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Carbon limitation may override fine-sediment induced alterations of hyporheic nitrogen and phosphorus dynamics

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Abstract:

The hyporheic zone underneath streamchannels is considered a biogeochemical hotspot reducing nutrient loads being transported downstream due to its high surface-to-volume ratio in combination with the hyporheic exchange. However, the effect of environmental stressors such as high amounts of fine sediment (FS; grain size <0.2 mm) on nutrient cycling in the hyporheic zone are not well understood. Physical clogging caused by fine sediment (FS) decreases the hyporheic exchange, thus, diminishing its potential to reduce nutrient loads despite increasing its surface-to-volume ratio. We determined the effect of physical clogging on nutrient cycling based on net change rates of dissolved inorganic nitrogen (DIN; nitrate-N, ammonium-N), soluble reactive phosphorus (SRP), and dissolved organic carbon (DOC) for a sand and gravel hyporheic zone. We performed three experimental runs in 12 flumes with four-week duration each following a factorial design. First, we determined nutrient cycling in sand and gravel in absence of clogging, and then tested the clogging effect for each sediment type under increasing clogging (0-480 g of FS addition increasing by 60 g per level).Without clogging, gravel acted as a source of nitrate-N; and both sand and gravel released SRP. Regardless of the clogging level and the resulting reduced hyporheic exchange, we found no changes in DOC and nitrate-N dynamics but net-release ofammonium-Nand SRP for gravel. In contrast, in sand, physical clogging inhibited DOC release for flumes with the higher FS. We propose that not physical clogging but DOC availability limited the nutrient uptake, as molar ratios of DOC to DIN and SRP ranged 1.2–1.5 and 77–191, respectively, indicating severe C limitation of N-uptake and partial C limitation of P-uptake. Our results suggest an interplay between nutrient molar ratios and physical clogging, which emphasize the interactions between hydrology and the stoichiometry of organic carbon, nitrogen and phosphorus in the hyporheic zone.

Keywords: Physical clogging, nutrient net-uptake, mesocosm experiment, gravel and sand bed sediment