

Phosphorus speciation and the redox transformation of iron in lake sediments

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Phosphorus (P) is an essential nutrient element to life, controlling primary biological production in ancient and contemporary aquatic environments. The P biogeochemical cycle is highly sensitive to redox conditions, and could be coupled to the redox transformation of redox-sensitive elements such as iron, manganese, and sulfur.

In this study, the speciation of solid P in sediments profile from Lake Taihu in eastern China was investigated using a sequential extraction method. Total P concentrations showed a slight increase from the surface to a depth of ~5 cm (0.6 mg/kg) and then remained stable with depth. Fe-bound P concentrations decreased from the surface to ~20 cm depth, which could be caused by the reduction of Fe/Mn oxyhydroxides. This is consistent with the change in Fe speciation in the sediment's profiles. Sequential Fe extractions showed that reactive Fe(III) oxides decreased from the surface to a depth ~20 cm, while the contents of Fe(II) carbonate and pyrite increased. X-ray absorption near-fine structure (XANES) analyses of Fe K-edge were performed and fitted with standards based on common iron mineralogy identified in the sediments. The results showed that the Fe oxides content decreased in the first 20 cm and the contents of Fe sulfide and carbonate increased from ~15% (~1 cm) to ~22% (~20 cm). In the deeper sediments, the feature of Fe K-edge XANES spectra and fitting results showed no obvious change in the mineralogical phases of Fe. In addition, a decrease in the content of Fe(III) in clay minerals occurred at ~10 cm, suggesting that structural Fe(III) in clays could also be reduced by microbes in anoxic environments. Furthermore, a geochemical model of the P cycle driven by Fe reduction was proposed. Under anoxic conditions in lake sediments, redox-sensitive Fe-bound P could be released or transformed into secondary phosphate minerals with the microbial reduction of Fe oxides to Fe(II) carbonate or sulfide minerals.