Framing Monitoring Needs to Detect Leakage from Wells to the Overburden

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Abstract

We have conducted 1000 simulations of CO\textsubscript{2} and brine leakage, driven by pressure changes in a compartmentalized storage reservoir, along a legacy well. The simulation results, which sample the heterogeneity and uncertainty in the storage system, are used to bound detection thresholds and frame monitoring strategies. Specifically, we use the synthetic data set to bound range of fluxes that would need to be detected along a well to identify and mitigate chronic leakage. We test the notion that monitoring directly above the primary cap rock provides early detection by analysing the changes in groundwater chemistry as a function of depth and time.

The geologic model is based on characterization of a potential storage site near Kimberlina, California. The storage reservoir is overlain by a series of stratigraphic units of varying permeability with multiple wells that penetrate the overburden and the storage reservoir [1]. The pressure and CO\textsubscript{2} saturations resulting from CO\textsubscript{2} injection into an idealized compartmentalized reservoir were used to drive leakage along the wellbore (note that the actual reservoir is thought to be an open system with minimal pressure build up [2]). Estimates of leakage along the well is conservative, sampling a fixed permeability for each simulation not accounting for the ability of the damage zones to seal in response to chemical and mechanical deformation [3]. The model of the overburden consists of two impermeable and four permeable strata.

In contrast to past work [4-5], where leakage occurred at a single source point, leakage in these simulations is distributed along the length of the well. The distribution along the length of the well is an outcome of physics based simulations of the wellbore and is not conceptual design. Distribution of CO\textsubscript{2} and brine flux along the length of the well results in changes in groundwater chemistry for all of the overlying permeable units at roughly the same order of magnitude. Permeability of any one unit is not great enough to serve as a sink for the cumulative leakage. This is particularly true for the formation directly above the primary cap rock. Permeability of the sandstone strata directly above the caprock would not be an effective thief zone for CO\textsubscript{2} and brine leakage because the permeability is too low to accommodate the leaking fluids. As a result, the dominant changes in water chemistry occur at the more permeable units closer to the ground surface. This finding stresses the importance of not only monitoring aquifers directly above the cap rock, but also monitoring all permeable units to increase the likelihood of detecting and mitigating a leak as soon as possible. It is also important to detect leakage within the legacy well itself. CO\textsubscript{2} injection into a compartmentalized reservoir that allows pressure build up for long periods of time yielded median fluxes along the well that were $\sim$$10^6$ t/m\textsuperscript{2}/a for both brine and CO\textsubscript{2}. These fluxes are comparable to those measured at abandoned wells in natural CO\textsubscript{2} reservoirs and volcanic activity.
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References


