Geophysical Research Abstracts
Vol. 12, EGU2010-7313, 2010
EGU General Assembly 2010

How important is the consideration of hyporheic nutrient attenuation for integrated water resource management?

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The 'hyporheic zone' or 'interstitial' characterises an area of intensive groundwater and surface water mixing within streambed sediments. Its physical conditions, as for instance the hydraulic conductivity and residence time, control fluxes and exchange rates between groundwater and surface water. Because of its often steep and dynamic redox gradients, the hyporheic zone can represent an area of high chemical activity. Previous studies described how the transport and redox processes in the hyporheic zone can cause effective nutrient attenuation, e.g. by denitrification. Hence, regulatory bodies and catchment management plans hope for the hyporheic zone to delimit the negative impact, polluted groundwater can have for the stream ecological health.

In this study we investigate spatial and temporal patterns of physical streambed characteristics and redox chemical conditions and its controls on the reactive transport and transformation of nitrogen in the streambeds of two UK upland and lowland rivers. For the streambed sediments of several stream reaches, pore water nitrate/nitrite and ammonia concentrations were monitored together with common anions, redox conditions, dissolved oxygen and organic carbon and rates of groundwater up-welling and surface water mixing in a dense system of nested piezometer over several baseflow periods. Spatial patterns of aquifer – river exchange were furthermore investigated by active and passive heat tracer experiments using fibre optic distributed temperature sensor networks at reach and heat pulse injection experiments at local scales.

The results of this study indicate that hyporheic nutrient transformation can well exceed the usually assumed streambed depths of a few cm and may occur in depths of > 1m. Our investigations furthermore detected, that within the research area the hyporheic passage has a spatially very variable impact on the exchange fluxes and nitrogen concentrations and transformation rates in the streambed. Nitrate attenuation due to denitrification was found in some areas as well as nitrification in others. The spatial patterns of nitrate attenuation or release areas were controlled by the hyporheic connectivity, described by the spatial and temporal coincidence of flow pattern and residence times within areas of variable redox conditions. The hyporheic nitrate contributions furthermore showed to have a seasonally variable impact on in stream concentrations. At the investigated lowland sites mosaics of confining peat layers within the streambed sediments have been found to function as hyporheic super-reactors, resulting in a complete uptake of nitrate in the up-welling groundwater which is important and needs to be considered for the planning of river regulation and conservation measures.