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Scales and Patterns of Nitrate Transport and Transformation in the Hyporheic Zone of a Lowland River

E. Naden (1), S. Krause (1), C. Tecklenburg (2), and M. Munz (2)

(1) Keele University, Dep. for Earth Science and Geography, Dep. for Earth Science and Geography, Keele, Staffordshire, United Kingdom (s.krause@esci.keele.ac.uk, 0044 01782 715261), (2) Potsdam University, Geoecology Dep., Potsdam, Germany

The Hyporheic Zone (HZ) represents the spatially and temporally variable part of the streambed that is affected by the mixture of groundwater and surface water and often characterised by strong redox gradients and high turnover rates of redox reactive substances. The HZ has often been understood as a complex bioreactor with a high potential to affect groundwater-surface water exchange as well control the chemical signature of waters along the hyporheic passage. Currently, 73% of groundwater and 28% of UK rivers sampled exhibit either high nitrate levels or rising trends (Defra, 2008)

Because of the high metabolic rates that have often be observed, the HZ is by many expected to potentially ameliorate groundwater nitrate fluxes and thus to reduce nitrate pollution and benefit freshwater ecosystems.

The objective of this pilot study was to set up a monitoring program on a typical lowland river within glacio-fluvial deposits and well connected to the shallow groundwater aquifer. This study aims to derive a conceptual model of hyporheic exchange and nutrient metabolism in an agriculturally used lowland system including the development of upscaling strategies that allow for the assessment of hyporheic uptake or contribution on a subcatchment scale.

The research area covers a 250 metre stream reach of the River Tern (Shropshire, UK), a lowland groundwater dependent surface water body at risk of failing to achieve 'good water' status under the WFD, primarily due to diffuse agricultural pollution.

In two horizontal arrays 42 multi piezometers have been installed in the river bed offering sampling from between three and eight sampling points ranging from 5 cm to 200 cm depth. These allow the sampling of streambed porewater from more than 150 locations. Additionally, ten shallow groundwater boreholes (up to 3m depth) have been installed within the riparian floodplain. From June to September 2008 head measurements were taken at the streambed piezometers, riparian groundwater boreholes and the river in order to determine the groundwater flowfield and exchange with the surface water. At the same time interval streambed pore water and riparian groundwater were sampled from piezometers and boreholes alongside surface water samples from the river. The samples were analysed for dissolved oxygen and major anion concentrations.

Initial results confirm indicate that the water sources mixing in the HZ are statistically distinctive. In contrast to the many observed head water streams the exchange between groundwater and surface water is not just determined by gradually changing hydraulic conductivities of the sediment material but strongly controlled by the spatial pattern of a discontinuous impermeable regional peat layer located in 50 cm depth on average. The peat layer is separating the fluxes within the streambed into two (partially connected) flow systems, with semi-confined conditions underneath and pattern of surface water mixing above the peat. Areas where the peat layer is disrupted are characterised by strong connection of both flow systems. Dependent on flow paths and residence times redox conditions and nitrate concentrations are showing substantial changes along the hyporheic flow path. The spatial very heterogeneous patterns of nitrate concentrations in the streambed were found controlled by complex flow processes at multiple scales covering small scale hyporheic exchange in pools, riffles and sand bars as well as large scale pattern of groundwater – surface water connectivity and riparian influences.