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Respiration in Hyporheic Zones: Advancing the Understanding of Coupled Transport and Microbial Biogeochemistry and their Representation in Open-source Mechanistic Models

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Hyporheic zones (HZs) are a key feature of river corridors because of substantial carbon and nutrients processing which happen in them. This processing is a cascade of microbially-mediated reactions. The most important of these reactions is respiration since it is thermodynamically favorable and the consumption of oxygen during respiration sets up a cascading redox ladder.

This project's goal is to improve the understanding of respiration in HZs. We seek predictive capabilities that can represent HZ processes in system-scale models. The project is broadly divided into the intertwined tasks of advancing mechanistic models and the mapping and monitoring of reactions and the microbial communities responsible for these in real-scale laboratory flume experiments. The flume experiments use real river water and have been continuously running for months. Direct measurements of CO_2 production and O_2 consumption in both the overlying channel water and throughout the HZ sediment reveal that there is substantial respiration and that the rates vary with HZ depth. The distribution of respiration- sensitive reactive tracers independently support the occurrence of respiration. Microbial community characterization shows that the communities in the flume are similar to those in natural river settings. The communities occupying oxic and anoxic zones are distinct. The experiments show that the CO_2 in the channel, which presumably is evaded to the atmosphere, is largely produced in the sediment and delivered to the channel by hyporheic return flow. This finding emphasizes the importance of considering the HZ, the channel and the overlying atmosphere as one continuum with fully, two-way coupled components. Thus, we are also advancing the modeling of processes that transcend the sediment-water-air interfaces. The model we have developed is called *hyporheicFoam* which is based on the open-source model OpenFOAM. It solves the Reynolds Averaged Navier-Stokes and modified Richards equations for the turbulent open-channel flow and flow in the porous sediment respectively. It takes user- specified biogeochemical reaction networks. Just as we observed in the flume experiments, modeling with *hyporheicFoam* showed that CO_2 produced from respiration in the HZ is released to the channel and eventually to the atmosphere. Our observational and modeling study is the first to show these facets of HZ respiration. Future plans include experimental and modeling assessment of the many factors which control HZ respiration including different forms and sources of carbon and varying hydraulic conditions. The results of this sensitivity analysis will be synthesized into quantitative predictive models.