Demonstration and Dissemination of CCS by Supercritical CO2 Flooding of Brine-saturated Carbonate Rock Samples Tests under Sub-Surface Reservoir Formation Temperature, Pressure, and Stress Field Conditions

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This research project responds to an Abu Dhabi initiative of economic growth, diversification, creation of clean technology, and sustainable development. Carbon Capture and Storage (CCS), in sub-surface geological formations, has emerged as the method of choice enabling the continued use of fossil fuels while meeting the stringent worldwide regulations on carbon emissions to the atmosphere by reducing this Green House Gas (GHG) and thus making a considerable contribution to the global warming problem solution. There is, nowadays, wide consensus in the scientific community that CO2 capture and storage in sub-surface geologic reservoirs (e.g. saline aquifers, and depleted oil and gas reservoirs) is the best techno-economically feasible method to reduce CO2 emissions into the atmosphere. The UAE, and due to its fast social and economical growth, has one of the highest carbon footprints per capita in the world. The Abu Dhabi government and especially through an ADNOC/MASDAR collaboration project has established an ambitious plan to capture CO2 from a wide range of the largest carbon emitting industrial plants, and then transporting it through pipelines to inject it for enhanced oil recovery and/or subsurface storage in geological formations. This way, the UAE and especially Abu Dhabi is making itself as part of the solution towards reducing GHG emissions and attaining sustainability instead of being part of the problem with its high carbon footprint per capita.

In this work we will present a Masdar Institute CCS research, demonstration, and dissemination laboratory. The laboratory equipments consist mainly of a tri-axial stress testing machine for carbonate rock samples with brine and super-critical CO2 flooding capabilities under geological formation conditions of temperature, pressure, and stress/strain field, in addition to a Computerized Tomography (CT) with the capability of obtaining time resolved 3D tomographical images of the rock samples within the tri-axial stress testing machine. These machines and techniques produce a real reproduction and demonstration of CO2 injection in geological rock formations for carbon sequestration in sub-surface reservoirs.

Despite the widespread research and development activities across the world on CO2 capture and storage in subsurface geologic formations, there remains some not profoundly investigated fundamental phenomena related to the geo-mechanical and the thermo-chemical effects of super critical CO2 injection in deep saline aquifers. These especially are related to the short and long term behavior of the injected CO2 on the brine saturated target formation, and the induced effects on the cap-rock integrity. The interactions between the injected CO2 and brine flow dynamics and the induced geo-mechanical deformations in the Abu Dhabi host rock formation must be investigated and quantified in order to make reliable predictions of large-scale sub-surface CO_2 storage operations. Due to the fact that large amounts of super-critical CO_2 is to be injected into the host deep saline aquifer formation, one has to understand the complex interactions between the flow, heat, and mass transport phenomena in addition to chemical kinetics in porous media and the local stress and strain fields in and around the storage rock formation. Such interactions can affect the structure and flow properties of the reservoir (e.g. porosity and permeability) in addition to the risk of activating and/or inducing mechanical failures in the storage formation and/or the cap-rock that will result in early CO_2 leakage to the surface of the ground. Thus, experimental studies, on rock samples characteristic of the selected Abu Dhabi target formation and imposed to reservoir conditions (i.e. temperature, pressure, stress field, and participating fluids) are performed to help understand the complex coupling between the transport phenomena and the geo-mechanical deformations in the host formation for CO_2 sequestration. Therefore, our main objective is to create a center of excellence for CCS in Masdar Institute that will foster, demonstrate, and disseminate the CCS technology in Abu Dhabi.

This particular research project focuses on investigating and disseminating two important fundamental physical phenomena related to CO_2 injection and storage in deep saline aquifers formations:

1. The injected super-critical CO_2 forms a fluid gasket between the cap-rock and the brine saturated host rock formation. When the CO_2 dissolves in the brines, the CO_2/brine mixture has a higher density than the brine. This will eventually induce density-driven convection fingering downwards thus promoting the trapping mechanisms of CO_2 in the brine and the formation. Several researchers have experimentally observed and analytically and numerically investigated this phenomenon but not under reservoir like conditions. The novelty of our approach is to use Abu Dhabi formation rock samples of the order of 4" diameter (to be able to generate the natural convection fingering) in a tri-axial stress environment, temperature, pressure, and multi-phase fluid conditions that are characteristic of the sub-surface saline aquifers storage conditions. The machine and especially the sample holder are instrumented by several acoustic velocity and electrical resistivity measurement sensors that allow for CT scans of the time evolution of the convection fingers to be observed.

2. The injection of large amounts of super-critical CO_2 in the brine saturated rock formation under its local stress field might induce mechanical failures as fingering cracks that will eventually grow into fractures in the formation. This will represent a considerable risk for early CO_2 leakage to the ground surface. We propose to study this cross over from fingering to fracture under the same sample and reservoir conditions described in item 1 above. The same measurement techniques (acoustic velocity, electrical resistivity, and CT scan) apply in this case too.