Geophysical Research Abstracts
Vol. 18, EGU2016-5908, 2016
EGU General Assembly 2016

Estimation of ground water residence times in the Critical zone: insight from U activity ratios

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The use of radioactive disequilibria as tracers and chronometers of weathering processes and related mass transfers has been recognized since the 60'. The development, over the last two decades, of analytical methods for measuring very precisely U-series nuclides (especially, 234U, 230Th and 226Ra) in environmental samples has opened up new scientific applications in Earth Surface Sciences. Here, we propose to present the potential of U activity ratios in surface waters as chronometer of water transfers at a watershed scale. This will be illustrated from studies performed at different scales, with the analysis of U activity ratios in surface waters from small watersheds (Strengbach and Ringelbach watersheds in the Vosges Mountain, France) but also from watersheds of much more regional extension (e.g., the Upper Rhine basin or the Ganges basin).
These various studies show that variations of U activity ratios in surface waters are mainly associated with 234U-238U fractionations occurring during the water transfer within the bedrock, which intensity depends on two main parameters: the petro-physical characteristics of the aquifer, principally the geometry of water-rock interfaces and the duration of the water-rock interactions. This readily explains why different U activity ratios (UAR) can be observed in the different aquifers of a continental hydrosystem and hence why UAR can be used to trace the source of river waters. For a hydrological system developed on a substratum marked by fairly homogeneous petro-physical characteristics, the main parameter controlling the UAR in waters draining such a system would be the duration of the water-rock interactions. Variations of UAR in stream or spring waters of such a system can therefore be modeled using simple reactive transport model, which allows the estimation of both the dissolution rate of the bedrock and the residence time of the waters within the aquifer.