Effects of Naturally Occurring Radium Activity and Activity Ratio Heterogeneity on Derived Water Mass Ages and SGD: Lessons Learned from Nueces Bay, Texas

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ABSTRACT

Numerous studies have used naturally occurring radium isotopes (^{223}Ra, ^{224}Ra, ^{226}Ra, and ^{228}Ra) to quantify water mass ages (i.e., time elapsed since water sampled departed its source where its age is zero [0]), coastal mixing rates, and submarine groundwater discharge (SGD); however, there is much variability in the Ra isotope activity and the derived activity ratios (AR) due to natural heterogeneities that result in a wide range of groundwater Ra concentrations. Therefore, estimates of Ra endmember activities and ARs are complicated by selection of sampling locations (both spatially and vertically) and direction of groundwater flow paths. Application of average groundwater ARs, as is common practice, may obscure accurate estimates of SGD rates and sources. Additionally, surface water Ra sources to coastal embayments are also used to assess water mass ages relative to surface inflows. With no SGD and a single surface water source mass ages are expected to decrease offshore as the short-lived Ra decays, thus ages younger than the identified source (i.e., surface water) indicate an alternative or additional source of Ra. To assess radium constraints on water mass ages and SGD, 16 wells were sampled around Nueces Bay, Texas, and 15 stations were sampled quarterly for two years in Nueces Bay and Nueces River. SGD calculations were based on ^{226}Ra activities as well as continuous radon (^{222}Rn) in water measurements conducted using a RAD–7 continuous radon gas monitor and time-lapse electrical resistivity imaging. Nueces Bay exhibits some of the highest dissolved radium activities observed (295–1102 dpm/m^3 seasonal mean ^{224}Ra and 348–983 dpm/m^3 seasonal mean ^{226}Ra) in coastal waters despite being in a semi-arid region with inconsistent surface water inflows. The surrounding groundwater contains large variations in ^{224}Ra (78.7 to 15,199.7 dpm/m^3) and ^{226}Ra (5483.9 to 344,389 dpm/m^3) activities and ARs (0.00144 to 0.52432). Such large variations in activities and ARs significantly impact derived water mass ages and SGD estimates, demonstrating the necessity to further constrain radium source terms. Time-lapse electrical resistivity imaging shows promise in differentiating between shallow, deep, and recirculated SGD sources and helped constrain the radium endmember used for quantifying SGD and estuarine water masses.

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