The Effects of Stream Organic Matter on Respiration in Hyporheic Zones: Combined Insights from Flume and Computational Experiments

Anna Turetcaia[1], Bing Li[2], Xiaofeng Liu[2], Xingyuan Chen[3], Robert Danczak[3], Matthew Kaufman[3], Vanessa Garayburu-Caruso[3], Emily Graham[3], James Stegen[3], and M. Bayani Cardenas[1,*]

[1]The University of Texas at Austin, Austin, TX
[2]Pennsylvania State University, State College, PA
[3]Pacific Northwest National Laboratory, Richland, WA

(cardenas@jsg.utexas.edu)

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Hyporheic zones (HZs) are a critical part of river corridors because of high rates of biogeochemical reactions which take place in them. The most important of these reactions is aerobic respiration because it is thermodynamically favored and it helps set up the redox ladder. This project's goal is to improve the understanding of respiration in HZs. We ultimately seek predictive capabilities for the collection of 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. Our most recent experiments are focused on determining how HZ respiration responds to perturbations in stream organic matter. In the flume, direct measurements of CO_2 production and O_2 consumption in both the overlying stream water and throughout the HZ sediment revealed that there is substantial respiration and that the rates vary with HZ depth. The experiments showed that the CO_2 in the stream, some of which is evaded to the atmosphere, is largely produced in the sediment and delivered to the channel by hyporheic exchange return flow. Computational flow and transport simulations, using the model we developed called *hyporheicFoam* which is based on the open-source model OpenFOAM, help explain the observed O_2 and CO_2 patterns. The simulations showed drastic gradients in the age of water flowing through the HZ. Most of the respiration happens in the shallowest HZ portion where the residence time is shortest and overlaps most with the respiration timescale and wherefrom the produced CO_2 is also easily expelled back to the stream. What therefore happened when stream organic matter increased was the respiration in the shallow HZ increased concurrently and linearly. As a consequence of the HZ-stream linkage, so too did the stream CO_2 concentration increase. Our study has shown that due to the strong coupling between the stream and the HZ, perturbations in stream dissolved organic matter are immediately felt within the HZ, which then quickly feedbacks to the stream. This new insight further highlights the importance of viewing the HZ and stream as a continuum, and that any predictive models will need to simultaneously and holistically consider these parts of the river corridor.