Uranium Elemental and Isotopic Constraints on Groundwater Flow Beneath the Nopal I
Uranium Deposit, Peña Blanca, Mexico

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The Nopal I uranium deposit in Chihuahua, Mexico, is an excellent analogue for evaluating the fate of spent fuel, associated actinides, and fission products over long time scales for the proposed Yucca Mountain high-level nuclear waste repository. In 2003, three groundwater wells were drilled directly adjacent to (PB-1) and 50 m on either side of the uranium deposit (PB-2 and PB-3) in order to evaluate uranium-series transport in three dimensions. After drilling, uranium concentrations were elevated in all of the three wells (0.1-18 ppm) due to drilling activities and subsequently decreased to ~5-20% of initial values over the next several months. The $^{234}\text{U}/^{238}\text{U}$ activity ratios were similar for PB-1 and PB-2 (1.005 to 1.079) but distinct for PB-3 (1.36 to 1.83) over this time period, suggesting limited mixing between groundwater from these wells over these short time and length scales. Regional groundwater wells located up to several km from the deposit also have distinct uranium isotopic characteristics and constrain mixing over larger length and time scales.

We model the decreasing uranium concentrations in the newly drilled wells with a simple one-dimensional advection-dispersion model, assuming uranium is introduced as a slug to each of the wells and transported as a conservative tracer. Using this model for our data, the relative uranium concentrations are dependent on both the longitudinal dispersion as well as the mean groundwater flow velocity. These parameters have been found to be correlated in both laboratory and field studies of groundwater velocity and dispersion (Klotz et al., 1980). Using typical relationships between velocity and dispersion for field and laboratory studies along with the relationship observed from our uranium data, both velocity (1-10 m/yr) and dispersion coefficient ($1\text{E-}5$ to $1\text{E-}2 \text{ cm}^2/\text{s}$) can be derived from the modeling. As discussed above, these relatively small flow velocities and dispersivities agree with mixing considerations derived from the $^{234}\text{U}/^{238}\text{U}$ data. While these results and the limited productivity of these wells consistently suggest limited groundwater flow and mixing, we anticipate additional work with artificial tracers to better establish groundwater flow velocities and gradient at this site.