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Challenges in dating groundwater with tracers in Precambrian bedrock and postglacial sedimentary aquifers

JANI WIKSTRÖM[1], RIIKKA KIETÄVÄINEN[1] AND KIRSTI KORKKA-NIEMI[1,2]

[1]University of Helsinki
[2]The geological survey of Finland

Groundwater dating tracers could improve our hydrogeological understanding of shallow aquifers important for water supply. However, research in suitability of tracers for old shallow crystalline basement and overlying young sedimentary aquifers, typical in Fennoscandia, is limited. Prior studies in Finland suggest potential problems, especially with chlorofluorocarbons (CFCs) and sulfur hexafluoride (SF_6) tracers. Thus, we investigate the suitability of groundwater dating tracers (^3H, $^3H/^3He$, CFCs, SF_6, ^{14}C, and ^4He) in Precambrian crystalline bedrock and young Quaternary sedimentary aquifers mostly from the Weichselian. Our dataset includes seven sites with groundwater dating tracers and hydrogeochemical data from this study (n = 31) and data from two previous regional studies (n = 22).

Identified potential issues were related to high amount of excess air, poorly identified helium sources, degradation of CFCs, and in-situ production of tracers. In this study, the majority of SF_6 concentrations were over 100 times the present atmospheric concentrations and ^4He concentrations up to 7600 times above solubility equilibrium. These concentrations were even higher than reported from southern Sweden [1], which is geologically similar to Finland. Furthermore, our high ^4He concentrations were frequently observed alongside modern water tracers, suggesting either mixing or in-situ helium accumulation from granitic basement or confining clay layers, which act as barriers for helium diffusion. Improper identification of helium sources, as well as mixing of old and young waters, also impacts the apparent ages derived from $^3H/^3He$ dating, explaining our observed apparent ages that are older than the atmospheric tritium bomb peak. The intermediate ^{14}C concentrations (30–80 pMC) are likely the result of modern recharge being diluted by mixing with very old waters that have low or absent ^{14}C, as indicated by the high ^4He concentrations.

We found the multi-tracer approach essential in shallow aquifers as the groundwater apparent ages frequently spanned over the timescales of multiple tracers. Also, the observed challenges in the use of SF_6 and CFCs would encourage seeking new modern water tracers for Precambrian bedrock aquifers, as even the more robust tritium has challenges with atmospheric concentrations approaching the natural background levels.

[1] Åkesson et al. (2015), Journal of Hydrology, 528. https://doi.org/10.1016/j.jhydrol.2015.06.022.