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Leakage Detection and Characterization to Accommodate Safe Storage of CO2 in Saline Aquifers

Mehdi Zeidouni, Mehran Pooladi-Darvish, David Keith
University of Calgary, Calgary, AB, Canada

Geological storage of carbon dioxide provides the possibility of maintaining access to fossil energy while reducing emissions of carbon dioxide to the atmosphere. One of the essential concerns in geologic storage is the risk of CO2 leakage from the storage formations. Leakage may occur through natural geological pathways such as faults and fractures or it may occur through human-created pathways such as existing wells. Current leakage detection methods are either based on core sample or geophysical measurements. Flow based systems have the potential for bridging the large gap that exists between these two methods.

We develop an analytical model to obtain the pressure at the monitoring aquifer in response to the leakage from the storage aquifer. The two aquifers (storage and monitoring) are separated by an aquitard and are in communication through a point source/sink leakage pathway. We consider a single-phase 1-D radial flow system in the storage and monitoring aquifers. For each aquifer the diffusivity equation is written and solved along with its relevant initial and boundary conditions. Both the aquifers are considered as homogeneous, isotropic, and infinite-acting with constant thickness. The reservoir fluid is single-phase and slightly compressible, having constant compressibility and viscosity. The injection (or production) rate is taken as constant.

Given a complete description of the aquifers and the leak, we can predict the pressure response due to leakage. The reciprocal situation, using the pressure measurements to infer the values of the leakage parameters, corresponds to the ‘inverse modeling problem’. The analytical model is used for sensitivity analysis to better understand the relationship between different parameters and the pressure response. The leakage parameters include: leakage pathway permeability, the distance from the leak to the monitoring well, and the distance from the leak to the injection well. We discuss the possibility of inferring the leakage parameters from the pressure response given over a specified time span. Based on the dimensionless groups obtained in the analytical solution we present criteria under which the leakage detection and characterization is possible.