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Quantifying aquifer residence times and subsurface processes during artificial infiltration using multiple tracers

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To develop adequate groundwater management and protection plans, knowledge about the residence time of artificially infiltrated water in the aquifer as well as the flow paths is essential. Typically, tracers are used to gain information about subsurface processes. A variety of tracers exist, all with their own advantages and limitations. The application of multiple tracers is however less common, although offers more insight than from a single tracer test.

In this study a 26 days pumping test was carried out at a site in Switzerland, where drinking water is pumped from an aquifer located close to landfills and industrial areas. At the study area groundwater is artificially recharged by infiltrating surface water through an excavated system of channels and ponds. We analysed water samples for major cations and anions, trace elements and organic micropollutants such as Acesulfame. In addition, samples for stable water isotope analysis were taken as well as time series of dissolved gas concentrations (He, Ar, Kr, N2, and O_2) and chlorinated solvents (e.g. Tetrachloroethylene (PCE)) were acquired. Furthermore, dye and heat tracer samples were collected between the artificial infiltration system and pumping wells. With this unique data set we systematically compare the value of information gained from the applied tracers and illustrate similarities and differences.

We show that estimated residence times determined from dye tracers and heat observations were similar. It was found that the amount of artificial recharge is spatially variable along a sampling transect between infiltration channel and pumping well. As a result of the temporal resolution data of gas concentrations and chlorinated solvents it became evident that the abstracted groundwater is a mixture of locally infiltrated surface water and regional groundwater originating from upstream. Changing boundary condition such as pumping and infiltration rates during our experiment had a strong impact on mixing ratios and contaminant concentrations. The high temporal resolution of dissolved gas concentrations in groundwater provides a new and additional analytical opportunity in tracing subsurface processes. Overall, our results will assist in the development of a conceptual understanding that is based on the approach of using multiple tracers to produce the most credible description of flow and transport processes.