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Comprehensive Smart Water–CO_2 Gas (SWAG) injection study for shaly-sandstone heavy oil reservoirs: Oil Recovery, Pressure Profile and Effluent Ion Composition Studies

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Abstract

One of the easiest and least technically challenging ways of increasing oil recovery from a pressure depleted hydrocarbon reservoir is low salinity water flooding (LSW). Contemporary studies have shown that LSW has the potential to improve oil recovery by 5-12% when initiated in sandstone reservoirs. The use of low-salinity water flooding is also recommended for shaly-sandstones as the salt present in the water mitigates the swelling in shale. However, salt has a tendency to crystallize and this may block pore channels, in effect, reducing oil recovery. Thus, researchers are currently investigating the composition of low salinity water as per need; the resulting injection water is referred to as smart water.

The aim of this study was to investigate the injection of CO_2along with smart water in a depleted oil reservoir. This will sequester away the harmful CO_2in the subsurface. CO_2 lowers the density & viscosity of oil which makes making it easier to flow and improve oil recovery.CO_2 and LSWAG (Low salinity water alternating gas) has a great probability of influencing oil production positively in shaly-sandstones as injected LSW will reduce shale swelling and CO_2 will make the oil flow easily.

All oil recovery experiments were conducted with a synthetic porous media of silica materials of size 200-380 µm. Shale of size 40-60 µm was used in specified quantity to induce shaliness in the sand-pack. The quantity of shale was gradually be increased in the sand-pack till the sand-pack takes the behavior of a shale reservoir (i.e. permeability reduces to less than 1 md). This was followed by the injection of smart water and CO_2 would be carried out in the sand-pack and the resultant oil recoveries were tabulated.

The composition of salts in the smart water was then altered and the resultant oil recovery was noted. To ascertain the role of dissolved ions in the smart water on oil recovery, an ion composition study of the injected water at both the inlet and outlet will be performed and the difference plotted for analysis. From these tests, it became evident that modifying salt concentration has an effect on oil recovery and the resulting smart water injection, improved oil recovery by a margin of 5% of OOIP (original oil in place) when compared to low-salinity water and by 12% over conventional water-flooding.

Gas injection process for more oil recovery and in particular CO2 injection is well-established method to increment oil recovery from underground oil reservoirs. CO2 sequestration which takes place during this enhanced oil recovery (EOR) method has positive impact on reducing the greenhouse gas emission which causes global warming. Direct gas injection into depleted oil reservoirs, encounters several shortcomings such as low volumetric sweep efficiency, early breakthrough (BT) and high risk of gas leakage in naturally fractured carbonate oil reservoirs. Carbonated water injection (CWI) has been recently proposed as an alternative method to alleviate the problems associated with gas injection. In this paper, the results of extensive experimental tests of ultimate oil recovery efficiency as both secondary and tertiary CWI tests and their CO2 storage capacity for an Iranian carbonate reservoir are presented. Besides, the CWI recovery efficiencies are compared with traditional water flooding (WF) test. The results showed that higher ultimate oil recovery is achieved when carbonated water is injected as secondary technique compared to tertiary process. The results showed 40.54% and 56.74% more oil recovery during tertiary carbonated water injection (TCWI) and secondary water injection (SCWI) compared to the corresponding water flooding, respectively. However, the CO2 storage capacities for both TCWI and SCWI cases were almost the same, as it was measured to be more than half of the total delivered CO2.

Low-salinity water flooding (LSW) is a promising new technique for enhancing oil recovery (EOR) in both sandstone and carbonate reservoirs. The potential of LSW has drawn the attention of the oil industry in the past decade. Along with the few successful field applications of LSW, various studies in this field in recent years have been conducted mainly at the lab scale. The main objective of this critical review was to investigate the potential of this EOR technique in improving oil recovery and the mechanism under which it operates. As a result, various mechanisms have been proposed. However, no consensus on the dominant mechanism(s) in neither sandstones nor carbonate reservoirs has been reported, and the oil industry is continuing to discover the leading effects. Herein, we provide the chronicle of LSW, analysis of the

proposed mechanisms of enhancing oil recovery using LSW in recent findings, some laboratory observations, and finally, some successful field applications. From this review, despite the promising potential justified by both laboratory studies and field applications, there exist a large number of unsuccessful field case studies. LSW is viewed as an immature EOR technique with many ambiguities because definitive conclusions about which mechanism(s) is responsible for improving oil recovery remains elusive and bewilderment to the oil industry.