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Spatio-temporal controls of nitrate removal in a restored riparian groundwater system

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The effect and interplay of environmental heterogeneity, hydrological connectivity and temporal flood disturbances on subsurface nitrate removal was investigated in a restored riverine floodplain. High environmental heterogeneity creates diverse types of functional process zones (FPZ), and strong hydrological connectivity tightly links and enhances the impact of river flood pulses on those FPZs. It thereby enables the transport of reactants in a vertical and lateral manner and creates the eventuality for biogeochemical hotspots. In 2008/09 water samples were collected along riparian hyporheic connectivity at the test site of the CCES Project RECORD (Restored corridor dynamics) at the prealpine River Thur, Switzerland. The distribution of nitrate, organic carbon (OC), and oxygen was monitored in the different FPZs in relation to discharge and season. The OC was chemically characterized by measuring its stable C isotopic ratio, polydispersity, and the yield of low-molecular weight organic acids. The activity and the potential for denitrification was determined by the dual stable isotope signature of nitrate and the abundance of genes, encoding different steps in denitrification (nirS, nirK, nosZ). The results showed that substantial losses of nitrate and an enrichment of 15N in the residual nitrate occurred post flooding in a FPZ, where the pioneer plant willow dominated the vegetation cover. At this location, flooding also introduced bioavailable OC into the groundwater flow and an increased abundance of the genes nirS and nosZ were identified. Willow plants are key integrative elements of riparian floodplains, and exhibit high below-ground OC-dynamics through excretion of labile compounds, e.g. low-molecular weight OC. A rising water table and high hydraulic conductivity facilitated OC re-dissolution and vertical mixing into the saturated regime. There it fuelled denitrification, which is mostly OC limited in this aquifer. This study showed how a complex interplay of different control mechanisms directs the formation of a nitrate removal hotspot in a riparian floodplain. This knowledge is also highly vital for the design of appropriate measures in river floodplain restoration.