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Analysing hyporheic exchange processes during unsteady flow in a small gravel bed river

Andreas Kurtenbach (1), Tobias Schuetz (2), Andreas Krein (3), and Reinhard Bierl (1)

(1) Department of Hydrology, University of Trier, D-54286 Trier, Germany, (2) Hydrology, Faculty of Environment and Natural Resources, University of Freiburg, D-79098 Freiburg, Germany , (3) Luxembourg Institute of Science and Technology, Environmental Research and Innovation Department, L-4362 Esch-sur-Alzette, Luxembourg

Quantifying hyporheic exchange in gravel dominated rivers still remains a challenging task in stream ecology and hydrology, in particular during unsteady flow. We adopted three strategies to decipher exchange processes with the hyporheic zone during unsteady boundary conditions. First, artificial floods were generated in the mid-mountain gravel bed river system of the Olewiger Bach, Germany (24 km^2). The advantage of the artificial flood approach lies in the selective control of governing processes by experimental design. Consequently, hydraulic boundary conditions such as maximum discharge, runoff volume and flood duration are steerable during the field experiments and the composition of the discharged water (e.g. low conductivity values) is known. Second, hyporheic exchange was analysed via heat dynamics using air, water and sediment pore water temperatures. Temperature dynamics in the hyporheic zone were monitored at the head, mid and tail of a riffle using specific lances (length: 67 cm, Ø: 3cm) containing temperature sensors in depths of 2, 5, 10, 15, 25, 45 and 65 cm. Short-term temperature variability during the unsteady artificial flood waves were analysed in high resolution of 10-30 seconds. In order to capture long-term seasonal fluctuations and dynamics during natural floods temperature was continuously measured at 5-min resolution. However, heat transfer in the hyporheic zone is affected by both advective and conductive transport. In a third strategy we therefore measure electrical conductivity and selected solutes in pore water during three artificial floods in 2015. Pore water was sampled from different sediment depths (5, 15, 25 and 45 cm) via stainless steel multilevel probes (length: 58 cm, Ø: 4cm). The investigation of temperature and pore water dynamics reveals that precedent hydrological conditions and ground-water levels are significant determinants for hyporheic exchange during unsteady flow. Stable groundwater stratification in spring for instance impedes hyporheic exchange even during the artificial flood waves with high maximum discharge. Our results show that artificial floods are a promising tool to investigate hyporheic exchange processes independent of external influences from precipitation events and associated natural floods. Implications of these findings on subsurface residence times as well as an outlook on future research regarding high temporal resolution of conductivity and solute monitoring in the hyporheic zone during unsteady flow will be discussed.