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Formation Fluids-CO₂-Sediment Interactions: Minimizing Environmental Impacts of CO₂ Storage

Yousif K. Kharaka¹, David R. Cole², Thomas D. Bullen¹, and Susan D. Hovorka³

¹U.S. Geological Survey, Menlo Park, California, USA

²Oak Ridge National Laboratory, Oak Ridge, Tennessee, USA

³Bureau of Economic Geology, University of Texas, Austin, Texas, USA

Carbon dioxide capture, transport and sequestration, especially its geologic storage, is now considered one of the necessary options to stabilize atmospheric CO₂ levels and global temperatures at values that are considered acceptable for society and the environment. To investigate the potential for the storage of CO₂ in deep saline aquifers, we participated (2004-2008) in the multi-laboratory Frio Brine Pilot I and II tests near Houston, Texas, where 1600 and 300 tons of CO₂ were respectively injected into the Frio C and Frio Blue sandstones at a depth of about 1500 m. Approximately 200 brine and gas samples were collected from the injection well and an observation well located 30 m updip before, during and after CO₂ injections, using a variety of tools and methodologies. The samples were subjected to detailed organic and inorganic chemical and isotope analyses of brine, associated gases, and added tracers.

Geochemical results proved powerful tools in: 1- Tracking the successful injection and flow of CO₂ in the reservoirs ; 2- showing that injected CO₂ was not detected close to the ground level, but some was detected in the overlying B sandstone that is separated from the C sandstone by 15 m of shale and siltstone; 3- showing mobilization of metals, including Fe (from 30 to 1100 mg/L), Mn and Pb, and organic compounds (DOC from about 5 to 700 mg/L), including BTEX, PAHs, and phenols following CO₂ injection; and 4- showing major changes in chemical and isotopic compositions of formation water , including a dramatic drop in calculated brine pH, (initially from 6.3 to 3.0) and major increases in alkalinity (from 100 to 3000 mg/L as HCO₃). Geochemical modeling, chemical data and Fe isotopes indicate rapid dissolution of minerals, especially calcite and Fe-oxyhydroxides, and that part of the Fe and other metal increases were caused by corrosion of well pipe. Results indicated that contamination from lubricants was not the source for the high DOC values, but they likely represent a ‘slug’ of organic matter mobilized by the injected supercritical CO₂, that is a very effective solvent for hydrocarbons. In addition to metals and other inorganic chemicals, mobilization of BTEX, PAHs and other toxic organic compounds should be monitored to detect their initial escape from the injection formation, and to prevent their accumulation in overlying potable groundwater.

Significant isotopic and chemical changes, including the lowering of pH, increases in alkalinity, mobilization of metals and detection of BTEX, were also observed in samples obtained from shallow (depth of ~2 m) groundwater following CO₂ injection through a slotted pipe placed horizontally at a depth of ~2 m in the ZERT site, Bozeman, Montana. Results from both the deep and shallow field tests show that geochemical methodologies have highly sensitive chemical and isotopic tracers for tracking changes resulting from water-CO₂-sediment interactions; these methodologies, are recommended for CO₂ injection sites to monitor injection performance, and for early detection of any CO₂ and brine leakages.