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Tracing the fate of P-binding forms at Hamilton Harbour (Lake Ontario): Geochemical and Microbial Analysis of the Water Column

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Hamilton Harbour, at the western end of Lake Ontario, is a highly urbanized embayment heavily impacted by industrial, municipal, and agricultural activities. The Harbour was designated as an area of concern (AOC) under the Great Lakes Water Quality Agreement owing to severely degraded environmental conditions and impairment of beneficial uses. Despite significant restoration effort, progress on reversing eutrophication has been slow. Upgrades to wastewater treatment plants (WWTPs) initially reduced phosphorus (P) concentrations, however internal loading from the sediments further contributes to elevated P concentrations. To study the geochemical and microbial processes in P cycling, and tracing the fate of P-binding forms, a two-year field study (2023–2024) was conducted. Sampling took place at two primary stations (1001 and 9031) from May to October 2023 across eight field campaigns, with additional sampling at Windermere Basin and Skyway WWTP on August 31. In 2024, water column sampling was repeated at the primary stations in August and near Windermere Basin and Skyway WWTP in October.

Measurements included dissolved oxygen, temperature, pH, photosynthetically active radiation (PAR), conductivity, salinity, chlorophyll *a*, alkalinity, and turbidity. Water-column samples were analyzed for different P binding forms, total phosphorus (TP), soluble reactive phosphorus (SRP), total dissolved phosphorus (TDP), particulate phosphorus (PP), dissolved organic phosphorus (DOP), polyphosphate (PolyP) quantification, alkaline phosphatase activity (APase), total alkalinity, major ions (e.g., sulfate, nitrate, ammonium), total metals (Fe, Mn, Al, Si), total organic carbon, total nitrogen, methane, carbon dioxide. Particulate matter was characterized using scanning electron microscopy-energy dispersive spectroscopy (SEM-EDS) to determine mineralogical associations. Microbial communities were analyzed via 16S rRNA gene sequencing to identify taxonomy associated with P-cycling.

This study demonstrates the influence of geochemical and microbial processes on phosphorus cycling, with seasonal and spatial variations in phosphorus speciation affecting internal and external loading dynamics. The interplay between redox-driven transformations and microbial activity underscores the complexity of phosphorus retention, release mechanisms, and tracing the fate of P-binding forms in the water column of Hamilton Harbour.