Simulation Study of Iwanohara Pilot Carbon Dioxide Injection

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Research Institute of Innovative Technology for the Earth (RITE) in cooperation with Engineering Advancement Association of Japan (ENAA) conducted the comprehensive research on geological CO_2 sequestration during 2000-2008, which included a pilot test of CO_2 injection into a deep saline aquifer as one of the main research objectives. Reservoir simulation played an important role throughout this pilot test.

The early studies were performed to examine the technical feasibility of the injection plan, including the optimization of the locations of the three observation wells. As an example of such studies, the study incorporating the interpretation results of the pumping tests at the injection well IW-1 (CO2-1) suggested the need of formation damage removal and reduction of the injection rate to 50 % of the planned rate. Based on these simulation results, acidization was carried out at Well IW-1 and continuous CO_2 injection started in July 2003 at the rate of 20 tons CO_2/day instead of 40 tons CO_2/day originally planned. The actual IW-1 bottom-hole pressure (BHP) was significantly lower than the pre-injection study predicted and hence the injection rate was increased to 40 tons CO_2/day after nearly one year of the low rate injection.

Monitoring during as well as after the continuous CO_2 injection generated various data on the CO_2 injection and migration behavior and the objectives of simulation during these periods were history matching and interpretation of this observed behavior. Among these various observed data, the bottom-hole pressure at Well IW-1 and observation well OB-4 (CO2-4), breakthrough times of injected CO_2 at observation wells OB-2 (CO2-2) and OB-4, and gas saturation changes thereafter, lack of breakthrough at observation well OB-3(CO2-3), distribution of gaseous (=supercritical) CO_2 on the cross-section between OB-2 and OB-3, and so forth. Relative permeabilities and their end points, irreducible water saturation and critical gas saturation in particular, areal permeability variation, vertical permeability, and pore compressibility were principal parameters varied during the history matching.

History matching finally generated a reasonable agreement with the observed data and the final aquifer model was then used to predict the long-term CO_2 migration/storage behavior over a 1000 year period. The prediction results indicated that the supercritical CO_2 exceeding residual gas saturation would move in the up-dip direction but dissolve into formation water within a relatively short distance and the injected CO_2 would essentially remain in the pilot test area and its close vicinity. Thus, the long-term prediction simulation implied safe underground sequestration of the injected CO_2 in Iwanohara.

The foregoing simulation studies made use of the simulator GEM-GHG, which was developed also within the RITE/ENAA's research program by adding to the compositional oil/gas reservoir simulator the functions that account for the phenomena considered important in long-term simulation of geological CO_2 sequestration. Such functions include dissolution and precipitation of rock-forming minerals and fluid outflow from an injection aquifer due to fissure generation in a cap rock and/or fault reactivation.