Characterization of phosphorus mobility in shallow, freshwater lakes under variable redox conditions

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Mobility of phosphorus (P) between sediments and water column in many freshwater lakes is a process partially governed by the dynamic interaction of iron and P. Dynamic redox conditions across the sediment-water interface (SWI) have been linked to nutrient mobility and harmful algal blooms in a study site in Missisquoi Bay, a shallow, eutrophic bay located at the northern end of Lake Champlain (Smith et al., 2011). Additionally, mobility and bioavailability of organic P species has been shown to behave differently from inorganic P species (Giles et al., 2015). Defining the timing of the link between redox chemistry changes across the SWI and nutrient mobility is needed to assess how nutrient flux between sediment and water column may be a controlling factor for cyanobacterial blooms.

A series of controlled mesocosm experiments manipulated redox conditions by changing headspace gas supply and light availability. Voltammetric Au-amalgam measurements of oxygen, manganese, iron, and sulfur speciation defined the spatial and temporal changes of redox chemistry in the water column and porewater through the SWI. In sediments, mineralogy and P speciation were examined using XRF, SEDEX extractions, and enzyme hydrolysis of different organic P pools. In water samples, soluble reactive P, total P, enzyme digested P, and metals content at different filter fractions were obtained.

Significant flux of P across the SWI to the water column required an initial 1-2-week interval of increasingly reducing conditions. Extended oxidation of the system caused an initial flux of P from the water column to SWI over a period of several hours.

Fluctuating redox conditions at the SWI (cycles of 24-hour oxidation followed by 24-hour reduction) produce the most redox sensitive P pools and result in a significant flux of P into the water column despite periodic oxygenation. Short term redox fluctuations likely favour a weakly bound sediment P pool sorbed to precursor iron oxyhydroxides (ferrihydrite), priming the SWI for increased P mobility.