# Optimal Zwitterionic Surfactant Slug for an Improved Oil Recovery in Oil Wet Carbonate Rocks - Silurian Dolomite

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## 1. Introduction

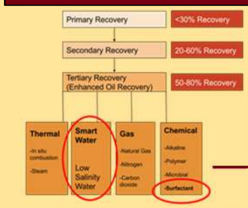



Figure 1 : Recovery Mechanism

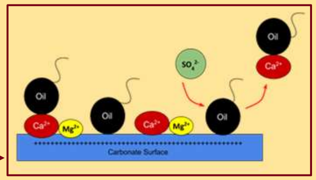



Figure 2 : Rock-fluid interaction

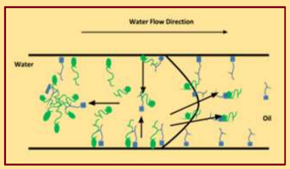



Figure 3: Working mechanism of a surfactant

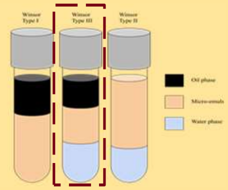


Figure 4 : Microemulsion phase behavior

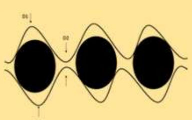


Figure 5: Conventional water flooding

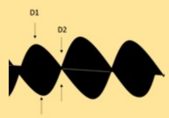
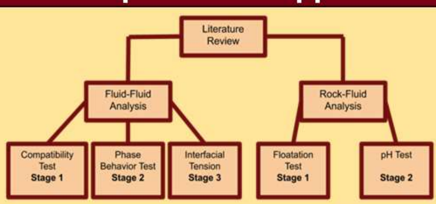



Figure 6: Smart water and surfactant flooding

**Research Question:**

What is the optimal surfactant slug that is required for an improved oil recovery in Silurian Dolomite rock?

## 2. Experimental Approach




| Salts | % Composition |
|---|---|
| NaCl | 62 |
| CaCl2.2H2O | 19.63 |
| Na2SO4 | 1.95 |
| MgCl2.6H2O | 16.3 |
| NaHCO3 | 0.12 |

Table 1: Synthetic Formation Brine composition

**Surfactant:**
1% Chembetaine zwitterionic surfactant

Figure 7: Interfacial Tension measurement

## 3. Results and Discussion

### Phase 1: Fluid-Fluid Analysis

#### Stage 1: Compatibility Test

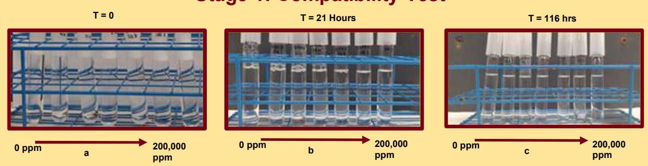



Figure 8: Compatibility Test

#### Stage 2: Phase Behavior Test

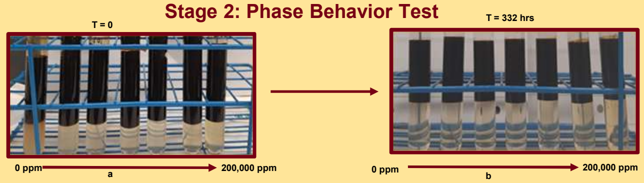



Figure 9: Phase behavior Test

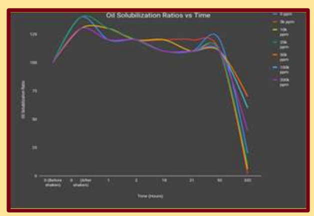



Figure 10: Oil Solubilization ratio vs Time

$$Oil\ Solubilization\ ratio = \frac{V_{oil\ in\ the\ microemulsion\ phase}}{V_{active\ surfactant}}$$

- **Figure 10:** A decrease in the oil solubilization ratio is observed with time.
- The decrease in the oil solubilization ratio is an indication of the reduced activity of the surfactant over time.
- The salinity with the lowest oil solubilization ratio at time 332 hours was 5,000 ppm and the highest for 50,000 ppm.

#### Stage 3: Interfacial Tension Measurements

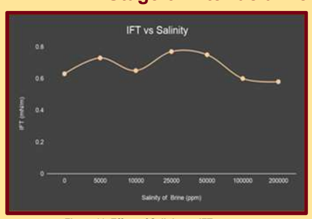



Figure 11: Effect of Salinity on IFT

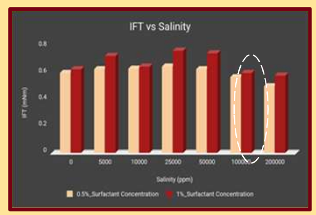


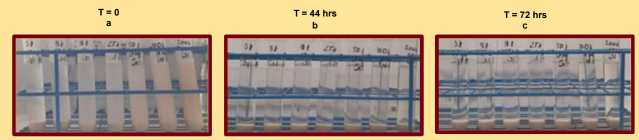

Figure 12: Effect of Surfactant concentration on IFT

- **Figure 11** shows the changes in IFT with salinity.
- There is a non-monotonous behavior of IFT with salinity.
- IFT is lowest at 200,000 ppm brine salinity since there is a competition for solubilization between brine and surfactant.
- Due to the presence of excess ions at high salinity, the surfactant is pushed further towards the oil-brine interface which results in a lower IFT.
- **Figure 12** shows the changes in IFT with surfactant concentration.
- A decrease in surfactant concentration from 1% to 0.5% results in a decrease in the IFT.
- Non of the concentrations yields ultra-low IFT values ($10^{-2}$ and $10^{-3}$ mN/m).

### Phase 2: Rock-Fluid Analysis

#### Stage 1: Floatation Test

Figure 13 (Below): Floatation Test




#### Stage 2: pH Measurements

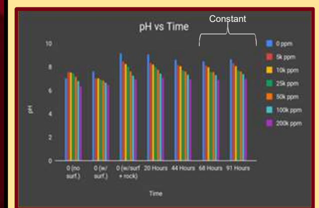



Figure 14: Change in pH with Time

- **Figure 14** shows the results for pH measurements over time.
- With the addition of carbonate rock, there is an increase in the pH
- No change in is seen from 68 hours
- The alkaline pH environment increases the chances of in situ surfactant generation in the reservoir.

## 4. Conclusions and Recommendations

- Based on the fluid- fluid analysis, surfactant retention is likely to occur with the zwitterionic surfactant analyzed.
- Based on the rock-fluid analysis, the zwitterionic surfactant cannot alter the wettability of oil wet carbonate rocks significantly towards more water wet conditions
- The pH of the solution reduces over time but remains at alkaline conditions which could be beneficial in oil recovery
- The concentration of the surfactant used should be further reduced to analyze the concentration and salinity in which the middle phase (Winsor type III) micro-emulsion will occur.
- Optimal surfactant slug in this case is at 10,000 ppm at 1% surfactant concentration

## 5. References

- Zhang, P., Tweheyo, M. T., & Austad, T. (2006). Wettability alteration and improved oil recovery in chalk: The effect of calcium in the presence of sulfate. *Energy & Fuels, 20*(5), 2056-2062.
- Yousef, A. A., Al-Saleh, S., & Al-Jawfi, M. S. (2012). Improved/enhanced oil recovery from carbonate reservoirs by tuning injection water salinity and ionic content. Paper presented at the *SPE Improved Oil Recovery Symposium.*

## 6. Acknowledgements

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