Phosphorus retention by compact filter systems treating agricultural drainage discharge

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Background

Phosphorus (P) losses in subsurface runoff from artificially drained agricultural land can locally contribute to surface water eutrophication. These losses are a function of hydrological processes and long-term P accumulation in soils due fertilization practices. As subsurface drainage systems concentrate water flow spatially, drainage filter technologies are a potentially cost-effective end-of-pipe mitigation practice for P losses. The aim of this study was to test a compact, full-scale P filter system under field conditions.

Field site and system design

The filter system near Fensholt, Denmark, was fed with tile drainage water from an arable field of ca. 25 ha with loamy soils.

Main system units (Fig. 1):
- a pump feeding drainage water at flow rates of typically 1-1.5 l/s from the main drainage outlet
- a WaterCare A/S DPF sediment filter
- KrohneTM electromagnetic flowmeter
- flow divider directing 10% of the incoming drainage water to the reactive filter
- filter box, CGK group BV, containing 30 l iron-coated sand (ICS)
- RBC flume
- three ISCO™ samplers for continuous automated water collection

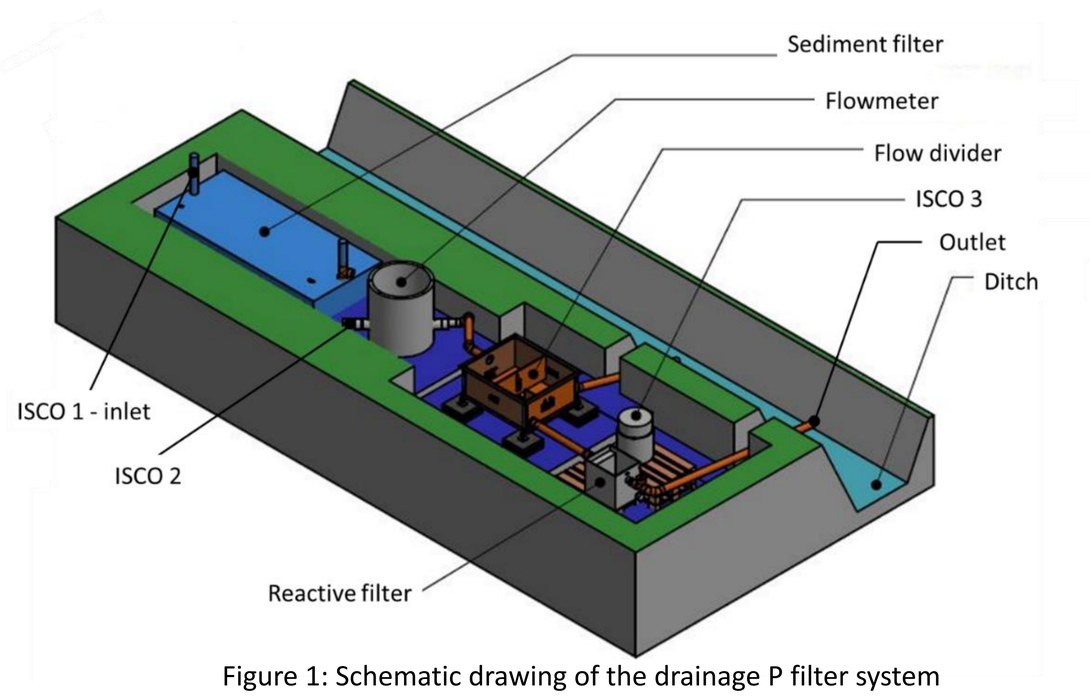

Figure 1: Schematic drawing of the drainage P filter system

Figure 2: Sediment filter (left) and reactive filter (right)

Drainage water analyses

Water samples were analyzed for pH, electrical conductivity and turbidity (NTU).

Total P (TP) and total dissolved P (TDP) were determined colourimetrically after persulphate digestion in an autoclave. For TDP samples were filtered through 0.45 µm cellulose-acetate membrane filters. The difference between TP and TDP is considered to represent particulate P (PP). Suspended sediment (SS) was measured as filter residue on 0.45 µm membrane filters.

Results and discussion

During the runoff season October 2020 to June 2021 the hydraulic load to the filter system was 18000 m^3 corresponding to an average hydraulic retention time (HRT) for the sediment filter of 92 minutes. Total P concentrations in drainage water at the system inlet varied between 0.03 and 2.47 mg P/l; TDP varied between 0.04 and 0.84 mg P/l. On average TDP represented 60% of TP.

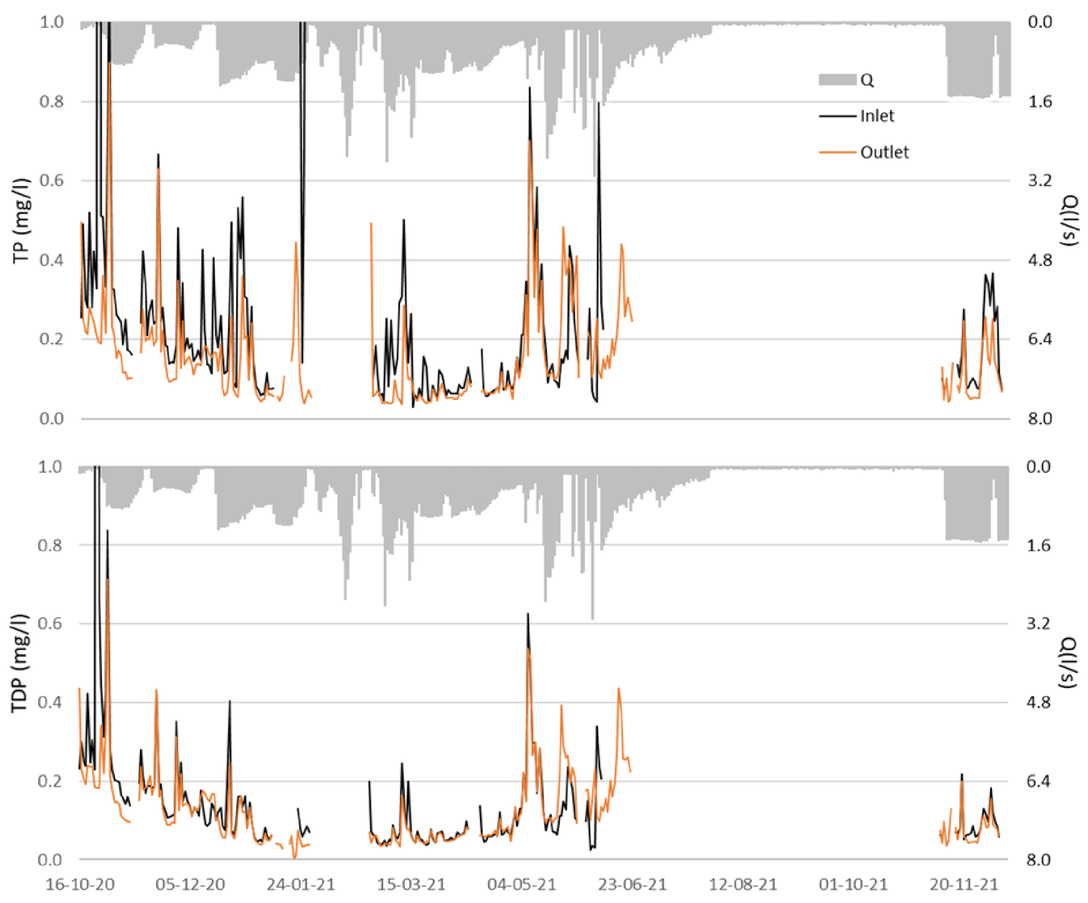

Figure 3: Daily values of total phosphorus (TP, top) and total dissolved phosphorus (TDP, bottom) for the sediment filter at the inlet and outlet. The hydraulic loading (Q) is given on the secondary axis.

The sediment filter retained 71% and 64% of the estimated sediment and PP load, respectively. Occasionally TDP was remobilized from the sediment filter in late spring. The TDP retention in the ICS filter averaged 51% for the drainage season. On a monthly basis TP retention in the filter system varied between -33% and 88% averaging 61% in 2020/21.

Table: Monthly hydraulic loading (Q), load and removal of total phosphorus (TP), total dissolved phosphorus (TDP), particulate phosphorus (PP) and suspended sediments (SS) for the sediment filter (top) and reactive filter (bottom). Months with incomplete data are shown in bold.

Month	Q	TDP		PP		SS	
		Load	Removal	Load	Removal	Load	Removal
	(m^3)	(g)	(%)	(g)	(%)	(kg)	(%)
oct-20	613	190	23	53	56	11	73
nov-20	1299	207	16	69	75	11	79
dec-20	1798	250	2	197	75	30	76
jan-21	2133	74	20	180	75	13	66
feb-21	1825	17	16	5	67	2	49
mar-21	3245	228	10	235	69	23	72
apr-21	1904	108	2	25	60	8	72
maj-21	2842	403	-7	178	42	33	63
jun-21	2398	164	-155	123	45	20	75
nov-21	2646	162	14	108	45	29	64
dec-21	697	75	12	80	55	17	56

Month	Q	TDP		PP	
		Load	Removal	Load	Removal
	(m^3)	(g)	(%)	(g)	(%)
nov-20	59	10	79	2	14
dec-20	225	23	61	7	18
jan-21	214	9	72	8	79
feb-21	27	1	68	2	72
mar-21	272	15	58	3	68
apr-21	190	10	57	1	28
maj-21	284	41	29	12	15
jun-21	209	36	33	3	-140
nov-21	254	18	33	8	35
dec-21	68	6	19	3	-3

Conclusions

The results compare positively with other end-of-pipe solutions such as constructed wetlands which tend to have lower TP retention efficiencies under Danish conditions. However, the effective storage capacity of the compact P filter system has to be better understood including the mechanisms of potential P release processes and the required frequency of filter cleaning.

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