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Respiration in Hyporheic Zones: Connecting Mechanics, Microbial Biogeochemistry, and Models

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Rivers are the primary carbon and nutrient conveyors of terrestrial ecosystems. River channels however are not simply inert pipelines. They are hotspots for sink and source reactions with magnitudes just as important as the conveyance. Reduced organic carbon, for example, can be extensively respired by bacteria residing in sediment. Although this respiration process is widely known, it has eluded broad quantification and mechanistic prediction. This incomplete knowledge of the fluxes across the land-water- atmosphere continuum is necessary for calculating terrestrial carbon budgets from plot to ecosystem to global scales.

This investigation seeks to develop plot-scale predictive understanding of carbon respiration in the shallow subsurface of riverbeds, the area referred to as the hyporheic zone. It addresses the overarching question of: "What are the physical and biogeochemical factors controlling hyporheic zone respiration of organic carbon and how are these factors inter-related?" The key factors to be tested are: (1) river hydrodynamics and bed morphology, (2) physical heterogeneity of the sediment hydraulic properties, (3) chemical heterogeneity and bioavailability of particulate organic carbon (POC) within the sediment, (4) riverine dissolved organic carbon (DOC) concentration and its bioavailability, and (5) the microbial community structure. The above factors are being analyzed through advanced computational simulations and laboratory experiments based on field observations from the PNNL SBR-SFA.

The general approach to testing hypotheses to the questions above involves novel flume experiments paired with multiphysics simulations which couple turbulent flow in river channels, hyporheic flow in sediments and reactive transport of carbon and nutrients within both domains. Our team has made a few major steps already and these will be reported in this poster. These include: (1) Flume experiments with detailed flow, chemical, and microbial characterization (2) Fully coupled model (one continuous domain) of turbulent open channel flow and porous media flow with reactive transport developed in OpenFOAM.

Based on (1), we found distinct microbial signatures between oxic and anoxic zones of the hyporheic zone in the sediment. The results also show that the microbial community that grew in the flume is similar to those found in natural aquatic settings. From (2), the novel model is able to replicate flow and transport observations from detailed experiments and from models using more primitive coupling schemes. Our incipient efforts in the past few months have shown the potential for upcoming discoveries regarding how carbon is respired in the hyporheic zones of aquatic sediment.