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Impact of flow conditions on ammonium uptake and microbial community structure in benthic biofilms

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Excess nitrogen in surface waters is widely recognized to be a major global problem that adversely affects ecosystems, human health, and the economy. Today, most efforts to understand and model nutrient dynamics at large scales relies on macro-scale parameterization, such as mean channel geometry and velocity with uniform flow assumptions, as well as gross averages of in-situ nutrient transformation rates. However, there is increasing evidence that nutrient transformations in hyporheic zone are regulated by coupling between physical, chemical, and microbiological processes. Ignoring this greatly hinders the estimation of average biochemical transformation rates under the variable flow conditions found in aquatic systems. We used a combination of macro- and micro-scale observations in laboratory flumes to show that interplay between hydrodynamic transport, redox gradients, and microbial metabolism controls ammonium utilization by hyporheic microbial communities. Biofilm structural characteristics were quantified using denaturing gradient gel electrophoresis (DGGE) and real time PCR, while redox and pH gradients were measured using microelectrodes. We found that overlying velocities had profound effect on ammonium uptake due to mass transfer of ammonium from the bulk water to the benthic biofilms, but also due to the delivery of oxygen into the sediment bed. Under laminar flow conditions we didn't observe any change of ammonium uptake as a response to increase in overlying velocity. However, under non-laminar conditions we observe monotonic increase in ammonium uptake, with the greatest uptake under the fastest flow condition. We will discuss ammonium uptake rates results in the context of the different microbial communities and the micro-scale observations that were obtained using the microelectrodes. We anticipate that combined knowledge of the response of the microbial community and bulk nitrogen utilization rates to flow conditions will support the development of improved strategies that rely on biofilm growth to enhance nitrogen removal in natural and engineered systems.