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The significance of GW-SW interactions for biogeochemical processes in sandy streambeds

Shai Arnon (1), Natalie De Falco (1), Aryeh Fox (1), Gerrit Laube (2), Christian Schmidt (2), Jan Fleckenstein (2), and Fulvio Boano (3)

(1) Ben-Gurion University of the Negev, Zuckerberg Institute for Water Research, Sde-Boker, Israel , (2) Helmholtz Center for Environmental Research – UFZ, Department of Hydrogeology, Leipzig, Germany, (3) Department of Environment, Land and Infrastructure Engineering, Politecnico di Torino, Italy

Stream-groundwater interactions have a major impact on hyporheic exchange fluxes in sandy streambeds. However, the physical complexity of natural streams has limited our ability to study these types of interactions systematically, and to evaluate their importance to biogeochemical processes and nutrient cycling. In this work we were able to quantify the effect of losing and gaining fluxes on hyporheic exchange and nutrient cycling in homogeneous and heterogeneous streambeds by combining experiments in laboratory flumes and modeling.
Tracer experiments for measuring hyporheic exchange were done using dyes and NaCl under various combinations of overlying water velocity and losing or gaining fluxes. Nutrient cycling experiments were conducted after growing a benthic biofilm by spiking with Sodium Benzoate (as a source of labile dissolved organic carbon, DOC) and measuring DOC and oxygen dynamics.
The combination of experimental observations and modeling revealed that interfacial transport increases with the streambed hydraulic conductivity and proportional to the square of the overlying water velocity. Hyporheic exchange fluxes under losing and gaining flow conditions were similar, and became smaller when the losing or gaining flux increases. Increasing in streambed hydraulic conductivity led to higher hyporheic fluxes and reduction in the effects of losing and gaining flow conditions to constrain exchange. Despite the evident effect of flow conditions on hyporheic exchange, labile DOC uptake was positively linked to increasing overlying water velocity but was not affected by losing and gaining fluxes. This is because microbial aerobic activity was taking place at the upper few millimeters of the streambed as shown by local oxygen consumption rates, which was measured using microelectrodes. Based on modeling work, it is expected that GW-SW interaction will be more significant for less labile DOC and anaerobic processes. Our results enable us to study systematically the coupling between flow conditions and biogeochemical processes under highly controlled physical and chemical conditions and are expected to improve our understanding of nutrient cycling in streams.