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In-Situ Radionuclide Transport Near the Nopal I Uranium Deposit at Peña Blanca, Mexico: Constraints from Short-Lived Decay-Series Radionuclides

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For nuclear waste management, an important mechanism by which radioactive waste components are isolated from returning to the human environment, the biosphere, is by the geological barrier in which the effectiveness of the barrier is characterized by in-situ retardation factor, i.e., the transport rate of a radionuclide relative to that of groundwater. As part of natural analog studies of the Yucca Mountain Project of the U. S. Department of Energy, we propose such characterization by using naturally-occurring decay-series radioisotopes as an analog. We collected large-volume (>1000 liters) groundwater samples from three wells (PB, Pozos, and PB4, respectively) near the Nopal I Uranium Ore site at Peña Blanca, Mexico, by using an in-situ Mn-cartridge filtration technique for analysis of short-lived decay-series radionuclides. Results show that the activities of short-lived radioisotopes (^{228}Ra , ^{224}Ra and ^{223}Ra) and activity ratios of $^{224}\text{Ra}/^{228}\text{Ra}$ and $^{224}\text{Ra}/^{223}\text{Ra}$ are higher at PB and Pozos than at PB4. In contrast, the ^{210}Po activity is much lower at PB and Pozos than at PB4. The high Ra activities and activities ratios at PB and Pozos are attributable to the high alpha-recoil input from the aquifer rocks, while the high ^{210}Po activity at PB4 is due to the enhanced colloidal transport. Based on a uranium-series transport model, we estimate that the in-situ retardation factor of Ra is $(0.43 \pm 0.02) \times 10^3$ at PB, $(1.68 \pm 0.08) \times 10^3$ at Pozos, and $(1.19 \pm 0.08) \times 10^3$ at PB4 and that the mean fracture width in the aquifer rocks is about 0.23 μm at PB, 0.37 μm at Posos, and 4.0 μm at PB4, respectively. The large fracture width at PB4 as derived from the model provides an additional evidence to the inference from the ^{210}Po measurements that particle-reactive radionuclides are transported mainly as colloidal forms through the large fractures in rocks. Our model also suggests that in addition to alpha recoil, decay of ^{226}Ra from the adsorbed phases also contributes a significant source of ^{222}Rn to groundwater. It appears that the information obtained from this study provides useful testing and validation for the Yucca Mountain total system performance assessment model (TSPA).