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Groundwater residence times using radon-222 isotopes: a review

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Measurements of dissolved radon gas (Rn-222; half-life 3.8 days) concentration in aquifers have been a valuable environmental tracer to determine groundwater residence times of recently infiltrated surface water. Published applications are based on assumptions, which limit the use of Rn-222 to a restricted number of hydrogeological settings. They include a homogenous distribution of the Rn-222 progenitor radium-226 in the solid material, no mixing of the infiltrating water with older groundwater, and steady-state hydrological boundary conditions (i.e. constant flow distance between infiltration and sampling location). Typical investigated field conditions are aquifers, where rivers, canals, or lakes form a constantly infiltrating boundary. Hence, required equilibrium Rn-222 activity is determined by sampling distant sampling locations where expected aquifer residence times of at least 20 days result in equilibrium radon activity. Along the alluvial plain of the Langen Erlen near Basel, Switzerland, surface water infiltration was controlled by flooding the wetland ponds in cycles of four weeks. Therefore, samples taken within the aquifer before flooding necessarily reached equilibrium activity. Remaining differences in measured Rn-222 activities between the sampling locations reflect the effects of geological heterogeneities on radon emanation along the respective flow path. The assumption, that there is no mixing of the infiltrating water with older groundwater, is typically biased if one does not calculate the residence time in the close vicinity of the infiltration boundary. Chloride tracer data permitted to separate older and recently infiltrated groundwater and to calculate resulting aquifer residence times for the infiltrating surface water part only. Finally, the variation of the flooding rate demonstrated that Rn-222 tracer information is also valuable while sampling under transient boundary conditions. The reliance of aquifer residence times calculated with the Rn-222-method was tested by comparing them to mean flow velocities predicted by a 3-D numerical flow and solute transport model.