Coupling Microbial Communities to Carbon and Contaminant Biogeochemistry in the Groundwater-Surface Water Interaction Zone

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Abstract: The proposed study will integrate molecular data generated through a combination of JGI and EMSL capabilities to support research activities under the Subsurface Biogeochemical Research-Science Focus Area (SBR-SFA) at Pacific Northwest National Laboratory (PNNL). The SBR-SFA is working to understand and predict the effects of variable groundwater-surface water mixing on microbial communities and, in turn, biogeochemical rates. The zone of groundwater-surface water mixing--the Subsurface Interaction Zone (SIZ)--is a critical and ubiquitous domain at the groundwater-surface water interface that strongly influences carbon and nitrogen cycling and regulates contaminant releases to surface waters. To generate knowledge and models relevant to rivers worldwide that flow through glacio-fluvial aquifers and for high latitude/elevation catchments with coarse-grained sediments vulnerable to climate change, the proposed work will take advantage of the Hanford Reach of the Columbia River as a model field system.

To generate fundamental knowledge that can support development of predictive SIZ models, JGI and EMSL capabilities will be combined to generate high-resolution molecular characterizations of field samples taken across groundwater-surface water mixing conditions. Ecological theory and modeling will be used to provide novel conceptual perspectives and data integration strategies in order to generate new knowledge of how mixing conditions influence the coupling between microbial communities and biogeochemical processes. Data streams include high-resolution dissolved and surface-associated organic carbon profiles (EMSL mass spectrometry), microbial community metabolic potential (JGI shotgun metagenomics), microbial community expressed enzymes (EMSL metaproteomics), bulk geochemical profiles (EMSL elemental analysis), and microbial community biomass (EMSL flow cytometry). These data will enable evaluation of the following two hypotheses, and resulting knowledge will ultimately guide predictive models of coupled processes within the SIZ.

Hypothesis -1. Microbial access to paired electron donors and terminal electron acceptors governs the balance between deterministic (e.g., selection by the environment) and stochastic (e.g., dispersal of microorganisms) ecological factors. Stochastic factors will dominate when groundwater mixes with surface water due to increased availability of paired electron donors/acceptors. The resulting predictions are that mixing will cause removal of electron donors/acceptors and greater spatial variation in microbial community composition, metabolic potential, and expressed enzyme profile. Ecological modeling and multivariate statistics will be used to evaluate predictions through the integration of data streams.

Hypothesis -2. High functional redundancy among microbial taxa will maintain consistent biogeochemical rates--through space--even when ecological stochasticity leads to variation in microbial community composition. The resulting prediction is that metabolic rate will be only weakly related to community composition. In addition to evaluating this prediction, we will elucidate the relative contributions of potential and expressed metabolisms to the inferred level of functional redundancy. To

do so we will characterize the multivariate relationships among microbial community metabolic rate, composition, metabolic potential, expressed enzymes, and biomass as well as profiles of composition and concentrations of electron donors and terminal electron acceptors.