

## Using Multiple Tracer Methods to Investigate Groundwater Residence Times During Bank Filtration in Berlin

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### ABSTRACT

Berlin relies on induced bank filtration from a broad-scale, lake-type surface water system. Because the surface water contains treated sewage, wastewater residues are present in surface water and groundwater. Multiple environmental tracers including tritium/helium-3 ( $^3\text{H}/^3\text{He}$ ), stable isotopes ( $\text{d}18\text{O}$  and  $\text{d}2\text{H}$ ) and a number of persistent sewage indicators such as chloride ( $\text{Cl}^-$ ), boron (B) and a selection of pharmaceutical residues (phenazone-type analgesics and their metabolites, carbamazepine and anthropogenic gadolinium, Gd<sub>excess</sub>) were used to estimate travel times from the surface water to individual production and observation wells at 2 sites. The study revealed a strong vertical age stratification throughout the upper aquifer at all sites with travel times of the bank filtrate varying from a few months to several decades in greater depth. While the shallow bank filtrate is characterized by the reflection of transient tracer input curves and young  $^3\text{H}/^3\text{He}$  ages, the deeper, older bank filtrate displays no tracer seasonality,  $^3\text{H}/^3\text{He}$  ages of a few years to decades and strongly deviating concentrations of several pharmaceutical residues, reflecting changing concentrations in the source surface water over time. Infiltration is only possible at the sandy lake shores, while impermeable lacustrine sapropels inhibit infiltration further into the lakes, which is why the older bank filtrate must originate from shores hundreds of meters away from the wells. This paper illustrates the importance of using multiple rather than single tracer methods to gain a comprehensive understanding of time scales and infiltration characteristics in a bank filtration system used for drinking water abstraction.