Low temperature-pressure batch experiments and field push-pull tests: Assessing potential effects of an unintended CO2 release from CCUS projects on groundwater chemistry

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Abstract:

Carbon Capture Utilization and Storage projects (CCUS), where CO2 is captured at point sources such as power stations and compressed into a supercritical liquid for underground storage, has been proposed to reduce atmospheric CO2 and mitigate global climate change. Problems may arise from CO2 releases along discreet pathways such as abandoned wells and faults, upwards and into near surface groundwater. Migrating CO2 may inversely impact fresh water resources by increasing mineral solubility and dissolution rates and mobilizing harmful trace elements including As and Pb. This study addresses the impacts on fresh water resources through a combination of laboratory batch experiments, where aquifer sediment are reacted in their corresponding groundwater in 100% CO2 environments, and field push-pull tests where groundwater is equilibrated with 100% CO2, reacted in-situ in the groundwater system, and pulled out for analyses. Batch experiments were performed on aquifer material from carbonate dominated, mixed carbonate/silicalstic, and siliclastic dominated systems. A mixed silicalstic/carbonate system was chosen for the field based push-pull test. Batch experiment results suggest carbonate dissolution increased the concentration of Ca, Mg, Sr, Ba, Mn, U and HCO3- in groundwater. In systems with significant carbonate content, dissolution continued until carbonate saturation was achieved at approximately 1000 hr. Silicate dissolution increased the conc. of Si, K Ni and Co, but at much lower rates than carbonate dissolution. The elements As, Mo, V, Zn, Se and Cd generally show similar behavior where concentrations initially increase but soon drop to levels at or below the background concentrations (~48 hours). A Push-Pull test on one aquifer system produced similar geochemical behavior but observed reaction rates are higher in batch experiments relative to push-pull tests. Release of CO2 from CCUS sites into overlying aquifer systems may adversely impact groundwater quality primarily through carbonate dissolution which releases Ca and elements that substitute for Ca in crystal lattices. Silicate weathering releases primarily Si and K at lower rates. Chemical changes with the addition of CO2 may initially mobilize As, Mo, V, Zn, Se and Cd but these elements become immobile in the lowered pH water and sorb onto aquifer minerals. A combined laboratory batch experiment and field push-pull test in fresh water aquifers overlying CCUS projects will best characterize the response of the aquifer to increased pCO2. The long experimental duration of the batch experiments may allow reactions to reach equilibrium however; reaction rates may be artificially high due to increased mineral surface areas. Field based push-pull tests offer a more realistic water rock ratio and test a much larger volume of aquifer material but the test must be shorter in duration because the high pCO2 water is subject to mixing with low pCO2 background water and migration away from the test well with groundwater flow. A comparison of the two methods best characterizes the potential effects on groundwater chemistry.

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