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Assessing Potential Impacts of CO₂ Upward Migration on Drinking Groundwater Quality at the SECARB Phase III Early Test Site

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1. Introduction

Understanding potential impacts of CO₂ upward migration on underground drinking resources is a critical concern for geologic carbon sequestration. A comprehensive groundwater study has been conducted at the Cranfield shallow aquifer, Natchez, MS—the SECARB Phase III early test site—using a combined approach of laboratory batch experiment, single-well push-pull test, and reactive-transport modeling to assess potential impacts of upward migration of CO₂ on groundwater quality.

- ❖ Located 15 miles east of Natchez, MS
- ❖ Oil field was discovered in 1940s and abandoned in 1960s
- ❖ Injection of CO₂ for EOR conducted since 2008

2. Cranfield shallow aquifer

- ❖ 12 field campaigns for groundwater sampling since August, 2008
- ❖ On-site measurements: pH, temperature, alkalinity, water level
- ❖ Lab analysis: Ag, Al, As, Ba, Ca, Cd, Cr, Cu, Fe, K, Mg, Mn, Mo, Na, Pb, Se, Zn, F⁻, Cl⁻, SO₄²⁻, Br⁻, NO₃⁻, PO₄³⁻, TOC, dissolved inorganic carbon (DIC), pH, alkalinity, VOC, δ¹³C of DIC

- ❖ Aquifer sediment mineralogy analyzed using XRD
- ❖ Groundwater chemistry dominated mainly by silicate-mineral weathering

Testing well

- Well was completed with 2" PVC and screened between 180 and 240 ft
- Depth of well: 240 ft to surface
- Depth of water level: 90 ft to surface

3. Batch experiments

- ❖ Conducted to understand responses of groundwater chemistry to CO₂ leakage under laboratory conditions
- ❖ 106 g of sedimentary samples and 420 ml groundwater from Cranfield shallow aquifer
- ❖ Bubbled with Ar for a week, then with CO₂ for ~half year

- ❖ Pros: easy to do, low cost
- ❖ Cons: disturbed conditions

4. Single-well push-pull test

- ❖ Injection phase: inject CO₂-saturated groundwater into target aquifer
- ❖ Resting phase: let injected water react with aquifer sediments
- ❖ Pulling phase: pump groundwater continuously to collect water samples

- Implementation:
- ❖ Injection started : ~3,825 L water over 8 hours
 - ❖ Resting phase: ~55 hours
 - ❖ Pumping phase: ~15,142 L groundwater pumped out over ~11 hours

Water samples

- ✓ IC analysis
- ✓ ICP-MS analysis
- ✓ DIC and stable carbon isotope of DIC

Onsite measurements

- ✓ pH, alkalinity
- ✓ conductivity
- ✓ temperature

5. Reactive-transport modeling

- ❖ In order to interpret the batch experiment and the single-well push-pull test in the field, we used a reactive-transport model for simulating groundwater flow and solute transport coupled with geochemical processes. The reactive-transport model consists of two sub-models: a model of groundwater flow and solute transport, and a geochemical model.
- ❖ Groundwater-flow and solute-transport model: radius of the model domain is 25 m, and thickness is 7 m. The top and bottom boundaries are assumed to be no-flow boundaries. Groundwater was injected into the aquifer through the testing well during the injection phase and pumped out during the pulling phase.
- ❖ Geochemical model: simulates geochemical processes (aqueous complexation, mineral precipitation/dissolution, cation exchange reactions, and adsorption/desorption) in the batch experiment and the push-pull test.

- ❖ For this study we used CORE2D V4, a code for modeling partly or fully saturated water flow, heat transport, and multicomponent reactive solute transport under both local chemical equilibrium and kinetic conditions.

6. Results

Laboratory Scale

Mobilization of trace metals dominated by two mechanisms:

1) Dissolution of carbonates such as Ba, Mn, Sr

■ Dissolution of carbonates

2) Desorption/adsorption of metals such as As, Pb

■ Dissolution of silicates

Field Scale

Mobilization of trace metals

■ Dissolution of carbonates

■ Dissolution of silicates

7. Concluding remarks

- ❖ Results of batch experiments, the field controlled-release test, and numerical modeling show that DIC and pH are sensitive to CO₂ leakage and may be used for detecting CO₂ leakage at the Cranfield shallow aquifer.
- ❖ Dominant geochemical processes for ion mobilization may include dissolution of carbonates and silicates and desorption/adsorption from clay surfaces.
- ❖ No obvious degradation in groundwater quality was observed in the batch experiments and the field test.
- ❖ Maximum concentrations of trace metals measured, such as As and Pb, are much smaller than EPA-specified contamination levels.
- ❖ The single-well push-pull test appears to be a convenient field-scale controlled-release test for assessing potential impacts of CO₂ leakage on drinking groundwater resources.
- ❖ The combined use of laboratory batch experiments, field-scale controlled-release tests, and reactive-transport models provides a comprehensive evaluation of potential impacts of CO₂ leakage on groundwater chemistry.