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Tile drains as efficient phosphorous traps during exfiltration of phosphate rich groundwater

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High phosphorus (P) concentrations in surface waters pose a risk of eutrophication. The majority of studies on P immobilization in lowland catchments focus on P retention in surface water bodies. Little or no attention has been given to the influence of tile drainage and landscape heterogeneity on P immobilization. This research assesses P retention dynamics in tile drains of a marine clay polder in the Netherlands, dominated by agricultural practices, taking into account the heterogeneity of the surroundings. For this purpose, soil samples from eight locations, spread across an agricultural parcel, were taken down to 4m below the surface and analyzed for main elements and reactive iron (Fe) and P phases. The same analyses were performed on solid material from the inside of the drains. Porewater was retrieved from the soil samples and together with deep groundwater samples from groundwater wells (12m, 28m, 49m and 64m depth) analyzed for main elements. Water from ten tile drains and from ditch water bordering the studied parcel was sampled monthly for one year and analyzed for main elements. Additionally, geochemical modeling (PHREEQC) based on the fieldwork data was performed to gain a better insight into the occurring processes relating to P retention and the potential degree of immobilization in the drains.

Results suggest that in these lowland areas the exfiltrating groundwater is rich in P and Fe and that this is the main source of phosphate to the surface waters, as opposed to the agricultural use. The Fe and P concentrations in the drains were sometimes larger than those found in groundwater and were highly variable in space. Such discrepancies may be ascribed to the heterogeneity of the parcel area and biogeochemical transformations occurring in the shallow subsurface (i.e. pyrite oxidation, degradation of organic matter), which are likely to be responsible for additional mobilization of Fe and phosphate during groundwater flow to the drains. Besides spatial variability, phosphate and Fe concentrations also varied seasonally. Sediment analysis pointed out that the ditch and drains particulate material holds nearly 20 to 80 times more phosphorus than in the geological sediment throughout the soil domain. The average P content of 23 mg P/g in the drains particulate material is also considerably higher than what others have found for P content of suspended particulate matter in agriculture dominated catchments. From this particulate P (PP) content, nearly 81% was P bound to ferric iron particles (P-Feox) in the ditch, and more than 95% was P-Feox in the drain sediments. The outcome of the geochemical modeling reinforced the findings that geochemical processes occurring in the shallow subsurface exert major influence in drain water composition and P immobilization. The modelling simulations also revealed that P could be completely immobilized in nearly all the drains when allowing the system to reach equilibrium. However, the residence time in the drains is insufficient to immobilize dissolved P completely by precipitation of Fe-hydroxyphosphate. These outcomes highlight the importance of a subsurface drainage network as major sink of P in lowland catchments.