Effect of temperature on nitrogen cycling and nitrate removal-production efficiency in bedform-induced hyporheic zones

LIZHI ZHENG[1], M. BAYANI CARDENAS[2], LICHUN WANG[3]

[1]Geological Sciences, The University of Texas at Austin, lizhizheng@utexas.edu
[2] Geological Sciences, The University of Texas at Austin, cardenas@jsg.utexas.edu
[3] Geological Sciences, The University of Texas at Austin, wanglichun@utexas.edu

Hyporheic flow in aquatic sediment controls solute and heat transport thereby mediating the distribution and patterns of nutrients and contaminants, dissolved oxygen, and water temperature in the sediment hyporheic zone (HZ). We conducted a series of numerical simulations with different homogeneous and steady temperatures, coupling turbulent open-channel fluid flow, porous fluid flow, and reactive solute transport, to study the temperature dependence of biogeochemical reactions and the HZ nitrate source-sink functionality and its associated efficiency. Two cases were considered: a polluted stream and a pristine stream. Sensitivity analysis was performed to investigate the influence of stream water [NO_3^-] /[NH_4^+]. The simulations show that in both cases warmer temperatures resulted in shallower denitrification zones and oxic-anoxic zone boundaries, but the trend of net denitrification rate and nitrate removal or production efficiency of the HZ for these two cases differed. For both cases, at high [NO_3^-]/[NH_4^+], the HZ functioned as a NO_3^- sink with the nitrate removal efficiency increasing with temperature. But at low [NO_3^-]/[NH_4^+], the HZ is a NO_3^- sink at low temperature, but then switches to a NO_3^- source at warmer temperatures in the polluted stream. For the pristine stream case, the HZ was always a NO_3^- source, with the NO_3^- production efficiency increasing monotonically with temperature. In addition, although the interfacial fluid flux expectedly increased with the increasing temperature due to decreasing fluid viscosity, the total nitrate flux into the HZ did not follow this trend. This is because when HZ nitrification is high, uniformly elevated [NO_3^-] lowers dispersive fluxes into the HZ. Our study shows that HZ temperature and stream [NO_3^-]/[NH_4^+] are key controls for the ability of HZs to remove or produce nitrate. It highlights the need for better understanding the complex links and feedbacks between hydrodynamic, biogeochemical, and thermal processes in the HZ.