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# Radium isotope response to aquifer storage and recovery in a sandstone aquifer

David S. Vinson[1,*], James R. Lundy[2], Gary S. Dwyer[3], and Avner Vengosh[3]

[1]-University of North Carolina at Charlotte, Department of Geography and Earth Sciences, 9201 University City Blvd, 324 McEniry, Charlotte, NC 28223 USA

[2]-Minnesota Department of Health, Environmental Health Division, 625 North Robert Street, St. Paul, MN 55164 USA

[3]-Duke University, Nicholas School of the Environment, Box 90328, Durham, NC 27708 USA

*-corresponding author: dsvinson@uncc.edu, +1 704 687 5977

## Abstract

Radium isotopes and water-rock interaction were evaluated in an aquifer storage and recovery (ASR) pilot study conducted in 2010-2011 in Minnesota (USA) in order to identify mechanisms governing Ra activities when low-Ra water is recharged into a sandstone aquifer. Groundwater in the aquifer selected for the study, the Cambrian Mt. Simon Sandstone, contains naturally occurring radium that in many areas exceeds United States drinking water standards (185 mBq/L or 5 pCi/L combined $^{226}Ra+^{228}Ra$), highlighting the need to identify the rates and mechanisms by which stored water acquires Ra isotopes. Major element concentrations of recovered water largely resembled recharged water, while Ra activities exceeded the Ra activities of the recharged water. $^{224}Ra$ reached ~100 mBq/L during the first 8 hours of recovery (overall range 15.5-133 mBq/L). $^{226}Ra$ and $^{228}Ra$ also increased during the 47-day recovery period (23.7-82.5 mBq/L and 33.7-85.5 mBq/L, respectively). Ra isotope ratios indicate the relative contribution of alpha recoil vs. chemical processes (e.g. adsorption/desorption). During recovery, the $^{224}Ra/^{228}Ra$ and $^{228}Ra/^{226}Ra$ ratios declined, approaching their expected limiting values near unity. Collectively, the rates of Ra activity change with time, trends in Ra isotope ratios, barium concentrations, and manganese concentrations suggest that Ra was governed by chemical processes and alpha recoil, in which the half-lives of each Ra isotope determined the primary mechanism(s) controlling radionuclide mobilization from the aquifer solids. Radium-mobilizing processes during storage may include: (1)