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4He as a dating groundwater tool in a shallow crystalline aquifer : evidence of mixing of young (<70 y) and old (< 10Ky) waters components

Thierry Labasque (1), Eliot Chatton (1), Aurélie Guillou (1), Luc Aquilina (1), Elise Fourré (2), and Virginie Vergnaud (1)

(1) Université de Rennes 1-CNRS, OSUR-Geosciences Rennes, Rennes cedex, France (thierry.labasque@univ-rennes1.fr), (2) UMR 8212 CEA/CNRS/UVSQ, Saint Aubin, France

Groundwater dating methods have been widely used since decades for studying subsurface water hydrological and hydrochemical processes. Estimation of groundwater residence time is essential for resource preservation, contaminant studies or groundwater recharge rates and flow velocities assessments. Due to the complexity of groundwater flow, the joint use of several environmental tracers has been often promoted as they offer integrative information on the structure of complex aquifers.
Anthropogenic gas tracers as CFC, SF6, 85Kr, 36Cl or 3H have been widely used to study shallow groundwaters with residence time of less than 70 yrs. For longer groundwater residence time (100- x1000 yr), 39Ar, 14C, 36Cl and 4He have been used. 4He can cover an age range of 100 to thousands years. The main difficulty is to estimate the production rate through U and Th decay and the others fluxes : atmosphere, crust and mantellic. In many cases U-Th production is not sufficient to explain the 4He concentrations observed in the aquifer. Other 4He fluxes can then be estimated through the use of other tracers: 14C, 36Cl or modeling. Fracturing may also enhance 4He concentrations in groundwater.

We present here the evaluation of 4He in a crystalline fractured aquifer in the Northwest of France (H+ national hydrogeological network), in order to investigate the range of groundwater residence time in this complex shallow aquifer. Previous studies on this aquifer reveal mixing between young (<70 yrs) and old waters (>1000 yrs) (Ayraud et al., 2008). The Helium radiogenic production rate is then evaluated through in situ production (U, Th) and calibration with CFC and 14C. Apparent ages are compared and uncertainties discussed.
4He proves to be a valuable tool for better understanding water mixing in shallow crystalline aquifers.

Ayraud, V. et al. Compartmentalization of physical and chemical properties in hard-rock aquifers deduced from chemical and groundwater age analyses. Appl. Geochemistry 23, 2686–2707 (2008).