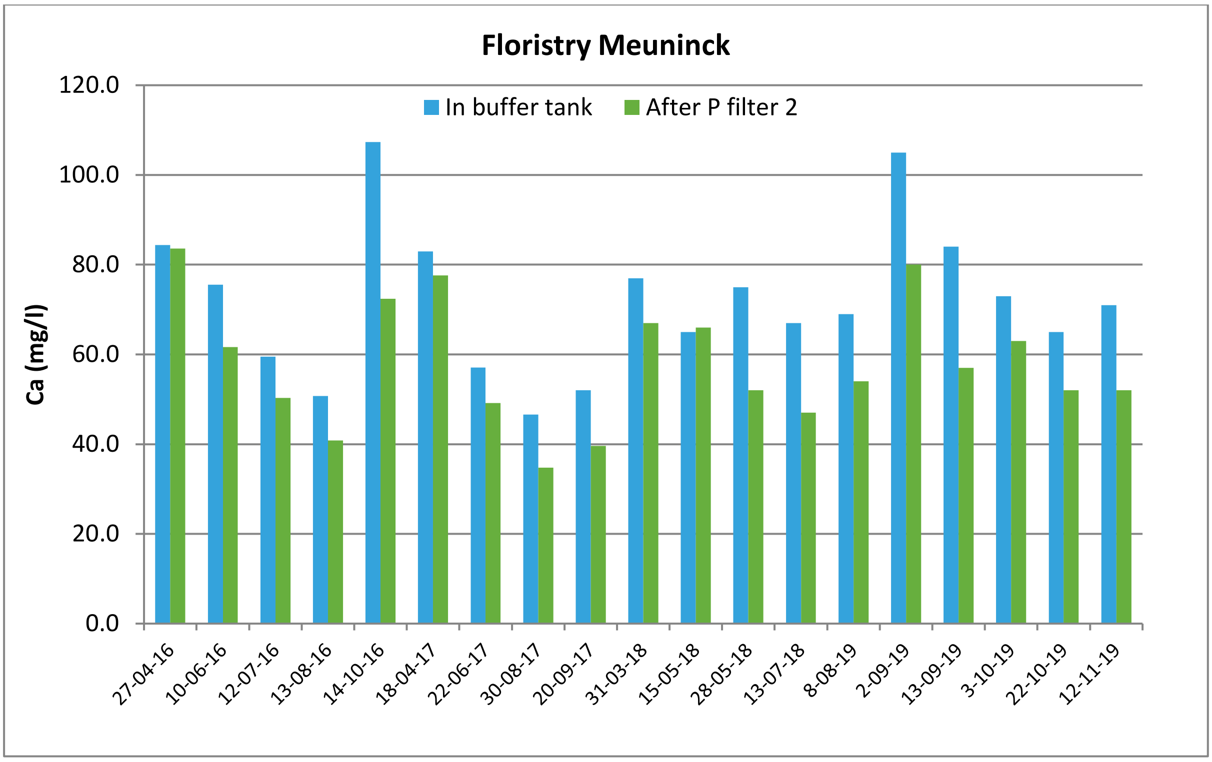

Figure 6 Results of Ca removal for P filters at Floristry Meuninck during the period 2016-2019

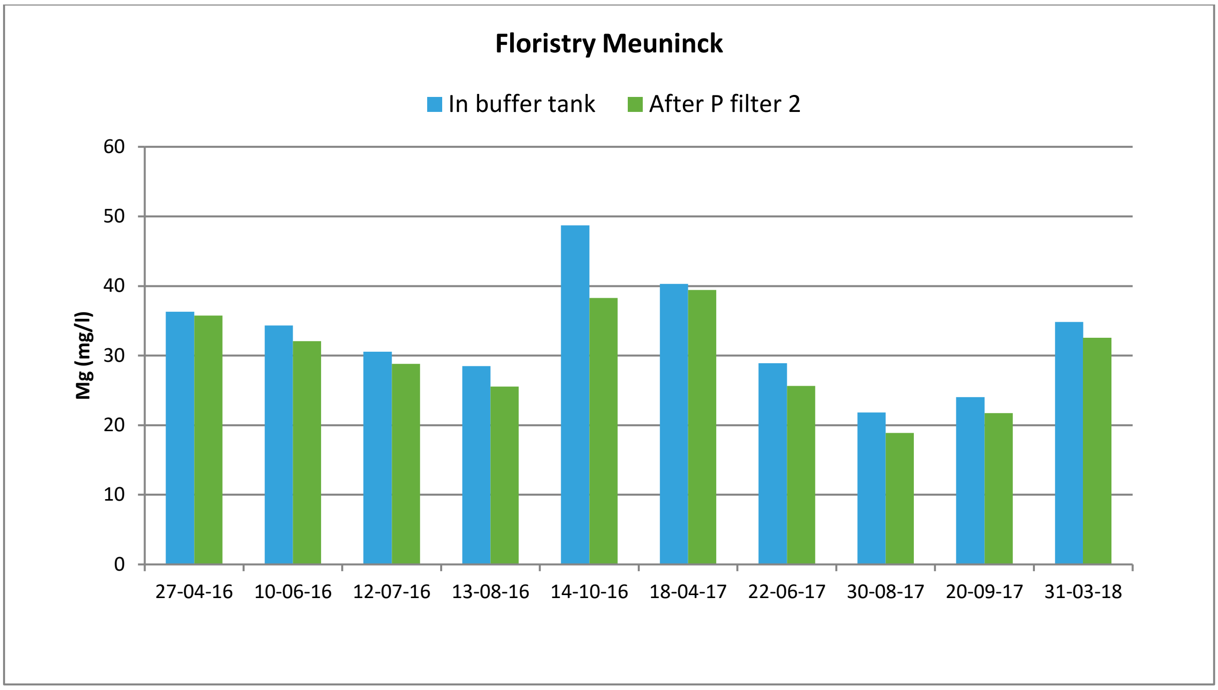

Figure 7 Results of Mg removal for P filters at Floristry Meuninck during the period 2016-2017

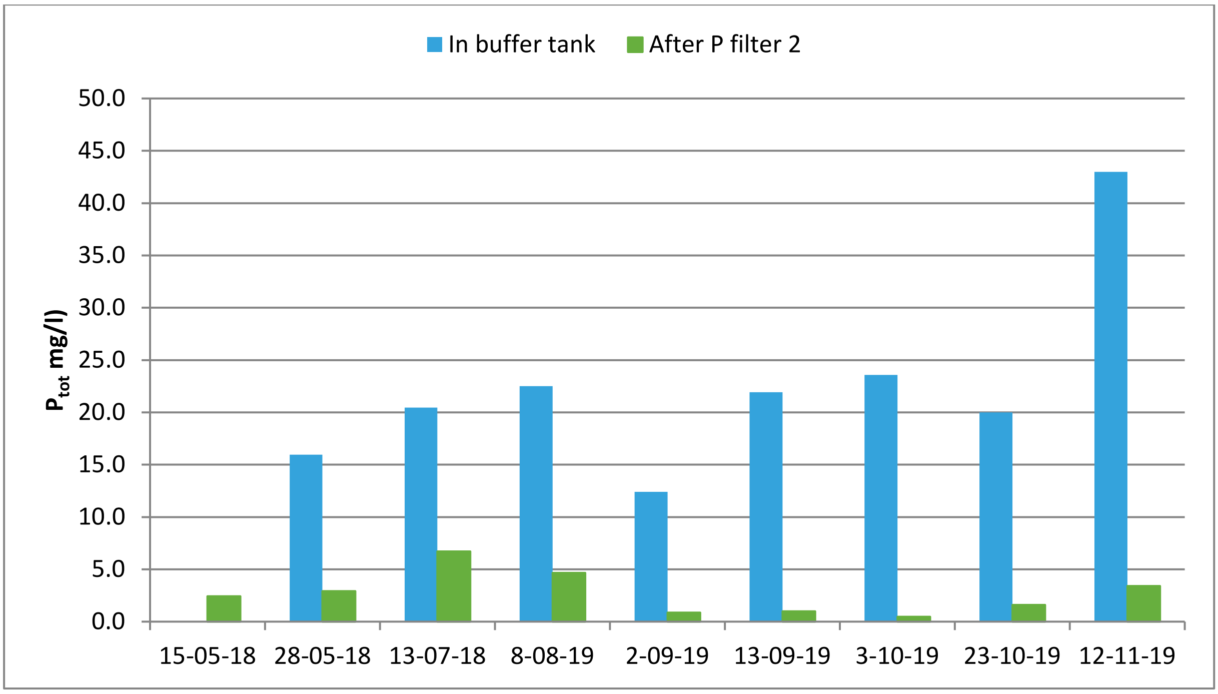

Figure 8 Results of P removal for P filters at Floristry Meuninck during summer 2018-2019

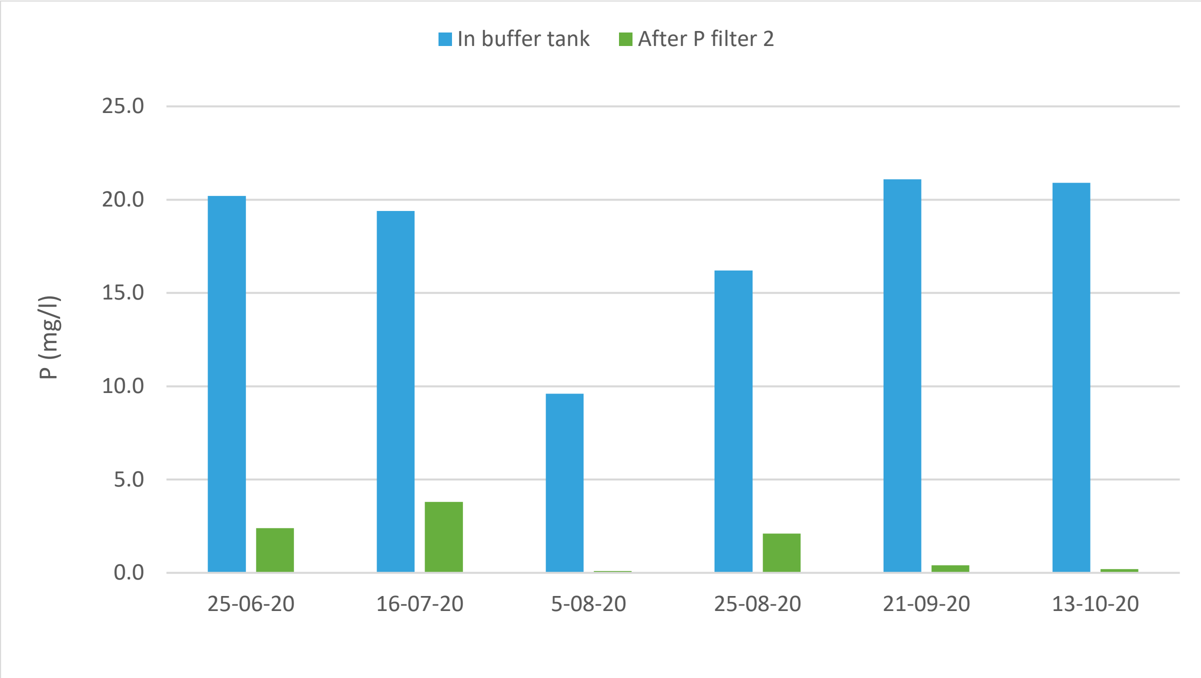

Figure 9 Results of P removal for P filters at Floristry Meuninck in 2020

	
Iron Coated Sand granules in filter 1 (ICS)	Iron Coated Sand granules in filter 2 (ICS)

Photo 5 Degradation of the ICS grains in filter 1 (left) and filter 2 (right) at Floristry Meuninck

In September 2017, the adsorption capacity of the ICS granules was determined for both filters by KULeuven. The following levels were achieved:

- Filter 1 = 14,3 mg P/g
- Filter 2 = 9,8 mg P/g

Financial aspect

The installation cost for a cubitainer P-filter is approximately € 690 and the yearly operation cost is € 95. The total yearly cost has been calculated and amounts up to € 164. The cost-effectiveness is € 85/ kg P. A cubitainer can handle 2 to 3 m^3/day. If this coincides with the water volume that a greenhouse discharges then this do-it-yourself solution is very affordable.

Conclusion

A P-filter is a very simple filter as it is a cubitainer filled with ICS-grains or pellets. ICS-grains are a waste product of drinking water companies. The filter can work for a few years without needing replacement of the filter material. Once the material gets saturated, the grains or pellets have to be replaced, and unfortunately, it is not yet economically viable to regenerate the ICS.
Of course it is necessary that greenhouses reuse their water as much as possible and only the water that can't be reused, is filtered before discharge, otherwise the amounts to treat are far too big.

A discontinuous water flow has a positive effect on the adsorption capacity. When there is no flow, P migrates deeper into the core and new adsorption places appear at the surface of the grain. Therefore the capacity before saturation is much higher in practice than determined in the lab. It is also important to flow high loaded P water slowly over the filter and not all in once, for instance after the winter period.