Title: Effects of Microbial Growth and Death and Sediment Movement on Hyporheic Zone Biogeochemistry

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Project: Effects of Surface Water Fluctuations and Sediment Movement on Hyporheic Zone Biogeochemistry and Microbial Communities (University project)

Project Abstract: The hyporheic zone beneath and adjacent to river channels is often more reactive than overlying surface water or deeper groundwater, and thus is an important area for chemical transformation within watersheds. This exploratory project developed a predictive mechanistic modeling approach to quantify the effects of microbial growth and death processes as well as bed sediment migration on hyporheic zone microbial populations and biogeochemical cycling. We focus on 1) baseflow conditions which are most common and sediment migration is well understood, and 2) riverbed dunes which are widespread in larger streams and rivers and often dominate hyporheic effects on water quality. We linked a series of existing models that simulate surface water hydrodynamics (OpenFOAM), groundwater flow (MODFLOW), and groundwater transport/reaction and microbial growth/death (SEAM3D). We developed and tested a moving frame of reference (MFOR) approach to simulate dune migration effects on biogeochemical transformations through modification of SEAM3D. We then conducted sensitivity analyses of controlling factors such as hydraulic, sediment, biogeochemical, and microbial model parameters and boundary conditions. For our results without dune migration, biomass reached a steady state in every simulation within ~ 2 days model time, and increased with hyporheic flow cell area as controlled by hydraulic boundary conditions. Not accounting for microbial growth and death tended to underestimate steady-state microbial biomass and DO/DOC consumption and overestimate DO/DOC concentrations. Increasing steady-state DOC availability caused the microbial population to grow more than did increasing steady-state DO availability. Decreasing DO availability, on the other hand, caused more microbial death than decreasing DOC availability. We also found that there are minimum DO and DOC steady-state concentrations required for microbial growth. Varying both hydraulic and biogeochemical steady-state boundary conditions affected spatial distribution of biomass, DO and DOC. Our results with dune migration are more preliminary, but indicate that dune migration reduced microbial populations dramatically relative to static dunes. This effect increased with dune celerity, while residence times and contaminant removal simultaneously declined. Overall, our results indicate that accounting for dynamics of both microbial growth/death and sediment movement can be important for correctly predicting the magnitude of hyporheic biogeochemical transformations, with important implications for material processing in watersheds.