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EUROPEAN UNION

FILTER SYSTEMS FOR A SUSTAINABLE AGRICULTURE

FIELD CASE DESCRIPTION

Phosphorus filter system for agricultural drainage water (first field case)

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Location

Country: Denmark
City: Odder
Coordinates: 55.979912 - 10.065351

Problem description

Phosphorus (P) leaching from tile-drained agricultural land contributes to diffuse pollution of surface waters. Critical P losses occur on hot spot areas where P-enriched soils are linked to a sensitive recipient by an effective hydrological process. As the scope of agronomic mitigation is limited, there is a need for end-of-pipe solutions. Phosphorus is transported in dissolved and particulate form (DP, PP), both of which have to be retained by an effective filter system.

Filter description

A full-scale experimental drainage P-filter system was established in February 2019 in the Fensholt catchment and near the town of Odder, Denmark. The system is fed with tile drainage water from an arable field of ca. 8.4 ha with loamy soils that had developed on Weichselian glacial till.
The drainage P-filter system (Fig. 1) consists of six cylindrical concrete wells connected consecutively by PVC pipes. Specifically it consists of:
- an inlet well housing an Krohne™ electromagnetic flowmeter.
- a distributor well fitted with a simple valve for regulating the hydraulic loading rate to the system and an overflow that permitted water bypassing during extreme runoff events.
- a Hydroseparator™ for retaining small particles and thus particulate P
- a reactive P-filter for removal of dissolved P.
- an outlet well housing a flow meter
- a sludge tank.

Sludge from the sediment filter is regularly being pumped into a storage tank with backflow to the P filter system. The purpose-built steel cage of the reactive P filter comprises two concentric cylinders of 1.8 m height with inner and outer diameters of 0.8 and 1.5 m, respectively. This cylindrical design provides a high cross-sectional area of flow into the reactive P-filter. The cage is filled with 2.4 m^3 of Diapure™, a calcined diatomaceous earth coated with iron oxides.
Three ISCO-samplers for continuous automatic water sampling are positioned at the inlet (ISCO1), between the sediment and reactive filter (ISCO2) and at the outlet (ISCO3). Total P (TP), total dissolved P (TDP), turbidity, pH and EC are measured in the lab on time proportional samples.

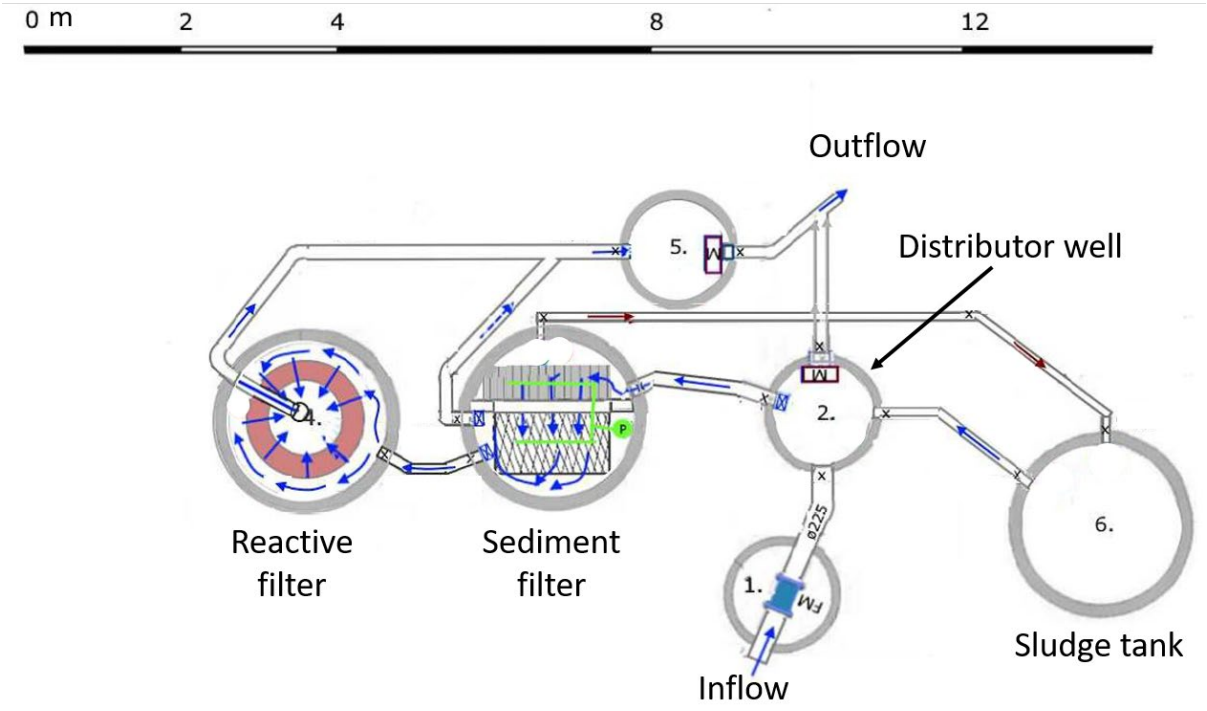

Figure 1 Schematic drawing of the drainage P-filter system consisting of six cylindrical concrete wells.

Visual impressions of the filter system

Figure 2 Drainage P-filter system near Odder, Denmark.

Figure 3 Well housing Hydroseparator™ for retaining drainage sediment and particulate P.

Figure 4 Reactive filter for dissolved P consisting of filter cage filled with Diapure™.

Results (through the different seasons)

Drainage season 2019-2020

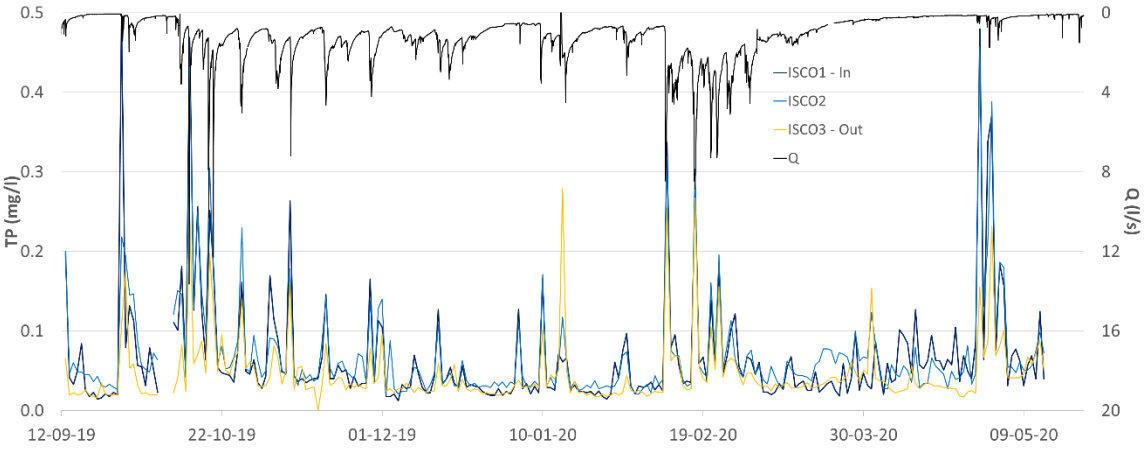

Figure 5 Daily values of total phosphorus (TP) at the inlet (ISCO1), between the sediment and reactive filter (ISCO2) and at the outlet (ISCO3) of the filter system during the drainage season 2019-2020. The hydrualic loading (Q) is given on the secondary axis.

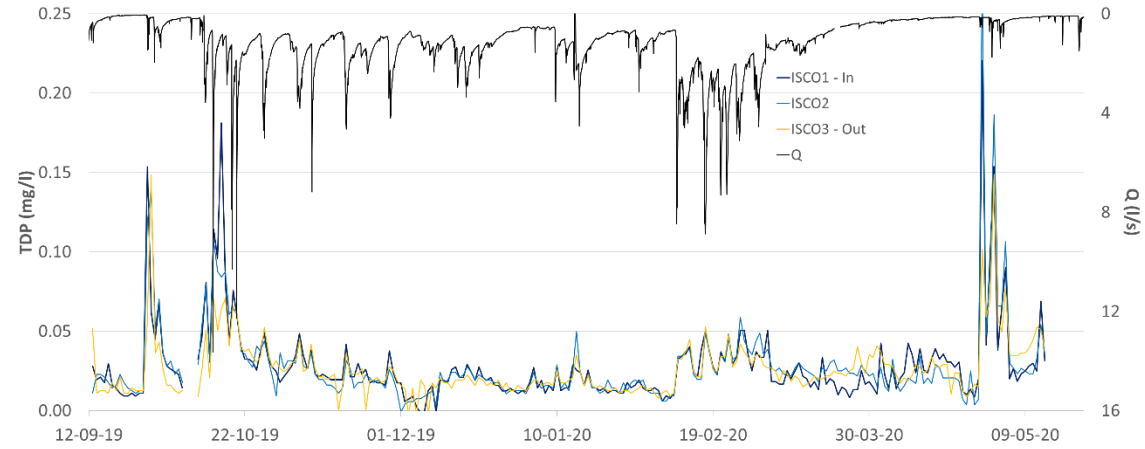

Figure 6 Daily values of total dissolved phosphorus (TDP) at the inlet (ISCO1), between the sediment and reactive filter (ISCO2) and at the outlet (ISCO3) of the filter system during the drainage season 2019-2020. The hydrualic loading (Q) is given on the secondary axis.

The hydraulic loading (Q) during the 2019-2020 season reached 13.64 l/s. A large number of distinct peaks was measured between October 2019 and March 2020. Peaks declined quickly, especially for isolated rain events.

Total P concentrations at the inlet (ISCO1) varied between 0.02 and 0.49 mg TP/l, while TDP varied between <0.01 and 0.22 mg/l. Total P concentrations at the outlet (ISCO3) ranged from <0.01 to 0.28 mg TP/l, while TDP ranged from 0.00 to 0.15 mg/l. Modest TP and TDP retention was observed due to the relatively low efficiency of the filter system in removing sediments.

Drainage season 2020-2021 (incomplete)

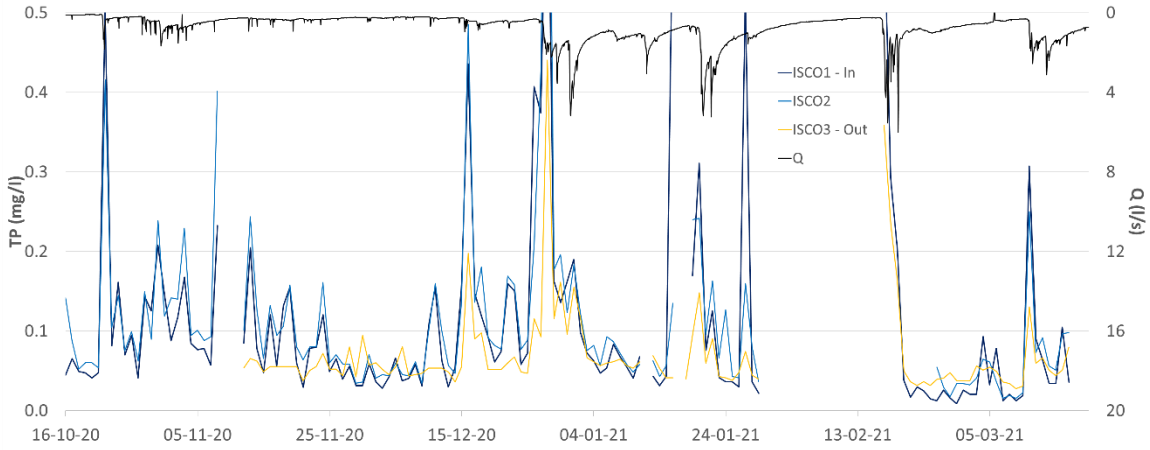

Figure 7 Daily values of total phosphorus (TP) at the inlet (ISCO1), between the sediment and reactive filter (ISCO2) and at the outlet (ISCO3) of the filter system during the drainage season 2020-2021. The hydrualic loading (Q) is given on the secondary axis.

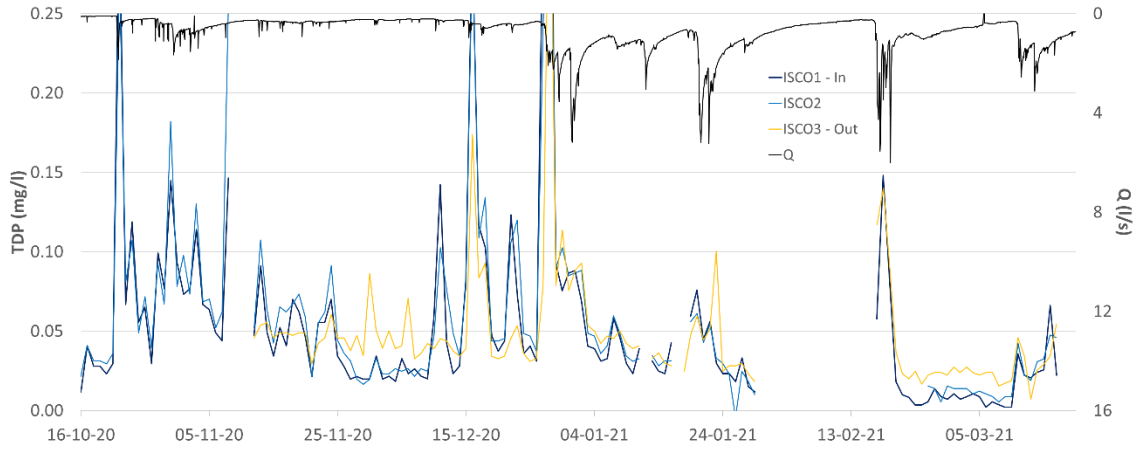

Figure 8 Daily values of total dissolved phosphorus (TDP) at the inlet (ISCO1), between the sediment and reactive filter (ISCO2) and at the outlet (ISCO3) of the filter system during the drainage season 2020-2021. The hydraulic loading (Q) is given on the secondary axis.

During the 2020-2021 season, flow through the system reached 6.01 l/s. The larger peaks occurred primarely between January and February 2021, and declined relatively quickly. Total P concentrations at the inlet (ISCO1) varied between 0.00 and 0.76 mg/l, while TDP varied between 0.00 and 0.47 mg/l. Values of TP at the outlet (ISCO3) ranged from 0.03 to 0.44 mg/l, while TDP ranged from 0.01 to 0.38 mg/l. The overall system TP retention was generally low and always below 16%, while there was a release of TDP during the investigated period. Results further indicated that the low TP retention was associated with particulate P accumulation and clogging of the reactive filter, being responsible for a reduction of sorption sites avaialble for retention. Remobilization of PP played also a key role in lowering the filter retention performance towards the end of the drainage season.

Financial aspect

Investment and operational costs of commercial systems are currently difficult to estimate as filter systems are under development. An operational filter system does not require a large use of sensors and flowmeters for continuous monitoring. Operational costs are site-specific and associated with risk of clogging and limited P sorption capacity of the reactive material.

Perspectives

Drainage water can be rich in PP, especially during the winter season. Sediments, which are not effectively removed by the sediment filter, can clog the entire filter system and reduce the P sorption capacity of the reactive filter. In the future, improved physical and chemical sedimentation will be tested using different compartment designs and involving coagulation or flocculation.
Transformations of P will also be investigated under varying redox conditions and drainage flow rates.