Modeling effects of physical and chemical heterogeneity of alluvial sediments on hyporheic exchange

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Exchange of water and nutrients between a river and the surrounding hyporheic zone is controlled by multiple factors, including river morphology, streamflow variability, connection with groundwater, and sediment properties. Among these factors, the heterogeneity of river sediments is known to strongly affect the fate of nutrients exchanged with the hyporheic zone, but this influence has received relatively little attention compared to other factors. Moreover, sediments are heterogeneous in terms of both physical properties (i.e., hydraulic conductivity) and chemical composition (e.g., organic carbon content), but studies about heterogeneity have mostly focused on variations of hydraulic conductivity compared to the variations of chemical properties of sediments.

This contribution presents a modeling analysis of the influence of physical and chemical heterogeneity of alluvial sediments on lateral hyporheic exchange in meandering rivers. Sediments are treated as a binary mixture of mineral sand and organic silt, and a coupled hydraulic and biogeochemical model is employed to simulate the effect of different silt/sand ratios on exchange and reaction of organic carbon, oxygen, nitrate, and ammonium. Model results show that sediments with higher content of silt are characterized by lower exchange fluxes, but their higher carbon availability fosters higher rates of biochemical reactions and hence leads to higher nitrogen removal by net denitrification. These results indicate the importance of improving the description of sediment heterogeneity in modeling studies of hyporheic exchange.