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Influences of microbial activity and sediment disturbance on hyporheic exchange in sandy sediments

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Besides the vertical hydraulic gradient, sediment permeability is the main controlling factor of water exchange across the stream bed. Reduction of permeability by microbial activity is reported from unidirectional percolated sediment columns. We investigated effects of algal and bacterial activity on hyporheic exchange (vertical water flux, VWF) under semi-natural stream conditions in 16 outdoor sand-bed flumes during 30 day. Variability of bedform was considered by 8 flumes having plane-bed and 8 flumes ripple-bed. To gain information on the relative significance of algae and heterotrophic microorganisms, half of the flumes were operated under constant dark conditions (no-light flumes), while the others were exposed to daylight. After 21 days, the upper 2 cm of the sediments was manually disturbed simulating moderate sediment dynamics which frequently occurs in natural sand-bed streams. VWF was measured by tracing loss of uranine from the water column while flumes were operating in re-circulating mode. Algae and bacterial abundance, organic matter, and $CaCO_3$ content in sediments were determined. Sediment potential respiration (SPR) was measured in flow through respiration chambers and oxygen bubbles from primary production were sampled. As expected, initial VWF was higher in ripple-bed. After 13 days, VWF was completely inhibited in both plane and ripple-bed flumes under daylight conditions. In no-light flumes reduction of VWF was moderate. Microbial precipitation of calcium carbonate and production of oxygen bubbles in the uppermost sediments blocked the pore space. After 3 weeks, abundance and biomass of algae and SPR in the upper 2 cm of sediment were higher in daylight flumes than in no-light flumes, while bacterial abundance was higher in no-light flumes. The sediment disturbance at day 21 released the oxygen bubbles increased bed permeability and therefore restored VWF to initial rates in day-light flumes. SPR was unaffected by the sediment disturbance. In conclusion, the activity of algae and bacteria can reduce the sediment permeability and the interplay of microbial activity and sediment disturbance can control the VWF in streams. Regarding the patchy and dynamic nature of these ecological processes, the VWF likely shows complex spatio-temporal pattern at small scales, which has yet to be appropriately considered