Abstract

Low Salinity Water Flood (LSWF) is a most promising enhanced oil recovery (EOR) method where injection water salinity/ ionic composition is modified to increase both microscopic and macroscopic displacement efficiency in carbonate/clastic reservoirs screened based on temperature, wettability, and potential determining ions (PDI) with the added advantage of reducing reservoir souring to a very large extent along with ease of injections into oil-bearing formations. Conventional liquid-based Enhanced Oil Recovery (EOR) methods struggle in India's western offshore carbonate oil fields due to factors like reservoir heterogeneity, pressure decline, high temperature, and the logistical challenges of an offshore environment. This research explores Low-Salinity Waterflooding (LSWF) as a promising alternative EOR solution to address these limitations and maximize oil recovery. Very few EOR projects have been carried out in offshore environments to date and the majority of the projects have been Miscible Gas Injection Projects.

While demonstrating the success of LSWF in a specific Indian offshore reservoir, this work extends beyond a single case study. It offers invaluable data relevant to the unique challenges faced in Indian offshore environments, including salinity variations, specific mineralogy, and distinct crude oil composition compared to other LSWF applications. This detailed data significantly addresses a critical knowledge gap for LSWF implementation in such settings. The research provides a comprehensive framework, encompassing laboratory studies, field observations, and a first-of-its-kind HPHT evaluation of wettability alteration. Furthermore, it establishes guidelines for screening carbonate reservoirs for their suitability with LSWF. This comprehensive approach offers essential answers for maximizing oil recovery in Indian offshore carbonate reservoirs using LSWF technology.

A multi-pronged approach integrating laboratory experiments, simulations, and field-scale evaluation was employed. Key areas of investigation include the Impact of Brine Composition, Rock-Fluid Interactions & fluid-fluid compatibility.

Experimental components included: compatibility between the injection water and the formation water, as well as the examination of the interactions between fluid/fluid and rock/fluid in carbonate reservoirs, sequential core flood displacement tests at reservoir conditions using low salinity brines to assess the impact of salinity on oil recovery, an Interfacial tension (IFT)study was used to assess the interface between the fluids, while the contact angle and Zeta potential measurements were employed to evaluate the compatibility of the interface between the rock and the fluid, investigation of wettability alteration in an HPHT imbibition cell.

Simulation components considered oil/brine/rock interactions and linked laboratory data to the reservoir.

Laboratory experiments revealed that the Wettability Index and Spontaneous Imbibition (SI) studies serve as effective screening tools for identifying suitable carbonate reservoirs for LSWF. These tests confirmed the occurrence of wettability alteration, where the rock surface became more water-wet. This shift resulted in a significant reduction in residual oil saturation, with recoveries exceeding traditional methods by up to 19 units. Compatibility tests demonstrated the successful use of diluted seawater. Compared to traditional seawater injection, core flood experiments demonstrated a significant 14-20% increase in oil recovery using Low-Salinity Waterflooding (LSWF). Notably, a 25% dilution of seawater proved to be the optimal salinity for this enhanced oil recovery method. Zeta potential measurements indicated a consistent decrease in values towards more negative levels as the seawater became more diluted. Elevating the concentration of $SO4^{2-}$ ions in the brine may lead to more pronounced negative zeta potential values in comparison to a 25% diluted seawater solution. A 1D core flood simulation model with a single porosity was created to adjust the parameters received from the laboratory. The goal was to generate a relative permeability curve for field scale simulation by matching the oil recovery and pressure profiles obtained from core flooding. An adequately accurate history match was achieved.

The field-scale simulation study envisages incremental oil of 1.373 MMt with 35% PV of LSWF which has envisaged additional oil gain of 4.2% of total oil production in the prediction period due to LSWF in field M & an additional 0.86 million metric tons of oil recovery using LSWF for field H. At last, a pathway is developed for implementing LSWF in a carbonate reservoir. Field M exhibited a promising response to LSWF, characterized by increased oil production rates, stabilized water cut, and a significant reduction in produced water salinity. The results of this research also open the gate for the 2nd field application of LSWF in the Western offshore Indian Basin.

Overall, this research presents a novel LSWF/SWF implementation approach for Indian offshore carbonate reservoirs. It significantly contributes to LSWF knowledge by addressing the unique challenges of these environments. The research establishes screening methods, evaluates wettability alteration mechanisms at high pressures and temperatures, and provides guidelines for optimal LSWF implementation.