Interreg
North Sea Region
NuReDrain
European Regional Development Fund
EUROPEAN UNION

FILTER SYSTEMS FOR A SUSTAINABLE AGRICULTURE

FIELD CASE DESCRIPTION

Inline P filter for drainage water

Landwirtschaftskammer Niedersachsen
Wir bieten Lösungen – regional & praxisnah!

Location

Country: Germany, Lower Saxony
City: 49179 Ostercappeln
Coordinates: 52.418883, 8.191645

Figure 1 Site of inline P filter at Venner Bruchkanal.

Problem description

P concentrations in the drainage water are too high (up to 4,0 mg/l) to meet the EU standard in the receiving surface water. The basic concept to reduce these P losses in drainages is to install an experimental inline P filter with a P-sorbing material (PSM) just before the end of the drainage pipes. In order to remove mineral and organic substances from the drain water, a pre-filter is installed upstream of the P filter. The water flows through the pre-filter into the P filter material that allows the removal of P from it before entering the receiving surface water (Figure 2). There is only a low hydraulic pressure head between the level of the tile drain and the surface water in the creek. The working principle of drainage at that (specific) site is suction drainage by streaming (creek) water. Therefore, a horizontal percolation of the P filter had to be facilitated.

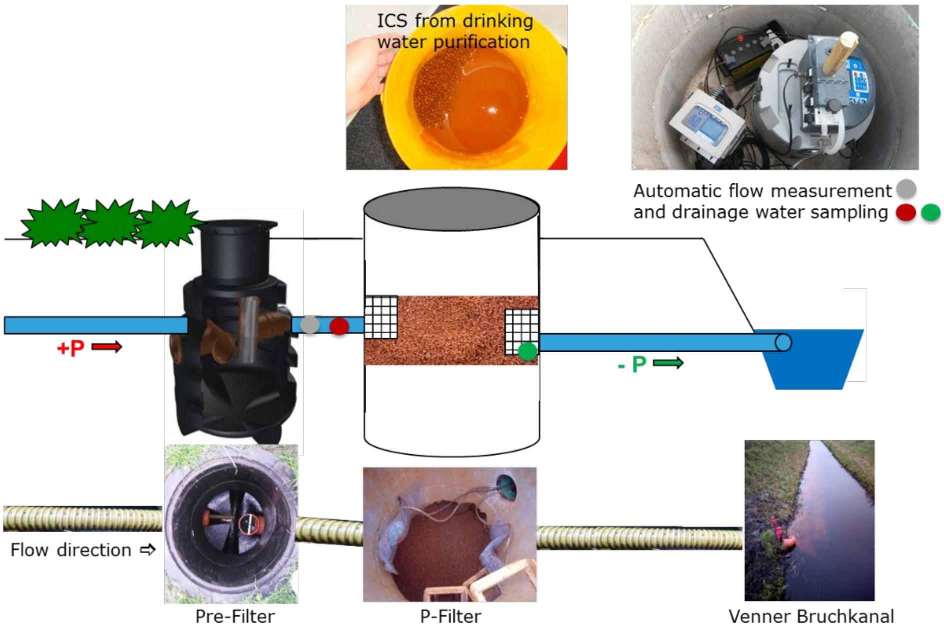


Figure 2 Schematic overview of the experimental inline P filter at Venner Bruchkanal with horizontal flow through the ICS.

Field site

The Dümmer is the second largest lake in Lower Saxony with a catchment area of about 324 km². In this area, about 590 farms operate on an agricultural area of about 17,500 ha.

The LBEG has identified drained sites in long-term measurements that show high nutrient losses via the drainages in the catchment area (Figure 3). Such a site was chosen for the experimental P filter installation.

The specific field site was chosen on the basis of its artificial drainage discharging into a creek (Venner Bruchkanal) identified as being high in P load (multi annual point measurements, research realised by LBEG), its soil type (high in organic matter) and its representative cultivation (silage maize or field grass).

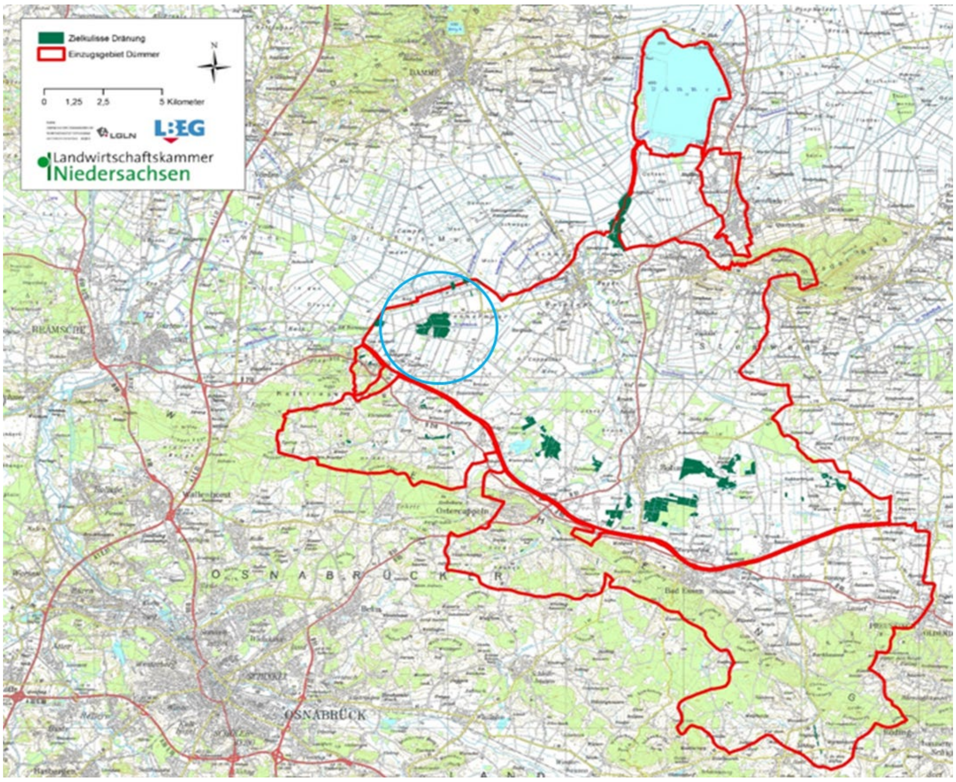


Figure 3 Sites with high P nutrient losses via drainage are marked in dark green (multi annual monitoring by LBEG). The location of the P filter system is circled in blue.

The site is located in the transition zone from meliorated organic soils (known for their low nutrient filtering capacity) to mineral soils, which are associated with a better nutrient binding capacity.

The organic soils are located upstream of the P filtration plant (Figure 4).

Figure 4 (Top-) Soil types at the field site (DTK50 der Landesvermessung + Geobasisinformation Niedersachsen, modified. The field draining into the P filter system is circled in red.).

Specific challenges at the field site

The measuring operation at the site is significantly influenced by two factors. On the one hand, by the input of amorphous organic matter (AOM) from the drainage pipes into the individual filter stages. The consequences of AOM discharge are clogging, piling up of the water, preferential flow or overflowing of the P filter and thus a reduction in the effectiveness of the P filter. Secondly, the flow velocity in the Venner Bruchkanal plays an important role: only with sufficient flow velocity is there sufficient suction on the drainages so that they can discharge their water. If the flow velocity is not sufficient, water flows back from the Venner Bruch canal into the P filter. The consequences are free standing water on the P filter without outflow. No measurements and values can be collected causing a gap in the data table. Under such conditions, the measuring operation must be stopped. The main cause of insufficient flow velocity is a high vegetation cover in the ditch. After mowing and dredging by the watercourse maintenance association in autumn/winter, the flow velocity increases and the drainage discharge is ensured.

Figure 5 Input of amorphous organic matter (AOM) from the drainage pipes into the individual filter stages of the experimental inline P filter.

Figure 6 Different flow conditions in the Venner Bruchkanal in relation to the degree of clearance of the watercourse at the beginning of the drainage season in november from 2017 to 2020.

Measurement technology

Two ISCO samplers (6712 Full Size) were selected to meet the scientific requirements for permanent discharge P monitoring. Continuous sampling was carried out in order to be able to map the strongly fluctuating values to be expected and was emphasised in its importance by Charlotte Kjaergaard during the kick-off meeting in Billund 2017. The Signature Flowmeter AV TIEnet 350 (velocity and total water flow) was selected because of the need for non-contact measuring of discontinuous (low) flow inside drainage pipes.

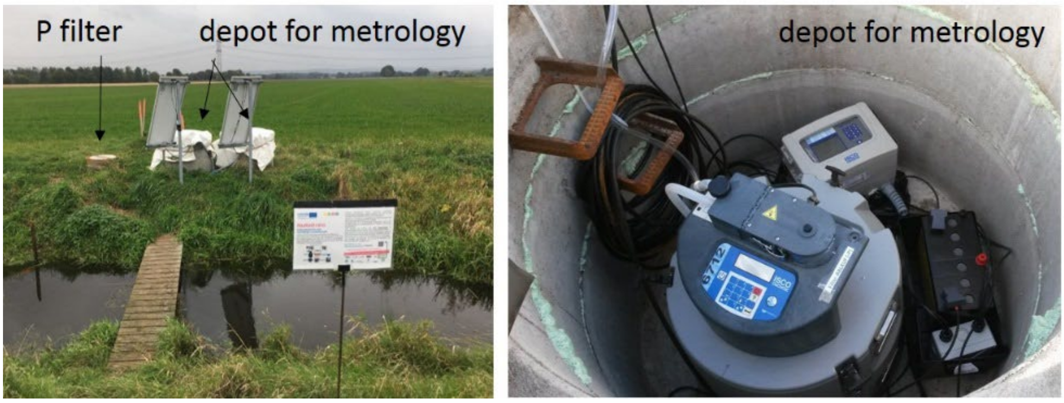


Figure 7 The LWK´s P inline filter system with ISCO sampler (two 6712 Full Size), Signature Flowmeter AV TIEnet 350 (velocity and total water flow), charge controller, battery and solar panels.

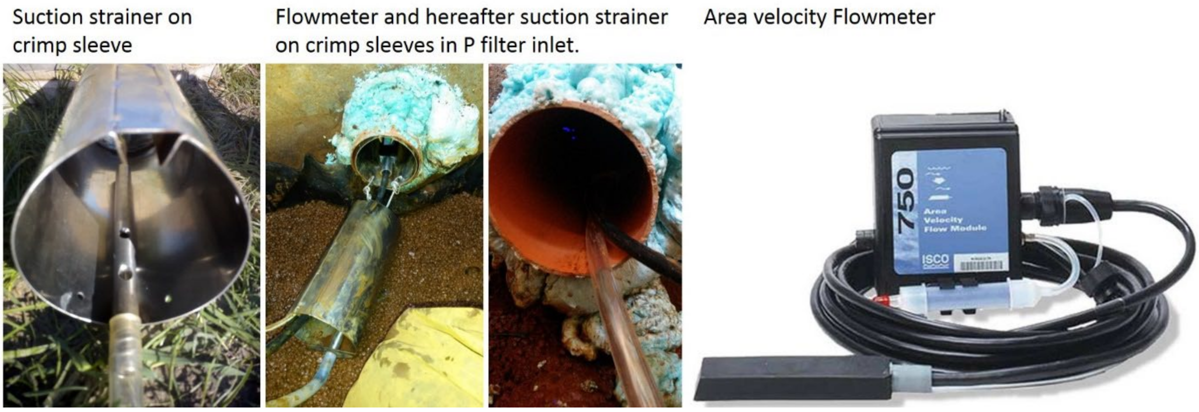


Figure 8 Suction strainer on crimp sleeve, Flowmeter and hereafter suction strainer during installation in the drainage pipe at the P filter inlet and Area Velocity Flowmeter.

Figure 9 Suction strainer on crimp sleeve and in grid basket during installation at the outlet of the P filter.

Figure 10 Pre Filter (left) and P Filter (right), the blue arrow indicates the flow direction. Transparent hoses: suction of the drainage water samples in the inlet and outlet, dark cable: flow measurement upstream of the P filter in the drainage pipe.

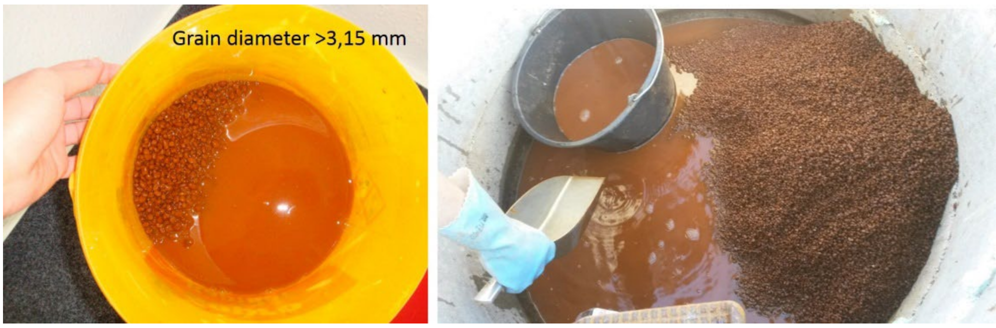


Figure 11 Sieved and rinsed ICS as P filter material. The grain size is >3.15 mm in order to achieve a sufficient saturated hydraulic conductivity with a prevailing low hydraulic gradient in the field.

Photo filter during operation

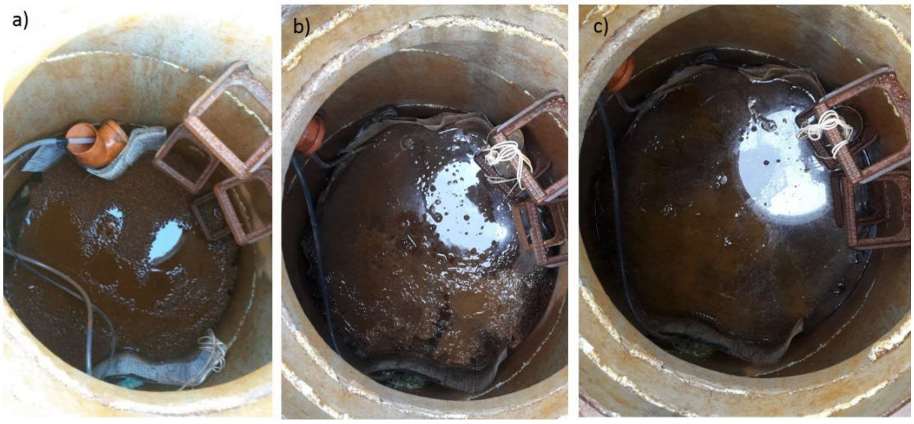


Figure 12 Different P filter conditions: a) Good: Good flow through the ICS. b) Bad: Silting up, resulting in preferential flow and superficial discharge, thus no good flow through the ICS. Cleaning of all filter stages necessary. c) Non-functional: The flow velocity in the receiving surface water is too low. There is backflow from the stream into the P filter. Loss of the P filter function, resulting in the filter system being switched off. Removal of aquatic vegetation required to enable good stream flow velocity and discharge of drainage.

Figure 13 The input of amorphous organic matter via the drain water leads to clogging of the screen filter in the pre-filter (b) and the wire filters in the inlet of the P filter (c and d), as well as the ICS. As a result, the water level in the pre-filter rises and causes overflow of the screen filter and the input of even more amorphous organic matter.

Results

The TP values measured in the laboratory in the unfiltered drainage water samples fluctuate between a minimum of 0.04 mg/l (detection limit) and a maximum of 3.07 mg/l in the period from 2018/2019 to 2020/2021. The mean values are 0.08 mg/l (2018/2019), 0.22 mg/l (2019/2020) and 0.10 mg/l (2020/2021). The target values of the Surface Waters Ordinance (0.1 – 0.3 mg/l) and the water framework directive are sometimes exceeded although the averaged measured values do not reflect this (Table 1). In order to be able to record the high fluctuation of the P contents, we decided to use automatic time-correlated sampling (10-day samples every 2.24 hours).

The range of variation for P dissolved in the study period 2018-2021 is much smaller and lies between 0.01 and 0.6 mg/l.

Table 1. Laboratory analyses of unfiltered and filtered drainage water samples for total P and dissolved P from 3 seasons.

	unfiltered (mg/l)		filtered (mg/l)		
	P tot.	P diss.	P tot.	P diss.	
min	0,04	0,01	<0,04	<0,04	2018/2019
max	0,17	0,03	<0,10	<0,10	
Mittelwert	0,08	0,02	no data	no data	
min	0,04	0,01	0,04	0,01	2019/2020
max	3,07	0,10	3,19	0,02	
Mittelwert	0,22	0,02	0,18	0,01	
min	0,04	0,04	0,04	0,04	2020/2021
max	0,44	0,06	0,07	0,04	
Mittelwert	0,10	0,04	0,04	0,04	

Flow measurement took place automatically (in season 2019/2020) and manually in season 2020/2021 after the failure of the measuring system. A test operation of a level measurement system does not provide usable data, as the level laws are violated in the experimental P filter setup.
Automatic flow measurement is characterised by a high temporal resolution and reflects the discontinuous nature of the flow (Figure 15). Manual sampling maps the flow at a specific point in time and produces a static flow pattern (Figure 16). The drainage flow begins in November and has its maximum between December and February/March. With intensity then decreasing sharply, it lasts until around May (season 2020/2021).
The data basis for the flow measurements is still incomplete due to the technical difficulties in collecting data in the drainage pipe (incomplete data in season 2019/2020), the failure of the flow meter and the change to manual measurements and is therefore considered preliminary. The average flow rate in season 2019/2020 (November to January) is 7052 l/day, which is in line with the average flow rate of 7056 l/day in season 2020/2021 (January/February). Nevertheless a validation of the flow data is required.

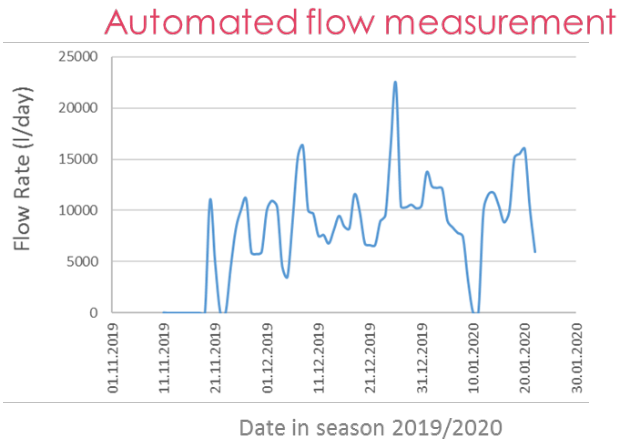


Figure 14 Automated flow measurement in drainage season 2019/2020.

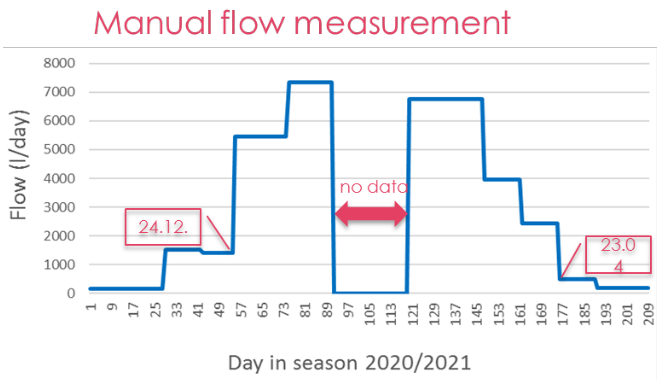
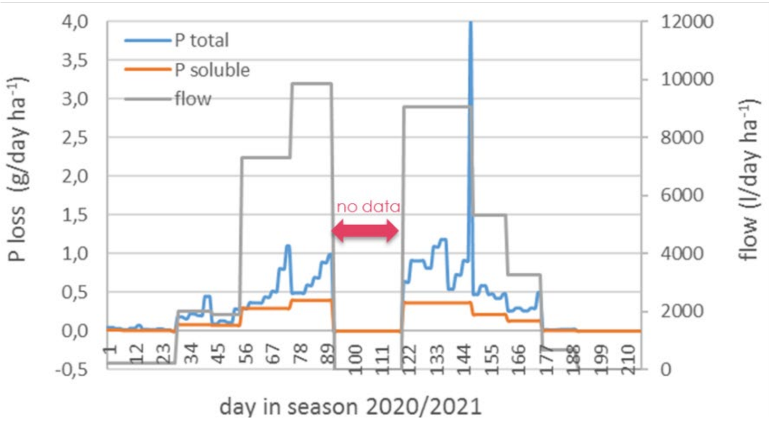


Figure 15 Manual flow measurement in drainage season 2020/2021.

There is a positive correlation between flow and loss of P, especially for P total, less for P soluble (Figure 17). The visible time-delayed change in effect (change in P loss) compared to a change in cause (change in flow) is known as the hysteresis effect and is also described by Ulén & Persson (1999). The total extrapolated P total loss per ha and year is 67 g, of which 30 g P dissolved (= 45%) in season 2020/2021. In season 2019/2020, the P total loss was 607 g/ha, of which only 7.6 g was P dissolved, which corresponds to 1.3%.



2020/2021

Figure 16 Loss of P total and P soluble as a function of flow in season 2020/2021.

There is a positive correlation between P loss and retention for P total as a function of flow (Figure 18, left). For P soluble, there is a relationship between P loss and flow (Figure 18, right). However, there is no relationship between P loss and P retention. The data for P dissolved indicate that the experimental P inline filter is not suitable for filtering that low P soluble concentrations.

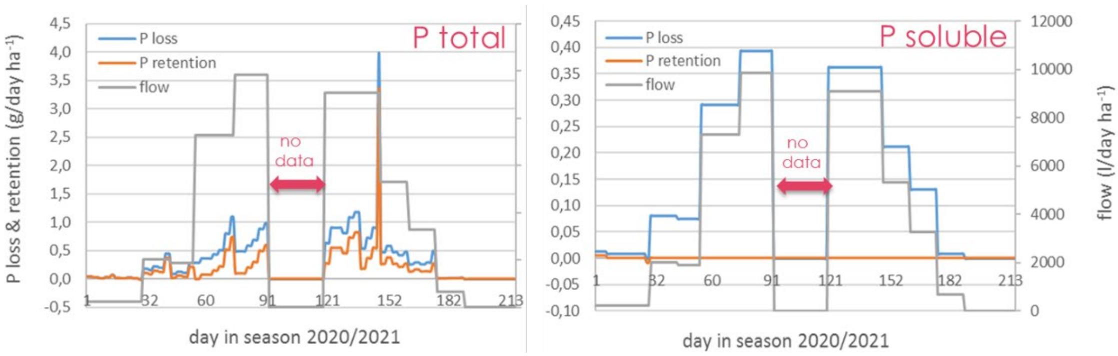


Figure 17 P loss and P retention as a function of flow for P total (left) and P soluble (right) in season 2020/2021.

The efficiency of the experimental P inline filter for particle-bound P is 83% in season 2019/2020. In season 2020/2021 it decreased to 54%. The efficiency of the experimental P inline filter for P soluble is <2% in season 2019/2020 as well as in season 2020/2021. Unlike the 2019/2020 season, the 2020/2021 season was characterised by a very heavy influx of AOM. AOM clogs the filter surfaces and the ICS and the water level in the filter system rises. As a result, the water flows down preferential paths and/or on the surface of the ICS. This reduces the (inner) surface area of the ICS available for the retention of P **and** the residence time of the water in the filter. Both reduce the filter efficiency.

Transfer into practice

The P inline filtration system is still at an experimental stage. Before the practical introduction it is required to enlarge the data base and obtain data on the long term filter performance. High filter efficiency can only be achieved if the filter has a good flow and is free of deposits. Therefore, the effective pre-filtration of AOM must be improved.
A guideline for assessing the suitability of a site for P filtration should be developed. The drainage conditions of the on-site drainage system should be taken into account when planning inline P filter systems. The P filter potential can only be fully utilised if free drainage is also guaranteed. In addition to practical issues, the legal framework must be clarified with the relevant authorities.
A P filtration plant could be a new installation or an extension of an existing drainage collector system (Figure 20).

Current used filter systems are drainage filter bedding (lidoniet/baselith around drainage tube) or drainage filter sheeting. In drainage filter bedding system P-adsorbing materials like lidoniet or baselith are surrounding the drainage pipes. Water is first in contact with the minerals, P is (partially) adsorbed onto the minerals and the water (containing less P) then enters the drainage pipe to be discharged in the surface water. A drainage filter sheeting systems refers to a P-adsorbing cloth (e.g. a coconut mat) around the drainage pipe. The main advantages of an inline P filter system with filter material are p

- Existing long term filter effect
- Only low space consumption
- ICS is a cheap filter material
- No energy supply necessary
- The material is interchangeable and replaceable by yourself

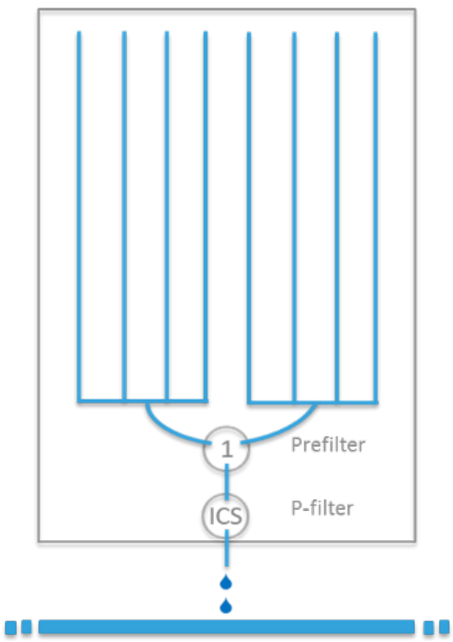


Figure 18. P filtration plant as a new installation or an extension of an existing drainage collector system.

Conclusion

Drainage water measurements in season 2019/2020 and 2020/2021 indicated that the P discharge is highly variable between individual events (*Macrae et al. 2007*). A significant proportion of the total P loss can occur within a short period of time. There can be a time lag between the change in cause and the onset of effect, known as the hysteresis effect. The main discharge takes place as particulate bound P (*Ulén & Persson 1999*).
During the season of 2019-2020 the ICS filter material showed a much higher P removal efficiency than in 2020/2021. In the season of 2019-2020, most of P (83% of TP but only 1% of DRP) was removed by the experimental P online filter. In the 2020-2021 drainage season, TP was only retained with a reduced P filter effectiveness of 53%. DRP is not retained in the P filter system, just as in 2019-2020.
After three drainage seasons, the prototype filter with ICS could still remove more than half of the P from the drainage water. Whether the reduction in P filter efficiency from 83% in the 2019/2020 season to 53% in 2020/2021 were caused by the high input of AOM and clogging or by increasing filter saturation could not be clarified. It is known that AOM is a carrier of P and causes a high P input into surface water (*Zimmer et al. 2016*). Further monitoring would be needed to see when the ICS gets saturated.
ICS has a potential for field use due to its high hydraulic conductivity, which is very important especially with the low hydraulic gradients in the field. It is important to find a balance between a sufficiently high conductivity and a sufficiently high retention time of the water in the filter for good P retention (*Chardon et al. 2012*). Clogging of the filter pores must be avoided at all costs.

Literature

Chardon et al. 2012, Journal of Environmental Quality, Vol. 41
Macrae et al. 2007, Agricultural Water Management, Volume 92, Issue 3.
Ulén & Persson 1999, Hydrological Processes Volume 13, Issue 17.
Zimmer et al. 2016, Agricultural Water Management 167.