ABSTRACT

A primary concern of Carbon Capture and Storage (CCS) is leakage of the stored carbon dioxide (CO₂) from the subsurface back to the surface. To ensure long term storage of the CO₂, mitigation strategies to seal high permeable regions, such as fractures present in the caprock or the near wellbore environment, are being developed. Microbial induced calcium carbonate precipitation (MICP) is a widely investigated technology utilizing the enzymatically driven process of ureolysis to alter porous media. The advantage of this technology over traditional fracture sealing methods, such as well cement, is the use of low-viscosity aqueous fluids enabling access to smaller fractures in a larger radius. However, CCS reservoirs provide a problematic environment for microbial activity due to the acidy of dissolved CO₂, high pressures, and elevated temperatures. A flow-through pressurized reactor experiment and batch high-pressure ureolysis rate experiments were conducted to investigate the application of MICP technology to mitigate CO₂ migration.

First, MICP was induced in a composite rock core in an environment simulating a CCS reservoir, using a novel high-pressure axial flow reactor, with an initial and final carbonated brine soak. As a result of MICP, the apparent permeability of the rock core was reduced by 5-orders of magnitude. The CO₂ challenge increased apparent permeability by 4-orders of magnitude, likely due to a preferential flow path created through the calcium carbonate (CaCO₃) seal, which was found with µ-CT imaging. The porosity of the composite rock core was assessed throughout the experiment with two non-invasive technologies, µ-CT and NMR, both reported a significant decrease in porosity due to MICP and a slight increase after the CO₂ challenge.

Second, ureolysis kinetics were assessed in the presence of a pressurized carbonated brine at the pressures 0-4 MPa. The kinetic studies were performed in a high-pressure batch reactor connected to high-pressure pH and conductivity probes. Samples could not be taken from the batch reactor without losing pressure; thus, conductivity was used as a surrogate measurement for urea concentration. It was found that for the pressures tested, ureolysis was capable of overcoming the initial low pH conditions of the carbonated brine and that the ureolysis rate may have been dependent on the pH of the solution.

The combination of these studies suggests that, if the challenge of dissolution could be overcome, bio-mineralization may be used to enhance CCS by reducing CO₂ leakage pathways.