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Mountain-Scale Transport of Radioactive Solutes and Colloids Through the Unsaturated Zone of Yucca Mountain, Nevada

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The US Department of Energy is investigating the technical feasibility of permanent disposal of high-level nuclear waste in a repository to be situated in the unsaturated zone (UZ) at Yucca Mountain (YM), Nevada. The objectives of this study are to evaluate the transport of radioactive solutes and colloids under ambient conditions from the potential repository horizon to the water table and to determine processes and geohydrologic features that significantly affect radionuclide transport. The radionuclide transport model considers the site hydrology and the effects of the spatial distribution of hydraulic and transport properties in the fractured rock units of the YM subsurface. Several radionuclides (Tc, Np, U, and Pu) with varying properties are investigated. The results of the study indicate that the most important factors affecting radionuclide transport are the subsurface geology and site hydrology, i.e., the presence of faults (they dominate and control transport), fractures (the main migration pathways), and the relative distribution of zeolitic and vitric tuffs. Radioactive decay, diffusion from the fractures into the matrix, and subsequent sorption (for solutes) or filtration (for colloids) onto the matrix are the main retardation processes. For radioactive solutes, arrival times at the water table are directly correlated with the sorption distribution coefficients of the various species, and are also affected by the decay daughters of certain radionuclides. Changes in future climatic conditions can have a significant effect on transport, as increasing infiltration leads to faster transport to the water table. The transport of colloids is strongly influenced by their sizes (as it affects diffusion into the matrix, straining at hydrogeologic unit interfaces, and transport velocity) and by the fracture attributes. This study presents the relative importance of the processes, mechanisms, and geologic features that significantly affect transport in the unsaturated zone.