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Groundwater residence time : tell me who you are and I will tell which information you may provide

Luc Aquilina (1), Thierry Labasque (2), Tamara Kolbe (3), Jean Marçais (4), Sarah Leray (5), Ben Abbott (6), and Jean-Raynald de Dreuzy (7)

(1) Université Rennes 1 - CNRS, Rennes, france, (2) Université Rennes 1 - CNRS, Rennes, france, (3) Université Rennes 1 - CNRS, Rennes, france, (4) Université Rennes 1 - CNRS, Rennes, france, (5) IFP Nouvelles Energies, Rueil-Malmaison, France, (6) Université Rennes 1 - CNRS, Rennes, france, (7) Université Rennes 1 - CNRS, Rennes, france

Groundwater residence-time or ages have been widely used in hydrogeology during the last decades. Following tritium measurements, anthropogenic gases (CFC, SF6, 35Kr) have been developed. They provide information at the aquifer scale on long residence times. They complement the more localized data obtained from sparse boreholes with hydraulic and geophysical methods.

Anthropogenic tracer concentrations are most generally considered as "Groundwater ages" using a piston flow model providing an order of magnitude for the residence time. More advanced information can however be derived from the combined analysis of the tracer concentrations. For example, the residence time distribution over the last 50 years can be well approached by the concentration of two sufficient different anthropogenic tracers in the group (CFC, SF6, 35Kr), i.e. tracers whose anthropogenic chronicles are sufficiently different. And, with additional constrains on geological and hydraulic properties, groundwater ages contribute to characterize the aquifer structures and the groundwater resources.

Complex geological environments also include old groundwater bodies in extremely confined aquifer sections. In such cases, various tracers are related to highly different processes. CFCs can be taken as a marker of modern contamination to track exchanges between shallower and deeper aquifers, leakage processes, and modification of circulations linked to recent anthropogenic changes. 14C or 36Cl can be used to evidence much older processes but have to be related to the history of the chemical element itself. Numerous field studies in fact demonstrate the broad-range extent of the residence time distribution spanning in some cases several orders of magnitude. Flow and transport models in heterogeneous structures confirm such wide residence times and help to characterize their distribution.

Residence times also serve as a privileged interface to the fate of some contaminants in aquifers or to trace geochemical processes. Among others, it is the case of (i) slow geochemical processes effective at large residence times such as silicate dissolution, (ii) biogeochemical reactivity activated by some modification of the flow structure, (iii) interactions between microbial diversity and biogeochemical reactivity. While first-order kinetics is commonly assumed, more advanced relations are developed between the nutrient and energy supply. O_2 and NO_3 nutrient relate to recharge processes on the one hand and Fe and S relate to dissolution in reducing environments on the other hand. Detailed studies of fractured aquifers in Brittany (France) are discussed.