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The impact of horizontal groundwater flow on the dissolution of CO2 in saline aquifers

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The dissolution of supercritical CO2 in aquifer brine is one of the most important trapping mechanisms in CO2 geological storage. As supercritical CO2 is less dense than the ambient groundwater, the injected CO2 is susceptible to leakage in case that the sealing layer is not perfectly impermeable. However, when CO2 is dissolved in water it is not buoyant anymore. In fact, CO2-saturated water is slightly heavier than CO2-free water. This situation where CO2-free water is overlaid by heavier CO2-rich water, leads to a hydrodynamic instability in which fingers of dense CO2-rich water are formed and propagate downwards, causing the CO2-free water to move upwards [1,2]. This convective process accelerates the dissolution rate of CO2 into the aquifer water.

The majority of previous studies assumed there is no natural groundwater flow in the aquifer and neglected the associated hydrodynamic dispersion and therefore assumed there is no effect on the dissolution dynamics. However, it was found that in some of the saline aquifers considered for CO2 storage groundwater flow rate, although small, is not zero [3]. A few studies investigated numerically the effect of groundwater flow and dispersion on dissolution dynamics [4,5] but no experimental evidence was provided yet.

In this research, we study the effect of groundwater flow on dissolution trapping by performing laboratory experiments and conducting numerical simulations. Experiments were performed in a physical aquifer model using a mixture of methanol and ethylene-glycol (MEG) as a CO2 analog while varying the water horizontal flow rate. Simulations were then carried out to reproduce experimental results. We found that water horizontal flow has a significant effect on the dynamic of the instability and the fingers morphology. As the horizontal flow increases, the number of fingers, their wavenumber and their propagation rate decrease. In high water flow rates, no fingers were developed and the dissolution process was driven by diffusion and dispersion alone. While the classic dissolution behavior, consisting of a diffusive regime followed by a convective regime was clearly observed, the effect of water flow on the dissolution rate did not show a clear picture. When increasing the horizontal flow rate, the convective dissolution flux slightly decreased and then increased. It seems that when horizontal flow rate increases, there is a tradeoff between the decay of instability which suppresses dissolution and the increase in dispersive flux and fresh water inflow which enhances dissolution.

References

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