Origin, reservoirs and fate control of natural uranium in northern Bavaria, Germany

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Uranium (U) is an ubiquitary trace element in the environment with potential adverse human health effects. It was shown that the risk of U exposure is primarily due to its toxicity as a nephrotoxic heavy metal rather than its radioactive character [1]

There is no general agreement on fixed limitations for U concentrations in drinking water to date. German legislation recently decided on a limitation of 10 µg L^{-1}, valid since November 2011, making Germany the first EU member state with a binding maximum U concentration.

Drinking water supply in northern Bavaria is dependent on groundwater extraction from terrestrial Norian sandstones. Partly elevated concentrations of geogenic U (up to 42 µg L^{-1}) were detected in this groundwater with the responsible sources and processes remaining uncertain. Therefore, we conducted a detailed geochemical and mineralogical characterization of aquifer material on a macro- and microscale and evaluated U remobilization behaviour. Results were set in relation to groundwater composition and physico-chemical conditions, also taking the distribution of the affected aquifer and the paleoenvironment into account.

We found that so-called "active arkoses" [2]– uraniferous inclusions within the aquifer sandstones – represent the most likely U source in the study area. Syndiagenetic mineral precipitation from paleogroundwater led to accumulation of sedimentary U which primarily originates from felsic-magmatic provenance areas. The sediments document U loss during weathering of carbonate fluorapatite accounting for up to 50 wt.% in freshly exposed material. This phosphatic rock matrix partly hosts U concentrations >1000 µg g-1 with the main uptake mechanism being stoichiometric substitution for Ca [3]. Coupled substitution (CO_3^{2-} + F- ↔ PO_4^{3-}) in the mineral lattice and critical doses of α-recoil damage due to high U contents, both of which could be confirmed in the present study, result in structurally and radiatively enhanced apatite solubility [4, 5]. Moreover, increased U mobility was detected in the presence of F- in solution, derived from carbonate fluorapatite breakdown.

Together with uraniferous dolomitic inclusions north

of the study area, phosphatic "active arkoses" are likely to control the geogenic U problem in northern Bavarian groundwater.

References

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