UNCERTAINTY ASSESSMENT OF TRITIUM TRANSPORT IN A NUCLEAR-STIMULATED LOW-PERMEABILITY NATURAL GAS RESERVOIR

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The U.S. Department of Energy (DOE) and its predecessor agencies conducted a program in the 1960s and 1970s that evaluated technology for the nuclear stimulation of low-permeability natural gas reservoirs. One of projects in the program, Project Rulison, was located in west-central Colorado. A nuclear device was detonated 2,568 m below the land surface in 1969, and a suite of radionuclides were released. Most of the radionuclides are contained in the melt associated with the vaporization and subsequent condensation of nearby rock. Of the mobile gas-phase radionuclides released, tritium migration in the subsurface from detonation point is of the most concern to the environment.

The objective of this work is to estimate travel distance of tritium in both gas and liquid phases under current environmental conditions as well as conditions in which a hypothetical gas production well is located within the domain. A three-dimensional geologic model was developed that includes interbedded sandstone and shale. A conceptual flow and transport model was developed to investigate the rates of tritium transport in the subsurface away from the chimney. The geologic and conceptual models were implemented in the numerical simulator TOUGH2, which solves for two-phase flow of gas and liquid, as well as transport of a component in both phases. The simulator allows for partitioning between phases as well as radioactive decay.

Due to the sparse data describing the highly heterogeneous subsurface rocks, significant uncertainty exists in the geologic and conceptual models of tritium transport. One source of uncertainty is a lack of knowledge regarding the true spatial relationships of sandstone bodies in the subsurface and the location and permeability of natural fractures in those sands.

Additional significant uncertainty is introduced by lack of knowledge regarding the extent of potential hydrofractures from a production well, and the hydrofracture permeability, a limitation compounded by the hypothetical nature of the simulated production well.

Propagation of the uncertainty to model results was assessed to facilitate decision making. A Monte Carlo method was used to assess the uncertainty. Multiple equiprobable realizations of sandstone and shale were generated using the transition probability method. Permeability and porosity distributions of sandstone were developed based upon the statistics determined from cores. Distributions were also developed for fracture permeability and hydrofracture length. These random variables were combined into 500 model realizations, and each realization was simulated to determine the most likely length and time scale of tritium transport away from the chimney.

Results show that under the current conditions without production, transport is controlled by gas diffusion and radioactive decay. During the hypothetical gas production period, transport was enhanced by the pressure gradient induced by the production well. Results of the Monte Carlo simulations suggest that the hypothetical production well will capture tritium at the 50th percentile. The effect of uncertainty can be seen in the magnitude of mass breakthrough which varies by almost two orders of magnitude between the 50^{th} and 95^{th} percentiles.

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