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Hotspots and hot moments of aquifer river exchange and biogeochemical cyclinbg in the streambed of lowland rivers

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Exchange fluxes across aquifer-river interfaces can have a major impact on the biogeochemical cycling in streambed environments. This paper presents integrated experimental and model-based investigations of physical drivers and chemical controls on streambed biogeochemcial cycling at two UK lowland rivers. It combines in-stream geophysical surveys, multi-level mini-piezometer networks and active and passive heat tracing methods for identifying spatial patterns and temporal dynamics of aquifer-river exchange fluxes with multi-scale hyporheic pore-water sampling and applications of reactive “smart-tracers”.

Hyporheic pore water analysis from nested multi-level piezometers and passive gel probe samplers revealed significant spatial variability in streambed nitrogen cycling in dependence of redox-conditions, dissolved oxygen and bio-available organic carbon concentrations. Hot spots of increased nitrate attenuation and anaerobic respiration were associated with semi-confining streambed peat lenses. The intensity of concentration changes underneath the confining peat layers correlated with the state of anoxia in the pore water as well as the supply of organic carbon and hyporheic residence times. In contrast, at locations where flow inhibiting peat layers were absent or disrupted - fast exchange between aquifer and river caused a break-through of nitrate without significant concentration changes along the hyporheic flow path.

Fibre-optic Distributed Temperature Sensing was applied for identifying groundwater - surface water exchange flow patterns in dependency of streambed structural heterogeneity and support the identification of the location and extend of flow inhibiting structures as indicators of streambed reactivity hot spots.

Coupled groundwater-surface water model simulations supported the experimental results, indicating that hotspots of exchange fluxes and biogeochemical activity were predominantly controlled by the spatial heterogeneous impact of streambed conductivity patterns on groundwater up-welling while surface driven processes as advective pumping had only marginal impacts.