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Intermediate-scale experimental study and modeling of effects of caprock fracturing on brine contamination of shallow aquifers during storage of CO2 in deep saline geologic formations

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Brine leakage resulting from induced fractures during CO2 storage in deep geologic formation from pressure buildup during injection or existing faults in the far field risk contamination of the shallow aquifers used for drinking and other economic activities. Our past investigations studied the effects of uncertainties in the hydraulic parameters of the storage zone on the plume development and methods for optimal monitoring of leakage and pressure release through brine extraction. One of the main challenges in validating such methods is the unavailability of field data, as no such events have occurred. In our past and ongoing research, for these types of problems, we have used intermediate-scale testing systems where some field complexities can be mimicked to generate high spatially and temporally resolved data under highly controlled laboratory environments. This paper presents a study of the effects of uncertainties of the caprock fractures on brine plume development using this approach. A novel intermediate-scale testing system was developed to couple a fractured caprock to a geologic formation with two overlaying aquifer layers representing the shallow and intermediate zones over the caprock. The fracture network was designed using predefined geostatistical parameters, and a realization of the random network was etched into a plexiglass sheet. The etched channels were filled with sand to obtain the needed transmissivities to create a hydraulic leakage pathway. By injecting tracers at four different fracture initiating points, it was possible to activate different leakage pathways and plume configurations. The 1.3m x1.3m fracture zone was hydraulically connected to the eight-meter-long soil zone with the shallow and intermediate aquifer layers. The aquifer was packed with six well-characterized test sand types to create spatially correlated random fields for the two zones with different mean and variance of the log hydraulic conductivities. Bromide was introduced as a tracer representing the leaking brine, and the plume along the intermediate stratigraphic zone was tracked through aqueous sampling. Aqueous sampling in the shallow zone was performed using a high spatial resolution grid with 448 ports. The data collected for four leakage scenarios were used to validate and verify a new numerical model that couples the fracture and the aquifer zones to simulate the migration of the leakage plume. The model was used to conduct the uncertainty analysis by varying the parameters of the fracture zone represented as an equivalent porous medium. This paper presents the experimental system design, the coupled model, and the results from the uncertainty analysis.

Participation

In-Person

References

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