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Simulation of Low-Salinity Water-Alternating Impure CO_2 Process for Enhanced Oil Recovery and CO_2 Sequestration in Carbonate Reservoirs

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Abstract: This study investigates the combined effects of impurities in CO_2 stream, geochemistry, water salinity, and wettability alteration on oil recovery and CO_2 storage in carbonate reservoirs and optimizes injection strategy to maximize oil recovery and CO_2 storage ratio. Specifically, it compares the performance of pure CO_2 water-alternating gas (WAG), impure CO_2-WAG, pure CO_2 low-salinity water-alternating gas (LSWAG), and impure CO_2-LSWAG injection methods from perspectives of enhanced oil recovery (EOR) and CO_2 sequestration. CO_2-enhanced oil recovery (CO_2-EOR) is an effective way to extract residual oil. CO_2 injection and WAG methods can improve displacement efficiency and sweep efficiency. However, CO_2-EOR has less impact on the carbonate reservoir because of the complex pore structure and oil-wet surface. Low-salinity water injection (LSWI) and CO_2 injection can affect the complex pore structure by geochemical reaction and wettability by a relative permeability curve shift from oil-wet to water-wet. The results from extensive compositional simulations show that CO_2 injection into carbonate reservoirs increases the recovery factor compared with waterflooding, with pure CO_2-WAG injection yielding higher recovery factor than impure CO_2-WAG injection. Impurities in CO_2 gas decrease the efficiency of CO_2-EOR, reducing oil viscosity less and increasing interfacial tension (IFT) compared to pure CO_2 injection, leading to gas channeling and reduced sweep efficiency. This results in lower oil recovery and lower storage efficiency compared to pure CO_2. CO_2-LSWAG results in the highest oil-recovery factor as surface changes. Geochemical reactions during CO_2 injection also increase CO_2 storage capacity and alter trapping mechanisms. This study demonstrates that the use of impure CO_2-LSWAG injection leads to improved oil recovery and CO_2 storage compared to pure CO_2-WAG injection. It reveals that wettability alteration plays a more significant role for oil recovery and geochemical reaction plays crucial role in CO_2 storage than CO_2 purity. According to optimization, the greater the injection of gas and water, the higher the oil recovery, while the less gas and water injected, the higher the storage ratio, leading to improved storage efficiency. This research provides valuable insights into parameters and injection scenarios affecting enhanced oil recovery and CO_2 storage in carbonate reservoirs.

Keywords: impure CO_2; water-alternating gas (WAG); enhanced oil recovery (EOR); low-salinity water; geochemistry; carbonate reservoir; carbon capture; utilization and storage (CCUS)

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