Use of helium as an artificial tracer to study surface water/groundwater exchange

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Groundwater - surface water interactions (SGI) fundamentally control groundwater recharge. The according dynamics are, thus, key for sustainable (drinking) water management. SGI are particularly relevant in the context of climate change and re-naturalization of canalized rivers, which might affect the availability and quality of groundwater pumped near streams. SGI are often not directly observable due to their complex spatial and temporal patterns. To complement the few available tracer methods (dye, electric conductivity, heat, etc.) to analyze SGI, we developed a novel method to quantify riverine groundwater recharge by using helium (He) as an artificial tracer.

We injected gaseous He into a Swiss pre-alpine river (river Emme, canton of Berne) through perforated tubing which was placed on the riverbed. Dissolved He (as well as Ar, N\textsubscript{2} and O\textsubscript{2}) concentrations were continuously monitored in the river (200 m downstream of the injection point) and in a piezometer (30 m away from the river) using a portable mass spectrometer allowing quantitative gas determination under field conditions (miniRUEDI, gas-equilibrium membrane-inlet mass spectrometer (GEMIMS), Gasometrix GmbH, Brennwald et al. (2016)). The He injection consisted of two pulses, each lasting around 8 hours, during which dissolved He became supersaturated by up to three orders of magnitude compared to the natural (atmospheric) He abundance in surface waters (concentration of air saturated water (ASW)). The two associated He pulses were clearly identifiable in the groundwater and appeared in the piezometer approximately one day after the injection phases. The measured He concentrations in the groundwater were four to six times higher than ASW.

In conclusion, our experimental setup allows the identification of the freshly infiltrated river water in an adjacent groundwater body in a concise, robust and straightforward manner. Our new method is also non-toxic and can thus often be implemented with minimal constraints. Such tracer methods provide useful observations to constrain physically based, surface water/groundwater models.