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Sedimentary roles on hyporheic exchange in karst conduits at low Reynolds numbers by laboratory experiments

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The relative roles of the sediment grain size/permeability, conduit flow rate and conduit geometry/angle on the hyporheic exchange between a karst conduit and its underlying sediments under low Reynolds numbers (Re) were investigated by means of laboratory experiments and numerical simulations. Two laboratory analogues consisting of siphon structured glass tubes (with bend angles of 15° and 45°) were used for the experimental studies. Tracer experiments were performed in each analogue with sediments of variable grain size (0.45 mm, 0.4–0.7 mm, 1 mm) to characterize the transport properties of contaminants originating from the sediments. Numerical simulations were used to probe the exchange flow patterns and exchange flux magnitudes between the conduit and sediment. Tracer experiments demonstrated a zone of forward flow and a zone of reverse flow in the sediments that were independent of grain size, which were reproduced well by numerical simulations. The exchange flux ranged from 0.02 % for fine grains to 2 % for coarse grains under the experimental flow conditions. A linear relationship between the exchange flux and the conduit Re value, which was independent of the conduit geometry and sediment grain size, was established with numerical simulations. This study demonstrated that sediment grain size/permeability has no influence on the exchange flow patterns. However, relative to the conduit flow rate and conduit geometry/angle, sediment permeability has a much stronger influence on the exchange rate of hyporheic flow.