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A multitracer approach to estimate groundwater residence time distributions at a managed aquifer recharge site

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Managed aquifer recharge (MAR) has become a common water management tool and serves various purposes such as improving the quality of groundwater (GW). At the study site, the Hardwald in Muttenz (Switzerland), MAR has been implemented in the mid-1950s to overcome increasing water demands. GW is artificially recharged with water from the river Rhine through a system of channels and ponds. The area is surrounded by potential contamination sites such as chemical industry, former landfills, a highway and a freight depot. Furthermore, the area shows a complex hydrogeologic setting with several fault zones and two main aquifers, the Quaternary Rhine gravel aquifer overlying a karstified Upper Muschelkalk limestone aquifer. Water from the deeper limestone aquifer is suspected to contain contaminants originating from the landfills. The fractures might serve as a hydraulic connection between the upper and lower aquifer. Further, groundwater pumping might enhance the mixing of recently infiltrated water with older water from the lower aquifer. Hence, the proximity to potential contamination sites and the complex geologic setting both pose risks for GW pollution and challenge the drinking water production in this area. To guarantee a safe drinking water supply, it is crucial to know the mixing patterns of young and old GW abstracted from the pumping wells.

With this study we aim to determine the spatial variability of GW residence time distributions to differentiate between recently infiltrated river water and older groundwater. To reach our objectives, we use a combination of the following tracers to cover a wide range of possible GW ages: (1) radiogenic ^{222}Rn (young water := <3 weeks); (2) tritium (^{3}H) in combination with its tritiogenic decay product ^{3}He (old water := 0.5–50 years); and (3) radiogenic ^{4}He (very old water := 100–1000 years). Additionally, we analysed other dissolved (noble) gases (O_2, N_2, Ar, Kr) to estimate the amount of excess air and to derive the equilibration temperature. We also sampled for physico–chemical parameters such as water temperature, electrical conductivity, alkalinity, total hardness, DOC, Na^+, Mg^{2+}, Ca^{2+}, K^+, Cl^-, NO_3^-, SO_4^{2-} and H_4SiO_4 concentrations to complement the interpretation of the age tracers. All parameters were analysed at 20 observation and pumping wells distributed throughout the study area. First results indicate that GW abstracted in the vicinity to the area with the highest recharge rates exhibits young water only. Wells further away from these high recharge areas contain a mixture of young and old GW. However, only one pumping well showed a mixture of very young, old and very old GW. Some wells within the fracture zones show higher ^{3}H/^{3}He ages which supports our hypothesis of a hydraulic connection between the deeper and the upper aquifer. As a next step, we plan on using a mixing model to quantify the fractions of young and (very) old groundwater.