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Characterization of PFAS plume transport in Oakey, Australia enabled by Atom Trap Trace Analysis (ATTA)

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Per- and polyfluoroalkyl substances (PFAS) are synthetic chemicals used in many products mainly due to their chemical durability. Problematically, PFAS are nowadays found not only confined to the original products but have been intruding various environmental systems. In the case of groundwater systems, this is critical especially if the water is used for drinking or irrigation. However, the transport characteristics of PFAS in groundwater is largely unknown and restricted to column experiments [Nguyen et al., 2022; Niarchos et al., 2022].

Therefore, this study aims to make use of age tracers to investigate the PFAS plume in Oakey, Australia, to produce real-world data for estimating retardation factors as well as predictions of future well contamination. Age tracers usually are substances present in the natural water cycle which dissolve in water from the atmosphere and whose concentration in a water package is dependent on the time since that last exchange with the atmosphere (due to concentration changes in the atmosphere or radioactive decay).

The PFAS plume study in Oakey is based on a variety of widely used age tracers (^{3}H, $^{3}H/^{3}He$, CFC's, SF_6, ^{14}C) but also on the noble gas radioisotopes ^{85}Kr (input variation since 1950s) and ^{39}Ar ($t_{1/2}$ = 269 a) which are measured by the Atom Trap Trace Analysis (ATTA) technology [Chen et al., 1999]. This technology relies on the isotopic shift in the resonance frequency of the atoms to manipulate the targeted ultrarare isotopes together with multiple resonant scattering processes which grants perfect selectivity. Using appropriate lasers in combination with magnetic fields ATTA enables to trap and count single atoms in a magneto-optical trap (MOT), while the huge background of abundant isotopes remains unaffected.

First tracer results show that noble gas radioisotopes might be the only applicable tracer on the timescale of PFAS introduction (other tracers have e.g. contamination issues), rendering this study a perfect example of how the ATTA technology enables connecting water age distributions with concentrations of contaminants. This however is the basis to accurately model plume transport through a groundwater system and future well contamination as well as to determine field-scale retardation factors.