Monitoring and Surveillance using Geochemical Analysis of Inorganic Fluid Samples in Saudi Arabia

Deena Tayyib, Peter Birkle, Abdulaziz Qasim, Sunil Kokal

Saudi Aramco

Abstract

Saudi Aramco has led an effort in designing and implementing a comprehensive monitoring and surveillance program for the first and largest Carbon Capture, Utilization and Sequestration (CCUS) project, in the Middle East. The key objectives of this program include monitoring the CO_2 migration, its breakthrough, and concentration profiles over time. Geochemical analysis and assessment played a pivotal role in monitoring the CCUS project and was a key part of this program. The comprehensive geochemical monitoring program was implemented to quantify geochemical changes occurring in reservoir fluids during water-flooding and CO_2 injection phases, to study the induced fluid-fluid and fluid-rock geochemical reactions, monitor CO_2 movement, and ensure the securement of CO_2 in the reservoir. 280 water samples were collected over a period of 9 years since the beginning of the project in 2012. The samples were collected from the wellhead of four CO_2 producer wells, the water outlet of a CO_2 -dedicated high-pressure production trap (HPPT), and nine shallow wells near the project area. The analysis and interpretation of the temporal variations of reactive elements (Ca_{2+}, Mg_{2+}, HCO_3^-, $SO_4$2) and conservative parameters (Na^+, Cl^-, TDS) provided a quantitative understanding of geochemical interaction processes between injected fluids, resident reservoir fluids and reservoir rock, that contribute to different CO_2 trapping mechanisms. The mixing of formation water with injected water during WAG cycles seems to be the dominant physical process during WAG. In the specific case of three producers, the arrival of injection fluid was detected almost three years after starting WAG, while one producer was affected at earlier stage. Additionally, chemical processes caused the secondary alteration of produced water composition due to interaction between injected fluids and host rocks. The behavior of aqueous species, such as Mg_{2+}, can be utilized to determine communication strength and sweep efficiency between injector-producer pairs. Deviating geochemical trends for one specific producer well suggest limited hydraulic connectivity to adjacent producer wells. Moreover, geochemical analysis enabled the assessment of sealing attributes for CO_2 sequestration as well as scaling tendencies. An important outcome was the detection of sealing conditions between the reservoir and shallower aquifers, which assures the confinement of CO_2 and sealing attributes between injection intervals and overlying groundwater zones. The study is novel by tracing different CO_2 trapping mechanism (i.e., mineral dissolution and precipitation), mixing processes during water-alternating-gas cycles, sealing attributes for CO_2 sequestration, and scaling tendencies. These processes and properties are essential to calibrate CO_2 reactive transport models for the prediction of a long-term sequestration of CO_2