

Toward an understanding of “Legacy P” - phosphorus sorption mechanisms in stream sediments as influenced by organic matter

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Water chemistry and phosphorus (P) forms were analyzed to determine the nature of legacy P in sediments of the West Holland River and the adjacent drainage canals of the Holland Marsh drainage system, located in southern Ontario, Canada. The river and canals route water from the intensively cropped muck polders of the Holland Marsh and drain Lake Simcoe.

Sediment samples were characterized for mineralogy using X-ray diffraction techniques (XRD); total P (TP); and Ca, Fe, Mn, and Mg contents, as well as cation exchange capacity and organic matter (OM) content. Forms of sediment P in five depth sections (ranging from 0–15 cm depth) were characterized and quantified by sequential P fractionation chemistry.

At all study sites, mobile P forms including organic P forms were found to be higher in surface sediments than in deeper sediments. The major P form within the sediments of the two canal sites, where the concentration of TP in the surface water was within the Ontario Provincial Water Quality Objectives (PWQO) of 0.03 mg P L⁻¹, was Ca-bound P, indicating a low risk of soluble reactive P (SRP) release. A trace of apatite (a stable Ca-P mineral) was also detected in these sediments. Conversely, sediments collected from the West Holland River at sites located within the Holland Marsh exhibited a high risk of SRP release, and redox-sensitive P was the dominant P form in the sediment despite the surface water exhibiting higher concentration of Ca and alkaline pH. In addition, the concentrations of TP as measured in surface water samples taken from the site were ~8 times greater than PWQO. In the sediments where the risk of SRP release was high, OM contents were also relatively high and traces of brushite (a labile Ca-P mineral) were detected.

The formation of OM and cation complexes, such as OM-Fe complexes, may play an important role in regulating the fate of sediment-P forms through the adsorption of SRP. These OM-Fe complexes may inhibit the formation of more stable Ca-P minerals, even under neutral to alkaline conditions. Thus, where OM-Fe-P forms predominate, we predict a high risk of SRP release from sediments when water chemistry changes. In addition, OM may inhibit the transformation of labile Ca-P forms to more stable Ca-P minerals. Loading of OM affects the development of hypoxia in aquatic systems, and the accumulation of OM can promote the release of both SRP and dissolved organic C to downstream environments. This study provides evidence that the presence of OM in stream sediments influences P sorption mechanisms and is critical in understanding P biogeochemistry in freshwater environments.