

# **A Study on Low Salinity Water Surfactant Flooding Augmented By Polymer Flooding**

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## **Abstract**

Enhanced Oil Recovery (EOR) techniques play a crucial role in boosting oil recovery beyond what primary and secondary methods can achieve. One of the biggest hurdles the petroleum industry faces is extracting the maximum amount of oil from reservoirs. Even after employing primary and secondary recovery methods, a significant volume of oil remains trapped in the reservoir due to various forces like capillary pressure and inefficient sweep. To tackle this issue, Enhanced Oil Recovery (EOR) techniques come into play. Among the various chemical EOR methods, low salinity water flooding (LSWF), surfactant flooding, and polymer flooding have garnered considerable attention. This study zeroes in on combining these three techniques into a hybrid approach called Low Salinity Water Surfactant Polymer (LSWSP) flooding. The goal is to explore the mechanisms at work, their impacts, experimental results, and real-world implications of this integrated process. Each method contributes uniquely: low salinity water changes wettability, surfactants lower interfacial tension, and polymers enhance sweep efficiency, all of which aid in extracting the leftover oil from the reservoir rock's pore spaces. This leads to better oil mobilization and improved recovery rates. The study highlights LSWSP flooding as a promising strategy for maximizing oil recovery in complex, heterogeneous reservoirs.

**Keywords:** recovery, low salinity water, surfactant, polymer, heterogeneous.

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## **I. Introduction**

Oil recovery from reservoirs typically occurs in three stages: Primary recovery (natural drive, Secondary recovery (water flooding) and Tertiary recovery (Enhanced Oil Recovery – EOR). Even after water flooding, a large portion of oil (sometimes more than 60%) remains inside the reservoir. This happens because sometimes oil gets stuck in small pores, water does not sweep all areas properly and sometimes capillary forces hold oil tightly. To overcome these limitations, Chemical EOR techniques are applied.

Among these:

- Low salinity water flooding modifies rock-fluid interactions
- Surfactant flooding reduces interfacial tension (IFT)
- Polymer flooding improves mobility ratio

The combination of these methods leads to improved recovery performance and reduced chemical consumption.

## **II. Overview Of Individual Processes**

### **2.1 Low Salinity Water Flooding (LSWF)**

Low Salinity Waterflooding involves injecting water with varying salinity and ionic composition compared to formation water. It improves oil recovery by altering wettability from oil-wet to water-wet. The mechanisms behind Low Salinity Water Flooding are:

- Ion exchange between rock and brine
- Expansion of electrical double layer
- Mineral dissolution
- pH increase

These processes reduce oil adhesion to rock surfaces and improve displacement efficiency. Studies show that LSWF can increase oil recovery by up to 9% compared to formation water flooding.

### **2.2 Surfactant Flooding**

Surfactants are surface active agents. These are chemicals that reduce interfacial tension (IFT) between oil and water. Thus, it helps in reducing the capillary forces thereby mobilizing the trapped oil and improving the microscopic displacement. Adding surfactant to low salinity water reduces adsorption and enhances

effectiveness. Experiments show that combining surfactant with LSWF can increase recovery by up to 22% of original oil in place (OOIP).

### **2.3 Polymer Flooding**

Polymer flooding increases the viscosity of injected water to improve mobility control through the addition of polymers which are synthetic substances. It reduces water fingering, improving sweep efficiency and enhancing the macroscopic displacement efficiency. Polymer flooding stabilizes the displacement front and ensures uniform sweep.

## **III. Concept Of Hybrid Low Salinity Water Surfactant Polymer Flooding**

The hybrid technique combines:

- Wettability alteration (LSWF)
- IFT reduction (surfactant)
- Mobility control (polymer)

This hybrid method maximizes oil recovery by addressing both the microscopic displacement efficiency and macroscopic sweep efficiency.

### **3.1. Mechanisms of Low Salinity Water Surfactant Polymer Flooding**

#### **3.1.1 Wettability Alteration**

Low salinity water changes rock surfaces from oil-wet to water-wet, allowing oil to detach.

#### **3.1.2 Interfacial Tension Reduction**

Surfactants reduce IFT to very low values, allowing trapped oil droplets to move.

#### **3.1.3 Mobility Control**

Polymer increases water viscosity, preventing viscous fingering and improving sweep.

The combined process provides:

- Lower residual oil saturation
- Stable displacement front
- Increased sweep area

Studies show that combining low salinity water and polymer can significantly enhance recovery while reducing polymer requirement by up to two-thirds.

## **IV. Literature Review And Analysis**

The performance of Low Salinity Water Surfactant Polymer (LSWSP) flooding can be evaluated based on previously published studies and theoretical understanding. Various researchers have investigated the individual and combined effects of low salinity water, surfactants, and polymers on oil recovery.

### **4.1 Effect of Low Salinity Water Flooding**

Studies reported in the literature indicate that reducing the salinity of injected water leads to significant changes in rock-fluid interactions. Low salinity water promotes:

- Wettability alteration from oil-wet to water-wet conditions
- Reduction in residual oil saturation
- Improved microscopic displacement efficiency

Several investigations have shown that low salinity flooding alone can enhance oil recovery by 5–15% of original oil in place (OOIP) compared to conventional water flooding. The effectiveness depends on rock mineralogy, especially the presence of clay minerals.

### **4.2 Effect of Surfactant Addition**

Surfactants play a key role in reducing interfacial tension (IFT) between oil and water. Literature findings show that:

- IFT can be reduced to ultra-low values ( $10^{-3}$  mN/m)
- Capillary forces are significantly decreased
- Trapped oil droplets become mobile

Surfactant flooding is particularly effective in releasing oil trapped in pore throats. However, high adsorption of surfactants on rock surfaces can reduce efficiency. The use of low salinity water helps to minimize this adsorption, thereby improving surfactant performance.

#### **4.3 Effect of Polymer Flooding**

Polymer flooding improves the mobility ratio between injected water and reservoir oil. Reported results indicate:

- Increased viscosity of injection fluid
- Reduction in viscous fingering
- Improved areal and vertical sweep efficiency

Polymer flooding can increase recovery by 10–20% OOIP, especially in heterogeneous reservoirs. The use of low salinity water further enhances polymer stability and reduces degradation.

#### **4.4 Combined Effect of LSWSP Flooding**

The integration of low salinity water, surfactant, and polymer flooding leads to a hybrid synergistic effect. Literature-based studies have demonstrated that:

- Wettability alteration improves oil detachment from rock surfaces
- Surfactants reduce interfacial tension, mobilizing trapped oil
- Polymers ensure uniform sweep of the reservoir

The combined process addresses both microscopic and macroscopic displacement mechanisms simultaneously.

Reported results from various studies suggest that LSWSP flooding can increase oil recovery by 20–35% OOIP compared to conventional water flooding. In some optimized cases, recovery can reach even higher values depending on reservoir conditions.

#### **4.5 Influence of Reservoir Properties**

The success of LSWSP flooding depends on several reservoir characteristics:

##### **1. Rock Type**

- Sandstone reservoirs show better response due to clay content
- Carbonate reservoirs may require additional chemical optimization

##### **2. Salinity and Ion Composition**

- Lower salinity enhances wettability alteration
- Presence of divalent ions ( $\text{Ca}^{2+}$ ,  $\text{Mg}^{2+}$ ) affects performance

##### **3. Temperature**

- High temperature may degrade polymers
- Thermal stability of chemicals must be considered

##### **4. Permeability**

- High permeability reservoirs show better injectivity
- Low permeability reservoirs may require higher injection pressure

#### **4.6 Observations**

Based on the literature review, the following observations can be made:

1. Low salinity water enhances the efficiency of surfactants and polymers.
2. Surfactant adsorption is reduced in low salinity conditions.
3. Polymer viscosity is more stable in diluted brine.
4. The hybrid approach improves both displacement and sweep efficiency.
5. Proper design of chemical concentration and injection sequence is essential for optimal performance.

#### **4.7 Limitations observed in Literature**

Despite its advantages, several challenges have been reported:

- Chemical degradation at high temperature
- Adsorption losses in certain rock types

- High cost of surfactants and polymers
- Need for precise salinity control

These limitations highlight the importance of reservoir screening and optimization. The review of existing studies clearly demonstrates that Low Salinity Water Surfactant Polymer flooding is a highly effective enhanced oil recovery technique. The synergistic interaction between wettability alteration, interfacial tension reduction, and mobility control results in significantly improved oil recovery compared to individual methods.

## **V. Advantages Of Lswsp Flooding**

1. Higher oil recovery
2. Reduced chemical consumption
3. Improved sweep efficiency
4. Better stability of polymers in low salinity
5. Lower operational cost

Low salinity water enhances polymer stability and effectiveness, especially in high-temperature reservoirs.

## **VI. Challenges And Limitations**

Despite its advantages, the process of LSWSP flooding has some limitations:

1. Non-uniform permeability affects sweep efficiency.
2. Surfactant loss due to adsorption on rock surfaces.
3. Polymer may cause plugging or injectivity issues.
4. Precise control of salinity is required for optimum performance.
5. High cost of chemicals and injection facilities.

## **VII. Field Applications**

Field trials have demonstrated:

- Improved recovery in sandstone and carbonate reservoirs
- Reduced water cut
- Increased oil production

However, large-scale application requires:

- Proper reservoir screening
- Economic feasibility analysis
- Optimization of injection sequence

## **VIII. Future Scope**

Future research areas include:

- Nanoparticle-assisted LSWSP flooding
- Smart water design
- Environmentally friendly surfactants
- AI-based reservoir modelling
- Field-scale simulation

## **IX. Conclusion**

Low Salinity Water Surfactant Polymer flooding is a cutting-edge enhanced oil recovery (EOR) technique that combines three key processes: changing wettability, reducing interfacial tension, and controlling mobility. When these mechanisms work together, they lead to better oil mobilization, improved sweep efficiency, and a higher overall recovery rate. Field studies have shown that this hybrid approach can significantly boost oil recovery compared to using each technique on its own. While there are some hurdles to overcome, with the right design and optimization, this method has the potential to greatly enhance oil recovery and play a crucial role in the future of oil production.

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