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Effect of Jatropha Bio-Surfactant on Residual Oil during Enhanced Oil Recovery Process

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Abstract

Surfactants are generated in situ during alkaline flooding when the injected alkali react with organic acids in crude oil. This commercial surfactant produced in oil-brine interface, decreases interfacial tension (IFT) leading to additional oil recovery. The aim of this study is to examine the performance of a specific surfactant on oil recovery. These include injection of surfactant (a blend of jatropha seed oil) by performing simultaneous experiments using a reservoir permeability testing equipment (RPT). Core sample flooding experiment was conducted on four core sample samples with different permeability and porosity. The surfactant is flooded through the core sample samples at different pore volumes using RPT as the flooding equipment. The surfactant blend causes foam formation to displace oil from the pores by altering its affinity to the rock and influencing oil/brine interfacial tension. The experiments were performed at ambient conditions. According to the results, the oil recovery noted was over 3% OOIP for the various core sample flooded.

INTRODUCTION

Enhanced oil recovery methods are the various ways of exploiting oil reserves after conventional methods. Additional oil recovery can support the world economy when more oil is produced at the least price. The surfactants are the major component of the injection fluids for EOR applications. Oil recovery methods are the different ways to recover oils either heavy or light oils from the oil reservoirs. Inexpensive alkaline reagents can react with the organic acids in crude oil and form massive amounts of surfactant in situ at the oil/brine interface, by which the interface tension (IFT) can be reduced greatly.

Alkaline surfactant flooding aim to improve oil displacement efficiency through reducing the IFT that exist between the brine and oil when a surfactant is added to the brine and an Alkali is added to the brine to decrease adsorption of the surfactant on the rock pore and ensuring minimal interfacial tension by regulating salinity (Ann Muggeridge., n.d)

Laboratory experiments has shown that surfactant flooding can decrease oil-brine interfacial tension, increase the spreading of oil in brine, restructures oil droplets making so easy to pass pore throat and decrease residual oil saturation.

Discoveries has shown that heavy oils have larger percentage of reactive organic acid in their oils than light oils. Alkaline flooding is more effective in crude oil with higher acidity. To this effect, injection of surfactant in EOR does not base its effectiveness on the acid content of reservoir crude oil. In the present study, several investigations were made to describe the surfactant and alkaline solution in terms of its ability to lower both surface tension and reduce residual oil saturation.

Series of flooding experimental work were carried out to find the further recoveries with surfactant flooding. Langlo, (2013) States that implementation of foam in EOR is been hindered due to lack of understanding of foams behavior and the effectiveness of foams remains unpredictable in the reservoir because of its complex nature.

EXPERIMENT SECTION

Materials

Core sample samples(Sandstone), light crude oil, Reagent grade sodium hydroxide (NaOH), jatropha curcas oil (acid value of 35.8mg KOH/g), Produced brine (Brine), Acetone.

Equipment.

The reservoir permeability tester, Soxhlet extractor, Manual Saturator, Pycnometer, Glass Capillary Viscometer, Desiccator.

Measurement of Physicochemical Properties

Porosity Determination

For ease of porosity calculation, the core sample was measured using experimental methods described below.

1. The bulk volume of the reservoir core sample was calculated through the length and diameter measurement.
2. Remaining water present in core was then oven dried to eliminate moisture.
3. The core sample was positioned in an evacuating chamber and air was removed from the chamber by a vacuum pump. The vacuum pump was operated for about 60 min. After this, Brine was then introduced

into the vacuum tight container and left to totally saturate core sample in the brine solution.

4. The core sample was then removed from the vacuum saturator and weighed.
5. With a known value for density of the brine solution, porosity and was calculated.

Establishment of Porosity and permeability of core sample samples

After saturating the core samples in the brine, the wet weights were measured. A permeability test was conducted on the core samples for absolute permeability of the core sample. Brine was injected into the saturator core samples by the pump at an initial flow rate of 10 cc/min

The absolute permeability was determined from the readings of differential pressure against time.

The porosity and the permeability are calculated and determined.

Flooding Apparatus and Method.

The Reservoir Permeability testing apparatus (**RPT**) built with pressure systems which are: Confining pressure, drive pressure and back pressure was used for core flooding experiment. Confining pressure helps in preventing the treating fluids from escaping through the sides of a core in the core holder and the drive pressure uses a hydraulic fluid to thrust the treating fluids through the core sample. The back pressure keeps the treating fluids from boiling at the test temperature.

During heating, confining pressure and back pressure are applied to the core sample. At test temperature, the Brines pump is switched on and pressure driven liquid is pumped into one of the accumulators. The accumulator contains a gliding cylinder that isolates the pressure driven liquid from the liquid used in treating. As the hydraulic liquid is pumped in, the treating liquid is pumped out and through the core sample. A transducer measures the pressure entering and leaving the core sample. As the experiment proceeds, the flow of pressure can be occupied into any of the three accumulators, taking into attention the testing of different treating liquids. All data is concurrently recorded on a PC.

Core sample flood Setup

The Core sample flood setup consists of three different vessels, filled up with brine, crude oil and surfactant. Each of the vessels had valves on the inlets and outlets to regulate the fluid flow. Fluid was pumped using a high precision pump into one of the vessels at the time, pushing a piston plate inside. From the representations of the core flood setup, all the vessels were linked to a flowline going to the core holder. To prevent the flow of fluid between the sleeve and the core sample, A constant confining pressure was applied in the core holder.

All the tests were done within ambient conditions and differential pressure was measured across the core sample holder. Measurements were taken every 1 minute, and were continued for all the flooding phases. Using differential pressure against time plots were important to investigate surfactant in the core sample. An increasing pressure during the surfactant flooding would indicate that the permeability had been reduced.

Table 1: Determination of porosity for all the core samples

Core sample	Length (cm)	Diameter (cm)	Bulk volume	Wet weight (g)	Dry weight (g)	Pore volume (cc)	Porosity (%)	Absolute K(md)
core 1	4.4	3.5	42.33845	108	98	9.259	0.219	129.7
core 2	4.1	3.3	35.0717895	103	94	8.333	0.238	50
core 3	4.6	3.4	41.769748	115	107	7.407	0.177	128
Core 4	5.3	3.5	50.9985875	133	119	12.963	0.254	134

Figure 1: Permeability and Porosity

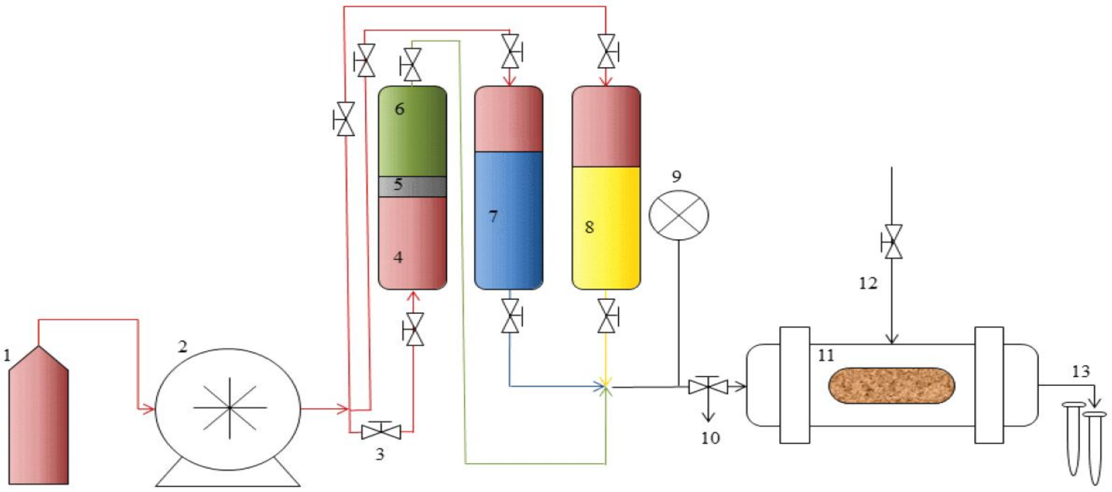

Figure 2: Experimental setup of the core sample flooding apparatus. (Aurand et al., 2014)

Core sample Flooding

The steps below were carried out for each individual core sample samples. Brine was injected at a specific flow rate; oil was injected also to determine the irreducible brine saturation (S_{wi}).

After these processes, brine flooding and other enhanced oil recovery processes are employed for oil recovery. These steps are detailed below

The effect of the surfactant was tested on different core sample samples at a single concentration. A constant pump rate of 5cc/min was used to pump the surfactant through the flowline. First residual oil saturation was reached as brine was injected continuously. Afterwards, the surfactant was flooded as an enhanced recovery method to see if any added oil could be mobilized. The recovered fluids were collected at a certain time interval. Each phase was continued till no oil was produced after 2-3pore volume injected.

RESULTS AND DISCUSSION

The results presented in this chapter were provided using the experimental procedures explained above. The purpose of these experiments was to the improve recovery by applying surfactant blend for enhanced oil recovery. All data and measurements given were performed at room temperature (21-23)^{0}C.

Analysis

Flooding core sample 1 (633)

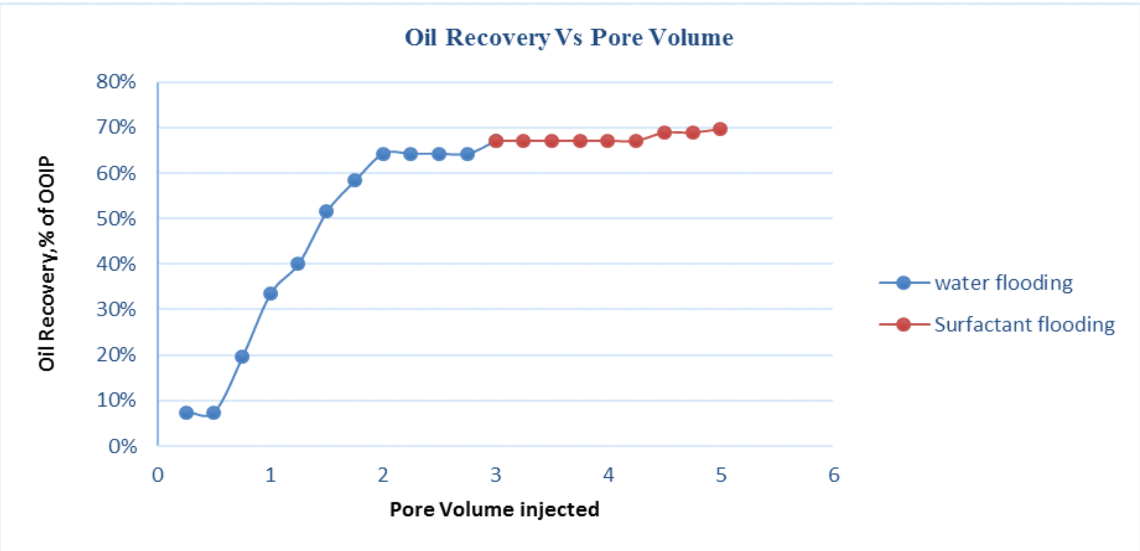

Figure 3: Oil recovery performance vs. injected PV for core sample plug surfactant blend with pH 11.66 (Core sample 1)

For Core sample 1 results, shows that at a pore volume of 2.75, brine could no longer be able to produce oil and there has been bypass leaving some of the oil behind. Core sample 1 was flooded at an injection rate of 5cc/min during the brine flooding and at 5cc/min during the surfactant flooding. The surfactants blend recovered an additional recovery of 2.74% of OOIP.

Flooding core sample 2 (C-25)

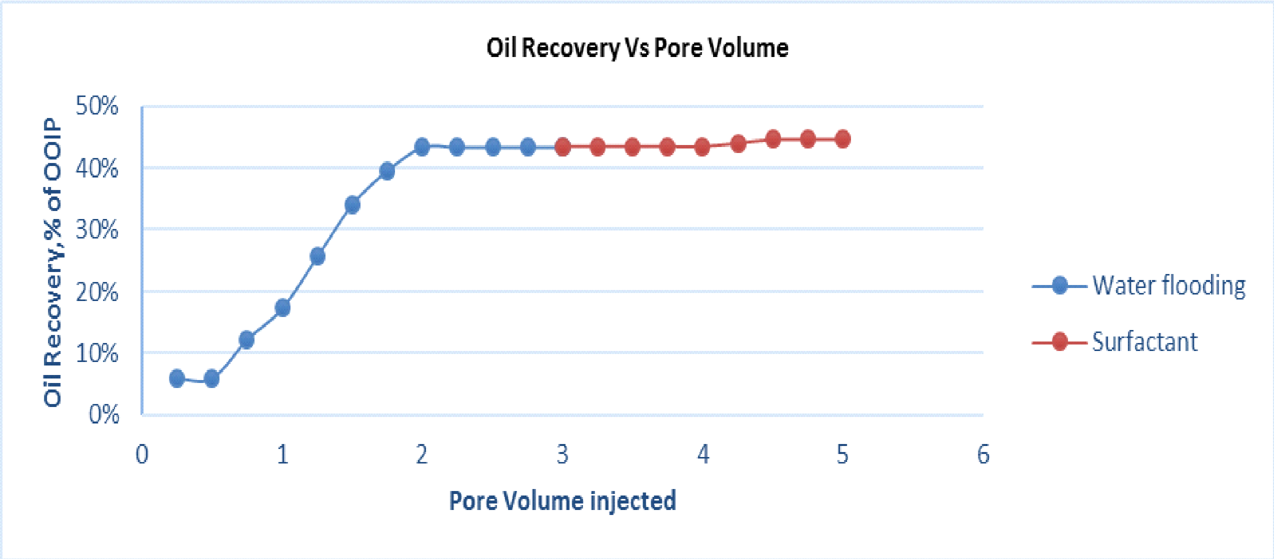

Figure 4: Oil recovery performance vs. injected PV for core sample plug surfactant blend with pH 11.66 (Core sample 2)

For Core sample 2 results, shows that at a pore volume of 2.25, brine could no longer be able to produce oil and there has been bypass leaving some of the oil behind. Core sample 2 was flooded at an injection rate of 5cc/min during the brine flooding and at 5cc/min during the surfactant flooding. The surfactant blend gave additional recovery of 2.56% of OOIP.

Flooding core sample 3 (611)

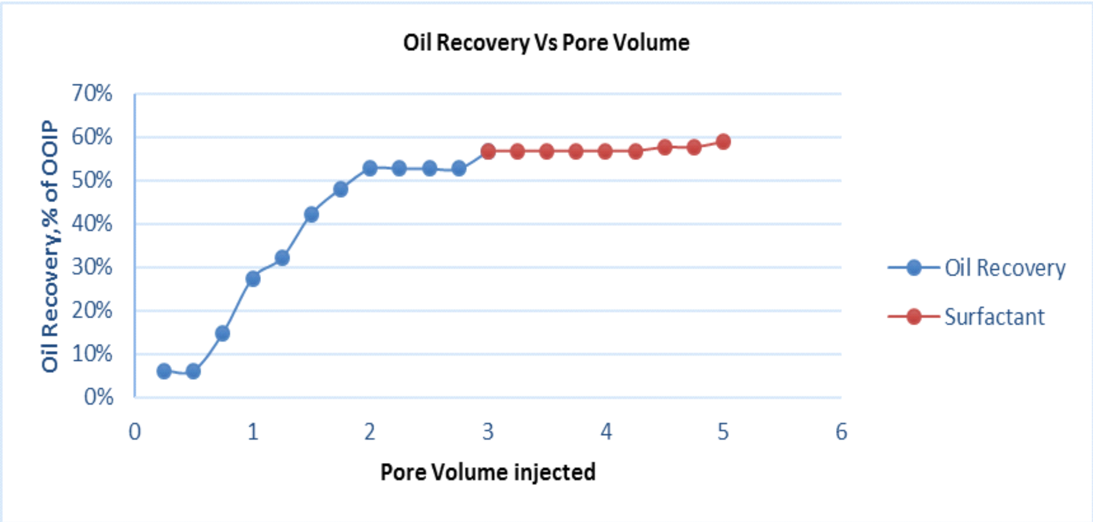

Figure 5: Oil recovery performance vs. injected PV for core sample plug surfactant blend with pH 11.66 (Core sample 3)

For Core sample 3 results, shows that at a pore volume of 2.75, brine could no longer be able to produce oil and there has been bypass leaving some of the oil behind. Core sample 3 was flooded at an injection rate of 5cc/min during the brine flooding and at 5cc/min during the surfactant flooding. The surfactant blend gave an additional recovery of 3% of OOIP.

Flooding core sample 4 (626)

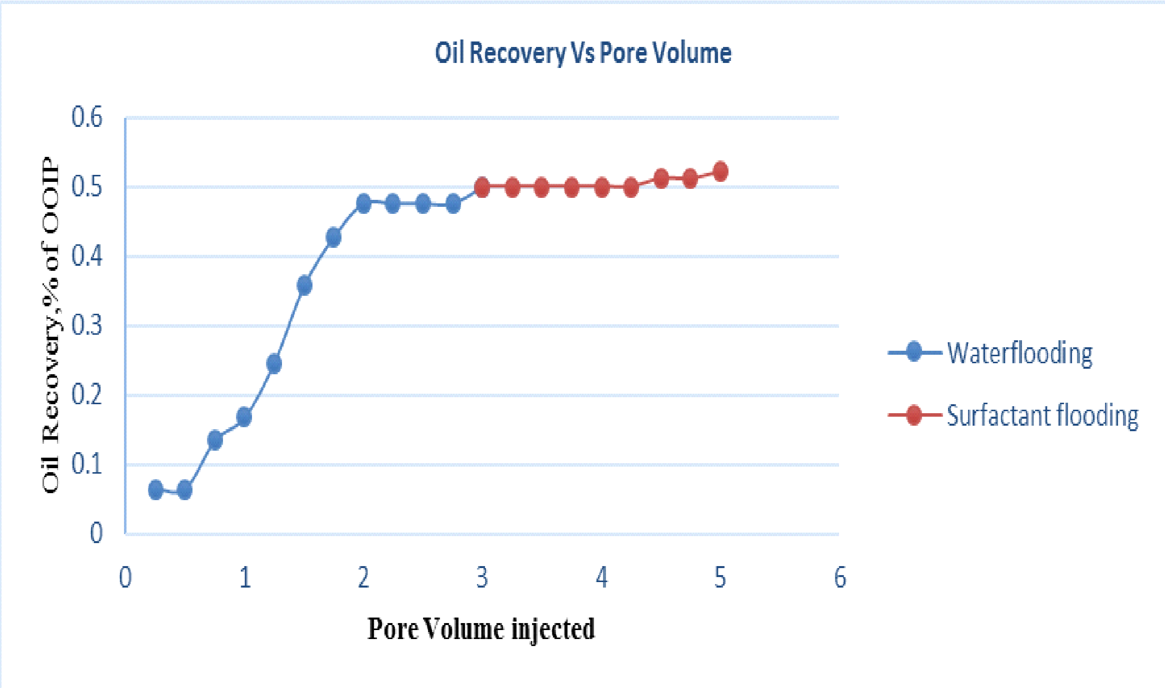

Figure 6: Oil recovery performance vs. injected PV for core sample plug surfactant blend with pH 11.66 (Core sample 4)

For Core sample 4 result, shows that at a pore volume of 2.75, brine could no longer be able to produce oil and there has been bypass leaving some of the oil behind. Core sample 4 was flooded at an injection rate of 5cc/min during the brine flooding and at 5cc/min during the surfactant blend.

The surfactant blend gave an additional recovery of 2.23% of oil.

Coresample611

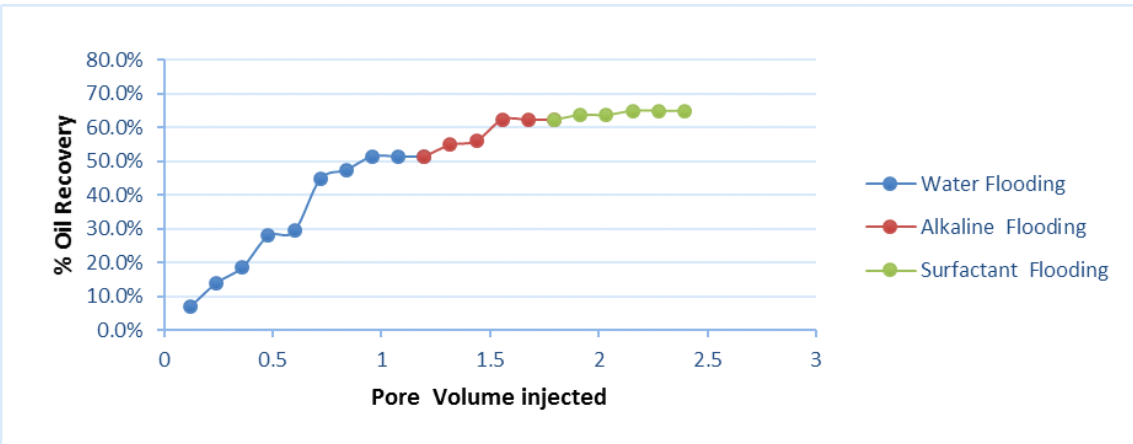

Figure 7: Incremental Recovery after alkaline flooding for Core sample 611

Application of the surfactant after alkaline flooding

The surfactant was flooded through two alkaline-flooded core sample samples and incremental recoveries were observed and were shown graphically below.

Core sample626

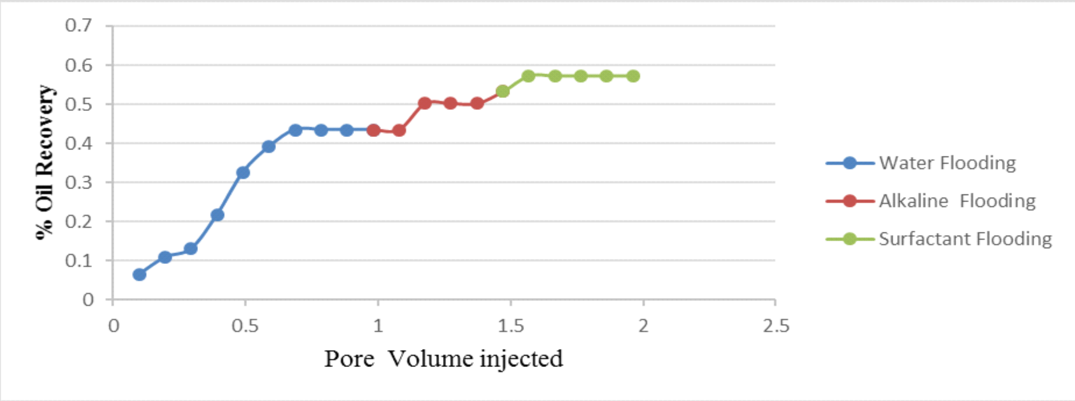

Figure 8: Incremental oil recovery for core 626

Analysis :

For Core sample 611,

At a pore volume of 1.5, surfactant flooding provided and incremental recovery after Alkaline flooding up to 65% addition to the OOIP making it an incremental recovery of 3%.

For Core sample 626,

At a pore volume of 1.5, surfactant flooding recovered about 57% of the OOIP making it an incremental recovery of 4%.

This indicate that the acid content in the light oil was not able to generate more surfactant/surfactant in-situ when alkaline was injected during core sample flooding compared with the one in the surfactant injected.

Permeability Impairment

Permeability is an important property of a porous medium. Investigation of permeability impairment was carried out by comparing the single-phase movement of brine into core sample pre-and post-surfactant injection.

Table 2: Permeability impairment

Core sample	Pre-permeability	Post-permeability	Impairment
Core sample 1	129.7	37.8	-0.70856
Core sample 2	50	15.4	- 0.692
Core sample 3	128	31.6	-0.75313
Core sample 4	134	34.4	-0.74328

The above table illustrates the reduction in the core sample permeability before and after the core sample samples are flooded. The reduction simply shows a blockage of the pore spaces of the core sample samples because absorption and precipitation occurred. This means there has been a reaction between the surfactant formed and some organic component of the rock type.

CONCLUSION

This paper presents the effect of injected surfactant blend through a core sample on improving oil recovery efficiency. For this aim, several core sample flooding experiments were carried out to investigate the potential of these process.

Based on these experiments, the following conclusions were inferred:

- The surfactant has the potential to mobilize trapped oil. By injecting surfactant as a tertiary recovery, oil recovery increased by about 3% through changing the wettability of rock surface and altering the interfacial tension of the reservoir fluids.
- Retention in pore throat may occur due to absorption based on the permeability values gotten.

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