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Metabolic Constraints of Organic Matter Mineralization and Metal Cycling During Flood Plain Evolution

Christian Dewey[1,2], Carolyn Anderson[3], Hannah Naughton[1], Rene Boiteau[4], Peter Nico[2], Markus Kleber[4], Scott Fendorf[1*], and Marco Keiluweit[2]

[1] Stanford University, Stanford, CA
[2] Lawrence Berkeley National Laboratory, Berkeley, CA
[3] University of Massachusetts-Amherst, Amherst, MA
[4] Oregon State University, Corvallis, OR

Contact: Fedorf@stanford.edu

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Floodplains are poorly understood and dynamic components of the global carbon cycle that not are well represented in Earth system models. Further, they have a dominant influence on the cycling of important metals within critical transport conduits between surface waters and groundwater. The physical characteristics of floodplains make the hydrology and associated coupled biology and geochemistry particularly responsive to ongoing and impending changes in climate, river management, and land development.

Using a combination of field-scale measurement with micro-scale laboratory experiments, we find that oxygen diffusion limitations lead to heterogeneous redox profiles, shifting microbial metabolism to less efficient anaerobic SOC oxidation pathways. During flooded periods, exhibiting strongly reducing conditions, DOC concentrations are elevated yet microbial C oxidation is limited by thermodynamic constraints on anaerobic respiration. Through laboratory incubations, we observed both kinetic and thermodynamic controls on carbon oxidation; anaerobic incubations were tested with nitrate and sulfate addition relative to an anoxic control and compared against aerobic conditions. Under anaerobic conditions, oxidation rates are consistent with thermodynamic succession in energy yields. Carbon oxidation rates are, however, highly sensitive to oxygenation, particularly in previously anaerobic soils, were oxidation rates are maximized. However, under field conditions, after a short-lived rise in C oxidation, rates decline again due to the formation of metal-organic complexes, which restrict the availability of DOC for microbial respiration. Our results suggest that these seasonally shifting controls on C oxidation rates across the floodplain are critical controls on C and metal export from the floodplain.

Export of metal-organic complexes varies depending on the hydrologic condition of the floodplain. We obverse different metal-organic complexes, and the preference for metals of differing chemistry, depending on the metabolic conditions of the soil. Combining our biogeochemical measurements with hydrological investigations of the East River flood plain, we are developing a reactive transport modeling framework that examines carbon and metal transformations and export to river water. A multi-level well-field providing the capacity for determination of hydrologic gradients and pore-water chemistry is being utilized within two contrasting river meanders, representing end-members of hydrologic conductivity and oxygenation. Collectively, our results illustrate the combined, and dynamic, impacts of mineral- associations and metabolic controls on carbon and metal fate. The highly variable hydrology of floodplains leads to concomitant changes in biogeochemical processes within soils that ultimate control organic carbon, nutrients, and metal cycles.