SLAC Floodplain Hydro-Biogeochemistry SFA: Colloid Dynamics at Floodplain Soil-Gravel Bed Interfaces

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Project Abstract: Subsurface interfaces are ubiquitous in floodplain environments and sustain a multitude of biogeochemical processes, including the formation and release of reactive, mobile colloids. Colloids are known vectors of micronutrient, contaminant, and organic matter transport and are suspected to be important export agents from floodplains to stream water. However, few studies have documented the impact of seasonally-variable field hydrological and geochemical dynamics on redox-active colloid occurrence, and transport in riparian floodplains.

We used a combination of cascade filtering, advanced analyses of field samples, lab-based column experiments, and reactive transport modelling (RTM) to characterize the fate of Fe-rich colloids at our floodplain field site of Slate River, CO. Cascade filtering revealed the presence of Fe-rich colloids in the riparian anoxic soil water, whose abundance and composition vary with season and depth, suggesting a strong link to hydrological and biogeochemical dynamics. Cryo-EM and TEM-EDS imaging showed mono-dispersed and nano-assemblages of spherical colloids in the 10-50 nm range containing Fe, O, Si, C, and Ca. Mössbauer spectroscopy indicated a poorly crystalline ferrihydrite-like phase, coated with organic matter and Si. Fe-EXAFS further verified ferrihydrite and Fe(II)- and Fe(III)-organic matter interactions. We therefore conclude the colloids are primarily composed of nanosized ferrihydrite spheres that are stabilized by organic matter, Si, and bridging cations (e.g., Ca). The fact that these Fe(III)-rich colloids existed in primarily anoxic zones is striking. We postulate that the Si-organic matter coating provides a primary protective layer against reduction, but its efficiency depends on the biogeochemical and hydrological conditions. In spring, porewater flow velocity was low in the anoxic soil, due to rising water table, and a higher abundance of Fe(II)-rich colloids was observed. We hypothesize that longer residence times coupled with high organic matter levels, contribute to the formation of the reduced, nanosized colloids. At baseflow, in summer and autumn, increased downward infiltration appears to flush the colloids into to the gravel bed, where relatively high (1.5 m/day) flow velocities may transport them to the river. Furthermore, findings from our column experiments coupled with reactive transport simulations suggest that organic matter-bearing colloids may substantially alter the biogeochemical functioning of the gravel bed itself.