Post-Closure Buoyancy-Driven Leakage of Sequestered CO2 Along Fault Zones

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Site selection studies for CO2 sequestration focus on identifying storage reservoirs with continuous, unfaulted confining zones. During long-term post-closure care of sequestered CO2, there is potential for unanticipated migration directions of the CO2 plume to occur resulting from spill-point breaching or incompletely characterized structure of the reservoir. Unanticipated migration can pose risks for the CO2 plume to contact and undergo buoyancy-driven leakage along mapped and undetected faults in the vicinity of the sequestration site.

At reservoir conditions of 1 to 2 km depth, supercritical-phase CO2 is buoyant relative to formation water. Buoyancy-driven flow along a transmissive fault can be calculated with the Darcy equation with near-hydrostatic pressure distribution (absence of pressure-driven flow) from the density difference between the supercritical CO2 and the formation water, the intrinsic permeability of the fault zone, and the viscosity of the CO2 phase. The ranges of Darcy velocities (volume fluxes) have been estimated for flow along moderate-sized fault zones with lengths of 0.5 to 5 km, fault-zone widths of 1 to 10 m, and displacements of 10 to 100 m. For transmissive faults with intrinsic permeabilities of 5 x 10-15 to 5 x 10-14 m2 (5 to 50 md), the Darcy velocities of buoyant flow could range from 10 to 100 m3/m2/yr and result in mass flow rates of 3,000 to 300,000 metric tons of CO2 per year (0.5-km fault case) to 300,000 to 3 million metric tons of CO2 per year (5-km fault case).

These estimated CO2 mass flow rates could exceed typical containment risk targets that are considered in CO2 sequestration projects (e.g., at least 99% of the total sequestered CO2 to be retained during 1,000 years of post-closure conditions). For commercial-scale sequestration projects with total masses in the 100 to 300 million metric ton range, the containment risk target could be exceeded in time frames from less than one year to on the order of 1,000 years based on the estimated fault leakage rates. The risk of buoyant leakage of CO2 along faults can be managed by more accurate detection and characterization of faults in the sequestration site area and by better constraining the potential long-term directions of CO2 plume migration.