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The eternal quarrel between Carbon-14 and Argon-39 in groundwater studies: fate or hope for reconciliation?

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Often, dating studies are focused either on young environmental tracers (e.g. $^{3}H/^{3}He$, ^{85}Kr, ^{222}Rn) for residence times < 100 years, or on older counterparts (e.g. ^{36}Cl, ^{4}He, ^{81}Kr) for the time range > 5'000 years, or on mixing processes between these young and old components. Studies involving tracers for the intermediate timescales (100 – 1000 years) are scarce because of the limited number of reliable tracers in this range.

Argon-39 ($t_{1/2}$ = 269 yrs) and Carbon-14 ($t_{1/2}$ = 5734 yrs) are most suitable to trace groundwaters that recharged 50 – 1'800, resp. 500 – 20'00 years ago. Discrepancies arise between apparent residence times derived from ^{39}Ar and ^{14}C, with the former often appearing younger than the latter. While mixing processes offer a partial explanation, they fail to bridge the observed discrepancy fully.

Based on a large multi-tracer survey covering a significant proportion of Danish aquifer systems and including ^{39}Ar and ^{14}C values, we propose an in-depth discussion of possible processes that are likely leading to diverging age information between these two tracers. Factors such as depth-dependent underground production (for ^{39}Ar), diffusive exchange between permeable and stagnant aquifer zones (for both ^{39}Ar and ^{14}C), and geochemical reactions are considered. A numerical modeling approach is suggested to explicitly simulate the behavior of ^{39}Ar and ^{14}C in the subsurface, aiming to provide insights into the influencing processes and reconcile the observed discrepancies. This research contributes to advancing our understanding of groundwater dating methodologies and improving the accuracy of resource management strategies.