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# Disentangling nitrate mixing and transformation processes in the riparian zone using a multi-isotope approach

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The riparian zone is a hydrologically and biogeochemically active zone, characterized by mixing of streamwater with groundwater and transformation of nutrients such as nitrogen. The riparian zone thus plays a key role in natural attenuation of nitrate pollution. Temporal variations in these processes have been recently studied in an intensively monitored groundwater well field along a 2 km stream section in central Germany (Trauth et al., 2018). Using an endmember mixing model with chloride and nitrate concentrations, it was possible to quantify mixing between groundwater and streamwater as well as to assess nitrate transformation in the riparian aquifer. However, the assessment of mixing and transformation processes using concentration data might be complicated by dilution effects that result in erroneous attribution of concentration decreases to transformation processes or mixing of the assumed endmembers. As isotope values are not altered by dilution effects, we applied the stable isotope sources and sinks model (SISS) model, which allows for both quantification of transformation and mixing between two sources using compound-specific isotope data (Lutz and van Breukelen, 2014). While the model has been previously applied to a locally polluted aquifer, this study represents the first application of the SISS model to a diffuse pollutant such as nitrate. Based on the nitrate isotope data, the SISS model indicates large seasonal variations in mixing between groundwater and surface water (i.e. in river water fractions in groundwater) as well as in the extent of denitrification. In agreement with Trauth et al. (2018), river water fractions are smallest in those wells adjacent to the gaining river section and largest in those wells along the losing river section. To gain more insights into the temporal and spatial variability of mixing and transformation processes, these results were complemented by a transit time characterization using stable water isotopes. This transit time analysis corroborates the SISS model results in that the wells along the losing river section show a larger contribution of young water than the wells along the gaining river section. Overall, this study demonstrates how to combine concentrations, stable water isotope and nitrate isotope data to obtain a detailed picture of mixing and transformation processes in the riparian zone.

References

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