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Noble gas tracers reveal order-of-magnitude differences in groundwater residence times in fractured bedrock aquifers of the West African Sahel

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The deeply weathered, fractured aquifer systems that supply drinking water to rural populations in Western and Central Africa are still little investigated in terms of groundwater quality, recharge processes and residence time. We used noble gas tracers to gain insights on groundwater residence times of shallow to moderately deep crystalline bedrock aquifers ($<$ 100 m b.g.l.) in a small catchment (80 km^2) of semi-arid Burkina Faso, where groundwater is affected by elevated geogenic arsenic concentrations stemming from the oxidation of sulphide minerals.

This first dataset of noble gas measurements in such aquifers in West Africa revealed a large variability in helium isotope ratios ($^3He/^4He$) ranging over three orders of magnitude from 0.06 to 1.6 ($\times 10^{-6}$). While some samples dominated by ^3He from atmospheric and/or tritiogenic sources are influenced by modern recharge, others have clearly been cut off from the modern water cycle, indicated by very low $^3He/^4He$ of 10^{-8} and subsequent residence times of $>10^3$ years. Such low He isotope ratios suggest prolonged water-rock interaction to accumulate radiogenic ^4He, and were already observed at depths of less than 50 m below ground level.

We propose that some water-bearing fractures, even at relatively shallow depths, remain isolated from modern recharge, possibly with connections/discontinuities to deep fracture zones and carry very old, slow-moving groundwater. These results contrast previous observations in similar settings (Northern Nigeria, Southern Mali) indicating predominating shorter residence times ($<$ 60 years) and question the sustainability of future increasing groundwater extraction in light of a rapidly growing population in this region. Furthermore, the large spatial variability in hydrochemical (e.g. arsenic) and isotopic parameters reflects the highly heterogeneous fractured subsurface and the necessity of high spatial density sampling campaigns to assess the sustainability and vulnerability of the groundwater resources in these regions.