Geochemical Approach to Monitor CO_2 Plume Migration

Mohammad Alrowaie, Ranya Algeer, Muhammad Almajid, Zuhair Yousif

Aramco

Abstract

Problem/Objective: Carbon capture and storage (CCS) is one of the most effective solutions for reducing greenhouse gas emissions. CO_2 sequestration and CO_2 enhanced oil recovery (CO_2-EOR) are two major processes that can expose underground rocks to CO_2 The long exposure time of rock surfaces to the CO_2 or CO_2-saturated brines results in petrophysical, geochemical, and geomechanical alterations that affect the macroscopic CO_2 dynamics in the subsurface. Isotope geochemical analysis is beneficial when the objective is to monitor the reactions of CO_2 in the subsurface and to differentiate injected CO_2 from the native CO_2 derived from host rocks and free gases, or both. Experimental/lab work: In this study, several samples were collected and were geochemically compared to different end-members (i.e., atmospheric CO_2, native CO_2 and injected CO_2 to trace the emplacement/migration of the injected CO_2 plume in the carbonate strata. Gas composition analysis of the pressurized gas samples was conducted using gas chromatography. The stable isotopic composition of the gas sample components is measured by GC-IRMS (gas chromatography - isotope ratio mass spectrometry). The precision of the measurements must be ± 0.2‰ for carbon isotopes. Measurements are reported in delta notation as part-per-thousand (‰) variations in atomic $^{13}C/^{12}C$ relative to the VPDB international reporting standard. Results: The results indicate that the CO_2 isotopic values measured from the native CO_2 in the strata are enriched in ^{13}C ($\delta^{13}C$- CO_2 = -3.5‰) for their isotopic composition values. The injected CO_2 is characterized by a depleted ^{13}C ($\delta^{13}C$-CO_2 = -10‰) value. The produced CO CO_2 gas samples after CO_2 injection compromise of different carbon isotopic values of CO_2 ranging from -8‰ to -10‰. Mass-balance calculations indicate that the produced gases contain 67 to 15% of the injected CO_2 . The vast percentage range of injected CO_2 in the produced samples indicates a variation in the effectiveness of CO_2 displacement. The measurements could also be correlated with other factors contributing to subsurface CO_2 migration within the rock, such as fractures, to better differentiate zones impacted by the CO_2 from unaffected zones. Novelty: The study demonstrates that monitoring the movement of CO_2 in the rock with geochemical and isotopic techniques is an effective and less expensive approach. The isotopic technique aids in determining CO_2 plume expansion, identifying potential preferential flow paths, and conducting long-term time-lapse monitoring in any CO_2 injection.