An integrated reservoir characterization approach for de-risking CO_2 sequestration in a high CO_2 carbonate field, Sarawak Basin, offshore East Malaysia

Sahriza Salwani Md Shah[1,2], Andreas Busch[2], Sebastian Geiger[2], M Zuhaili Kashim[1], W M Luqman Sazali[1], Zainol Affendi Abu Bakar[1], M Fakrumie Zaidin[1,2], Siti Syareena M Ali[1], Ahmad Ismail Azahree[1], Farhana Jaafar Azuddin[1,2], Ana Widyanita[1], David N Dewhurst[3], Ausama Giwelli[3]

PETRONAS Research Sdn Bhd, Lot 3288&3289, Kwsn Institusi Bangi, Selangor, Malaysia
[2] Heriot-Watt University, Edinburgh UK
[3]CSIRO Energy, Perth, Australia

Global warming due to increasing levels of CO_2 in the atmosphere has been acknowledged worldwide and most countries are currently ratifying the 2015 Paris Climate Agreement as a follow-up of to the 1997 Kyoto Protocol. The Paris Agreement targets a maximum increase in global average temperature of 2ºC by 2030 (IEA, 2017). Fugitive emission from oil and gas operations such as development of high CO_2 gas field contributes to the increasing anthropogenic CO_2 level in the atmosphere and due to that, PETRONAS has been proactively developing an end-to-end solution to manage its greenhouse gas (GHG) emissions.

An estimated ~20 TSCF of non-associated gas is yet to be developed in Malaysia due to high CO_2 contents. A strategic technology pilot project has been set up to mature both surface and subsurface technologies including CO_2 separation and storage technologies which are designed for developing high CO_2 fields. The S field, located approximately 200km offshore Sarawak, was selected as the primary field to test these technologies. The reservoir is a Miocene age carbonate build-up with calcite dominated and overlain by a clay-rich caprock. The carbonate reservoir properties are heterogeneous: porosity ranges from 17% to 40% and permeability ranges from 10mD to 1.3D. The S field has the highest in-situ CO_2 content (~70%) in the region and is characterized by challenging reservoir conditions, with datum temperatures and pressures of 150°C and 350bar. With this high CO_2 content, the S field will be the first CCUS project worldwide for offshore carbonate reservoirs. The in-situ CO_2 storage in the reservoir provides the advantage of no transportation cost, similar to the Norwegian Sleipner field.

Cyclic hydrocarbon production and CO_2 re-injection will be implemented with the start of gas production as well as CO_2 injection planned by the end of 2022. One of the technical challenges in S field pilot project is to understand the impact of fluid-rock interactions following CO_2 re-injection. Although the aquifer is in equilibrium with CO_2-saturated pore fluids for millions of years already, the pilot project, involving raw gas production, separation of CO_2 from CH_4 and re-injection of CO_2 into the water leg of the reservoir, will ultimately increase the CO_2 partial pressure on the long run. This indirectly alters the CO_2 solubility levels and is expected to impact the geochemical equilibrium, hence will increase uncertainties on the reservoir properties, such as porosity, permeability and mineral alteration due to chemical reaction. This can lead to a reduction in storage capacity and degradation of mechanical integrity either in reservoir or in the cap rock.

An integrated experimental design has been developed to study and enhance the understanding of these challenges in order to de-risk possible uncertainties. Prior to that, 200m of carbonate reservoir rock and 20m of shale cap rock has been cored in 2015 during an appraisal well campaign. In addition, samples and information from previous wells have been used to establish a more generic understanding of the field, such as the distribution of mineralogy, porosity and permeability.

Experiments testing is based on identified potential risks and involves geomechanical, petrophysical as well as geochemical and mineralogical laboratory data. Reactive transport and batch experiments have been conducted to evaluate the impact of CO_2-water-rock (CWR) interactions on porosity and permeability as well as rock strength. Assessment on microstructure and micro fabric changes has been done by high resolution imaging. All experiments have been conducted under in-situ reservoir pressure and temperature conditions. Geochemical modelling was conducted using PHREEQC to verify laboratory observations and to perform sensitivity analysis. Findings from laboratory studies will be used as input for model calibration as well as for reservoir model coupling study. From the reservoir scale model, risks can be evaluated and mitigated by incorporation into the field development plan, if necessary. This integrated approach can be used as a guidance and reference for other future high CO_2 fields development projects.