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Internal loading of phosphorus in streams described by a Phosphorus Sediment-Water Exchange Model (PSWEM)

TOON VAN DAEL, CHARLOTTE VERMEIREN AND ERIK SMOLDERS

KU Leuven

Presenting Author: toon.vandael@kuleuven.be

The reaction of phosphorus (P) between sediments and water in streams strongly affects the surface water P concentrations. A new reactive transport model was developed to describe redox dependent P sorption in the sediment and vertical diffusive transport of solutes to the overlying stream. The model was validated using P release data from ten different sediment-water batch incubations (static system) and from two flumes (dynamic system). The dissolved P concentrations in the overlying waters ranged from 0.02 to 1.2 mg P L^{-1} in these systems and were predicted within, on average, a factor 1.3 (batch) or 1.1 (flume). Input parameters are the degree of P saturation (DPS) of the sediment, its organic matter content, dissolved oxygen (DO) concentration and temperature. The P flux towards the overlying water increases with increasing sediment P:Fe ratio, sediment respiration rates and with decreasing DO and water pH.

After model validation, the monthly average P concentration in Flemish rivers was predicted using the total P emission data, total discharge, average sediment properties and the monthly averaged water temperatures, DO concentrations and electric conductivity. These monthly average P concentrations oscillate annually between 0.24 and 0.73 mg P L^{-1} and predictions matched the long-term monitoring data within 10% using only one adjustable parameter.

The model shows that summer P peaks in slow flowing systems are related to internal loading rather than to emission-dilution effects. It further demonstrates that surface water P can be lowered by enhanced DO concentrations in the water or by the addition of Fe and Al rich binding agents to the sediments and are not, on the short term, affected by reducing P emissions.

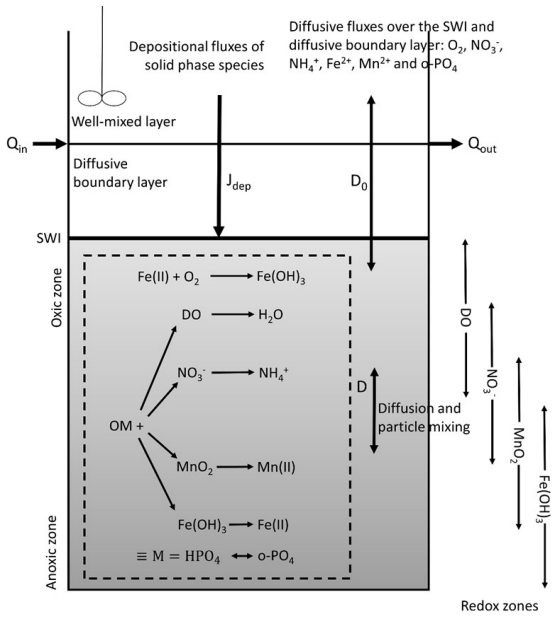

Figure 1: Schematic representation of the main reactions taking place in the sediment. Alternative e^- acceptors are only used when energetically more favourable alternatives are below a certain limiting concentration, generating overlapping redox zones (right-hand side). The greyscale indicates the lowering of the redox potential in the sediment. The equilibrium sorption reaction of phosphate will be affected by reductive dissolution of $Fe(OH)_3$ in deep sediment layers and again by re-oxidation in the oxic surface sediment.