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Gases as artificial tracers to study SW-GW interactions

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Understanding groundwater (GW) and surface water (SW) interaction is essential for drinking water management and ecosystems. However, these interactions can be notoriously difficult to grasp because of the subsurface heterogeneity, which causes preferential groundwater flow.

Tracers are commonly used in the context of GW-SW interactions. Traditional artificial tracers like dyes are difficult to handle. Moreover, the coloring of rivers may cause negative public perception. Gas tracers present a promising alternative as they are conservative, invisible, non-toxic, and easy to handle. Recent advances in portable mass spectrometry facilitate their direct and continuous measurement in the field [1], enabling their operational use in GW [2]. However, there are technical and economical limitations that impede the routine usage of gas tracers to study SW-GW interaction, e.g., gas (especially noble gases) injection into rivers by bubbling requires large volumes that often can be financially prohibitive.

We present a cost-effective method for diffusive gas injection into rivers using easily available materials. We tested our approach with the noble gas helium (He) in a pre-alpine river connected to an alluvial aquifer (Emmental, Switzerland). The gas injection was sustained for 35 days and oversaturated the river water with He by one order of magnitude compared to natural conditions. Dissolved gas concentrations (He, O_2, N_2, Ar, and Kr) were monitored in the river, a drinking water well, and several piezometers. Gas measurements provided quantitative information on connectivity and river infiltration dynamics. The results demonstrated a direct hydraulic connection between the infiltrating river and the drinking water well. Moreover, results from a pulse gas tracer test, conducted by injecting Krypton directly into the aquifer, highlighted the existence of preferential groundwater flow paths in the aquifer, with measured groundwater velocities above 3 mm/s (13 m/h).

[1] ES&T, 2016, 50, 13455-13463; ES&T, 2017, 51, 846-854; [2] Front. Water, 2022, 4, 925294.