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River-groundwater connectivity and nutrient dynamics in a mesoscale catchment

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Diffuse solute exports from catchments are governed by many interrelated factors such as land use, climate, geological-/ hydrogeological setup and morphology. Those factors create spatial variations in solute concentrations and turnover rates in the subsurface as well as in the stream network. River-groundwater connectivity is a crucial control in this context: On the one hand groundwater is a main pathway for nitrate inputs to the stream. On the other hand, groundwater connectivity with the stream affects the magnitude of hyporheic exchange of stream water with the stream bed.

We present results of a longitudinal sampling campaign along the Selke river, a 67 km long third-order stream in the Harz mountains in central Germany. Water quality at the catchment outlet is strongly impacted by agriculture with high concentrations of nitrate and a chemostatic nitrate export regime. However, the specific nitrate pathways to the stream are not fully understood as there is arable land distributed throughout the catchment. While the sparsely distributed arable land in the mountainous upper catchment receives much higher amounts of precipitation, the downstream alluvial plains are drier, but more intensively used.

The three-day campaign was conducted in June 2016 under constant low flow conditions. Stream water samples were taken every 2 km along the main stem of the river and at its major tributaries. Samples were analyzed for field parameters, major cations and anions, N-O isotopes, nutrients and Radon-222 (Rn) concentrations. Additionally, at each sampling location, river discharge was manually measured using current meters. Groundwater influxes to each sampled river section were quantified from the Rn measurements using the code FINIFLUX, (Frei and Gilfedder 2015).

Rn and ion concentrations showed an increase from the spring to the mouth, indicating a growing impact of groundwater flux to the river. However, increases in groundwater gains were not gradual. The strongest gains were observed downstream of where the Selke River leaves the Harz Mountains and enters the alluvial plains. At this location, land use, hydrogeological setup and river slope as well as average slope of the contributing catchment area change significantly. Downstream of this point 15N isotope values were also significantly higher, suggesting higher denitrification activity in the deeper aquifers of lower catchment. While specific discharge (discharge per catchment area) was 3 times higher in the upper catchment, nitrate mass flux per area was more than 3 times higher in lower catchment compared to the respective other part of the catchment. We conclude that catchment morphology, (hydro)geology and hydrology control river-groundwater connectivity while the interplay with land use controls in stream nitrate concentrations. Repeated sampling campaigns will allow assessing seasonal changes in solute inputs and turnover.

References

Frei, S. & Gilfedder, B.S. (2015): FINIFLUX: An implicit finite element model for quantification of groundwater fluxes and hyporheic exchange in streams and rivers using radon. Water Resources Research, DOI: 10.1002/2015WR017212.