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Enhancement of Oil Recovery from Sandstone Reservoirs by Local Surfactants Injection

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ABSTRACT
The rising demand of hydrocarbon and the continuous depletion of naturally drive reservoir has increased the search for methods aimed at enhancing oil recovery. It is necessary to use local agents cost wise to enhanced recovery of crude oil amidst high cost of production. In this work, local surfactants were injected using core flooding on a laboratory scale to enhanced oil recovery from sandstone reservoirs. Three surfactants (local soap, saponin, detergent) were formulated at 0.1wtml, 0.2wtml 0.5wtml, 1.0wtml, 1.5wtml and 2.0wtml in brine solution to generate the foam for injection. Sandstone core sample was prepared, washed with water, methanol and toluene to remove salts and dirt's respectively. It was then placed in the core flooding system and injected with the local surfactants. The density, pH, and viscosity of the three prepared surfactants were measured at the different dosage (0.1wtml, 0.2wtml, 0-5wtml, 1.0wtml, 1.5wtml, 2.0wtml). The results obtain shows that with local soap as surfactant, the maximum recovery efficiency was 75ml at 1.5wtml dosage, and the detergent gave 92ml recovery efficiency at 1.5wtml dosage while saponin also gave the result with detergent at 1.5wtml dosage. Detergent gave a better recovery efficiency at all dosage level and hits the maximum recovery efficiency earlier than other surfactants, having 92.5ml at 1.0wtml when compared with local soap of 75ml and saponin at 85ml recovery efficiency. Therefore, the use of local surfactant has proven effective in enhancing oil recovery and should be encouraged as detergent gave over 92ml recovery efficient with core flooding system applied.
Keywords: Core flooding, Enhanced Oil recovery, foam Injection, Local Surfactants, Sandstone Reservoir

1. INTRODUCTION
Sandstone reservoirs containing stable minerals like quartz, feldspar, and rock fragments, interspersed with fluid-saturated pores pivotal to the oil industry as they hold large volumes of crude oil (Sivasakthi & Tjprc, 2018). Due to the complex nature of sandstone reservoirs, recovery through conventional methods often leave significant reserves untapped within these formations, hence enhanced oil recovery methods (EOR) have been widely sought after to improve displacement of trapped hydrocarbons and maximize production from major reservoirs including sandstone. Previous studies have explored various EOR methods in fractured sandstone reservoir, highlighting the effectiveness of techniques such as gas injection, polymer flooding, foam flooding, and low salinity water assisted.
Ersland, (2008) observed that applications involving mixed gases result in interfacial tension reduction between crude oils and injected gases reducing contrast present among capillaries. According to Foroozanfar, (2016); polymer flooding remains the most common chemical approach utilized based on full-field case histories reviews. Invariably, foam flooding emerges as a promising strategy to enhance mobility control and sweep efficiency (Sunmonu & Onyekonwu, 2013). Foam usage resulted from need for better mobility control, improve sweep efficiency and profile modifications. Sunmonu & Onyekonwu, (2013) employed static models in her investigation of the effectiveness of foam injections towards enhancing oil production and observed substantial reductions in G.O.R compared to gas flooding accompanied. Shabib-Asl et al. (2019) investigated new hybridized Low Salinity Water Assisted Foam Flooding (LSWAF) method potentials targeting sandstone rocks. The study conducted by Abdelaal et al. (2020) solved the problem of generating CO_2 foam above supercritical condition replacing part CO_2N with mixed-CO_2/N foam). The mixed solution generated strong foaming capabilities surpassing normal limitations. Sustainability of foams from surfactants is a plaguing limitation of current approach making it difficult to fully utilize the reservoirs' potential. A novel approach

involving the injection of cost effective locally produced modifiable surfactants (foam) into fractured sandstone reservoir promises sustainability. The objective of this research is to investigate and compare the efficiency of bio-friendly surfactants capable of producing enough foam to lower the interfacial tension between oil and water and enhance flow. The study seeks to investigate how locally produced surfactants (foam) can improve oil recovery from fractured sandstone reservoir using laboratory experiments by comparing the performance of locally produced foams with traditional foaming agent. Although Saponin and sodium palmate have been investigated individually, comparative study of stable foam formation of both have not been recorded hence the novelty of this study.

2. MATERIALS AND METHODS

2.1 Materials

The crude oil X was obtained from a Niger Delta field. Sodium Palmate, Triterpene glycosides and Alkylbenzenesulfonates were purchased from Eddy Chemicals and Safety Supply Co., Diobu, Rivers State. The materials used in carrying out this research includes, water container (A), Air compressor (B), Heskey pump (C), Measuring cylinder (D), Valve (E), Core sample (F), Overburden pressure gauge (G), Differential pressure gauge (H), Accumulator (I), Diaphragm (J), Brine/Crude/Surfactants (K), Displacement pump (L), Core holder (M)

2.2 Methods

2.2.1 Surfactant preparation

Surfactant solutions were prepared by adding 0.1wt%, 0.2wt%, 1.0wt%, 1.5wt% and 2.0wt% surfactant in brine solution and shaken to generate foam. The stability of the generated foam for the brines was visually inspected to know if it is the best candidate for the foam injection in the fracture rocks. The high surfactant concentration was used to avoid adsorption problems in these experiments.

2.2.2 Core Sample preparation

Core samples sorted by grain sizes were obtained, washed with water to remove dirt, and then with methanol and toluene to remove any salt and soil respectively. Then partially dried to ensure easy packing into core plugs. The sandstone core samples were mounted horizontally into a Hessler sleeve jackets to form core plugs. Two screens (membranous and coarse) placed at each end face of the core plugs to prevent loss of grains, and to maintain sample integrity respectively before been packed into an oven to ensure they are completely dried. The dry weight of each core plugs was then obtained.

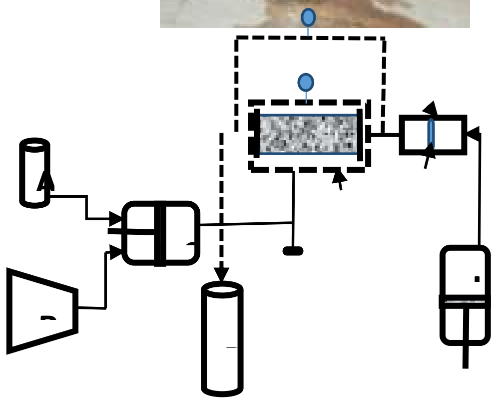

Fig 1 Core Flooding Equipment (Obuebite, 2018)

2.2 Experimental Procedure

The core sample is first saturated with brine and then inserted horizontally into the core holder. Crude is placed in the accumulator and injected into the core system to mimic the drainage and thereafter, brine is injected to complete the imbibition processes of the reservoir.

The air compressor with electric motor sucks successive volume of air from the atmosphere and then reduces the volume by compressing each volume of the trapped air to increase its pressure in a confined space. The pressure generated is transferred to a receiving tank (horizontal cylinder). The pressure pump simultaneously sucks water from the water container and gas from the receiving tank of the compressor to generate overburden pressure on the core system. The accumulator contains the volume of the injection fluid like brine, crude, and various surfactants to be injected via the core sample. The core system was constructed with special design to prevent back flow of fluid. The end stern in the core holder is used to produce the recovered oil which flows directly into the separator and receiver (measuring cylinder).

After each experimental run, the core and accumulator are cleaned with toluene before the next run.

3. RESULTS AND DISCUSSION

3.1 Recovery Efficiency

Recovery efficiency is the fraction of oil in place that can be economically recovered with a given process. The efficiency of primary recovery mechanism varies from reservoir to reservoir but the efficiencies are normally greatest with water drive, followed by intermediate gas drive and lastly solution gas drive.

Table 1: Recovery efficiency results for the three (3) local surfactants

dosage (ml)	Recovery Efficiency (ml)		
	Local Soap	Detergent	Saponin
0.1	50	70	55.5
0.2	57	75	62.5
0.5	72.5	80	80
1.0	75	92.5	85
1.5	75	92.5	92.5
2.0	70	87.5	87.5

The experimental results of recovery efficiency for all three (3) local surfactants are presented in Table 1. Local soap ranged from 50ml to 75ml as the dosage of the aqueous solution increases from 0.1ml to 2.0ml, more so the recovery efficiency of Detergent also ranged from 70ml to 92.5ml as the dosage of the aqueous solution increased from 0.1ml to 2.0ml, however the recovery efficiency of Saponin ranged from 55.5ml to 92.5ml as the dosage of aqueous solution is increased from 0.1ml to 2.0ml.

3.2 Density

The result of the density for local soap, detergent and Saponin is presented in Tables 2

Table 2: Density Results for the three (3) Local Surfactants

dosage (ml)	Density (g/cm^3)		
	Local Soap	Detergent	Saponin
0.1	0.982	0.992	0.970
0.2	0.990	0.996	0.986
0.5	0.992	0.998	0.992
1.0	0.994	0.999	0.994
1.5	0.996	0.999	0.996
2.0	0.998	1.000	0.998

In Table 2 the density results for the three (3) local surfactants are presented, local soap increase from 0.982g/cm^3 to 0.998 g/cm^3 as the dosage of the aqueous is raised from 0.1ml to 2.0ml. while Detergent increase from 0.992g/cm^3 to 1.000g/cm^3 and the dosage of aqueous is raised from 0.1ml to 2.0ml., more so Saponin increase from 0.970g/cm^3 to 0.998 g/cm^3 as the dosage of the aqueous is raised from 0.1ml to 2.0ml respectively.

3.3 pH

pH is a scale used to specify the acidity or basicity of an aqueous solution. It is also defined as a measure of the hydrogen ion dosage. Acidic solutions are measured to have lower pH values of a range of 0 to 6, while 7 is neutral and basic solution have a range of 8 to 14.

Table 3: pH Results for the three (3) Local Surfactants

dosage (ml)	**pH**		
	Local Soap	**Detergent**	**Saponin**
0.1	6.2	7.8	5.5
0.2	6.3	8.0	5.6
0.5	6.6	8.4	5.8
1.0	6.9	8.8	6.0
1.5	7.2	9.1	6.2
2.0	7.5	9.5	6.3

In Table 3 the pH values for the three (3) local surfactants are presented as follows local soap is increased from 6.2 to 7.5 as the dosage of the aqueous raised from 0.1ml to 2.0ml, hence the solution is still in the acidic media, also Detergent is increased from 7.8 to 9.5 as the dosage of the aqueous solution is raised from 0.1ml to 2.0ml, hence the solution is still in the basic media, while saponin is increased from 5.5 to 6.3 as the dosage of the aqueous is raised from 0.1ml to 2.0ml, hence the solution is still in the acidic media.

3.4 Viscosity

Viscosity is defined as the resistance of a fluid (liquid or gas) to a change in shape, or movement of neighbouring portions relative to one another, in general terms viscosity is the opposition to flow. There are two kinds of viscosity: Dynamic and Kinematic viscosity. SI unit of viscosity is Pascal second (Pas) other smaller units are poise or centipoise.

Table 4: Viscosity Results for the three (3) Local Surfactants

dosage (ml)	**Viscosity (Cp)**		
	Local Soap	**Detergent**	**Saponin**
0.1	0.908	1.003	0.921
0.2	0.920	1.006	0.939
0.5	0.958	1.027	1.008
1.0	0.977	1.031	1.027
1.5	0.992	1.044	1.034
2.0	1.008	1.056	1.048

In Table 4 the Viscosity results of the three (3) local surfactants presented as follows, local soap increases from 0.908cp to 1.008cp as the dosage of the aqueous solution rises from 0.1ml to 2.0ml, more so Detergent increases from 1.003cp to 1.056cp as the dosage of the aqueous solution rises from 0.1ml to 2.0ml., while Saponin increases from 0.921cp to 1.048cp as the dosage of the aqueous solution rises from 0.1ml to 2.0ml respectively.

3.5 Sensitivity Analysis

3.5.1 Variation of Combined Recovery Efficiency with dosage

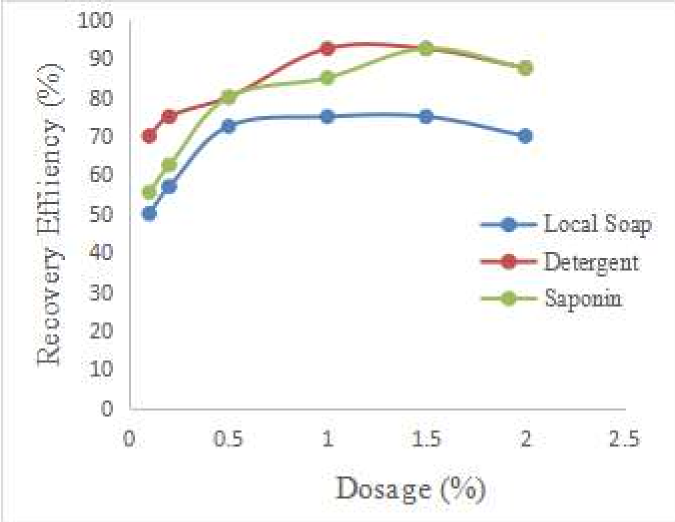

Figure 2: Recovery Efficiency of the 3 local surfactants against dosage

In Fig 2 shows the recovery efficiency results of the three (3) local surfactants that were used in recovering the residual oil in place from the sandstone reservoir in the Niger Delta coast line for dosage of the aqueous solution from 0.1ml to 2ml, respectively hence Detergent was found to have the highest recovery efficiency followed by Saponin and local soap had the least recovery efficiency.

3.5.2 Variation of Density with dosage

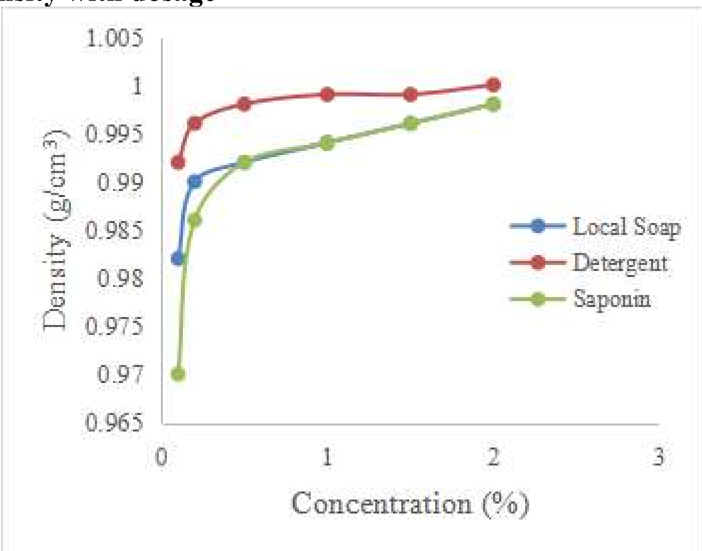

Figure 3: Density for the 3 local surfactants against dosage

In Fig 3 shows the combined plot of density for the three (3) local surfactants against dosage of the aqueous solution from 0.1ml to 2ml respectively, Detergent has the highest dosage followed by local soap while saponin had the least density.

3.5.3 Variation of pH with dosage

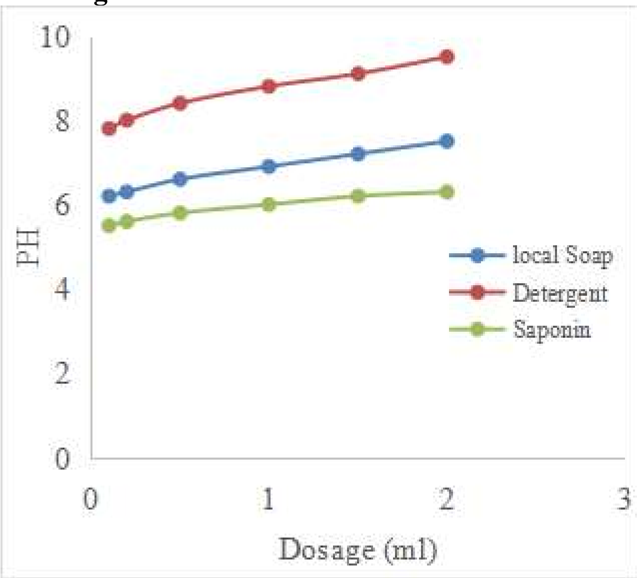

Figure 4: pH for the 3 local surfactants against dosage

Figure 4 shows the plot of combined pH for the 3 local surfactants against dosage of the aqueous solution from 0.1ml to 2ml, respectively. It was observed that increasing dosage dropped the toxicity as the pH moved the alkaline area. Overall, the pH of the oil samples recovered with saponin are gradually detoxifying and could not break above neutral which is safe, the local soap-maintained pH within 6 and 7.5 which also considered safe, industrial detergent is in the alkaline region which might develop chemical scales on the walls of the equipment.

3.5.4 Variation of Combined Viscosity with dosage

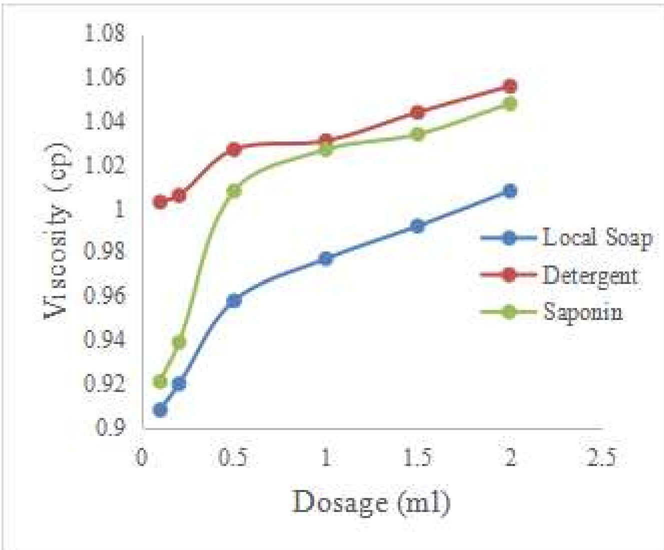

Figure 5: Viscosity against dosage

Figure 5 shows the effect of surfactant dosage on viscosity of produced fluids. From Figure 5, fluids produced with industrial detergent has the highest viscosity followed by saponin while local soap has the least viscosity. It is observed that local soap had the most positive effect on viscosity this implies that local soap decreased fluid viscosity most and resulted in higher volumes of oil produced. However, as the dosage increased, the viscosity tends to increase this is as a result of micelles formation. Similarly, saponin and detergents increased the fluid viscosity with the viscosity of the produced crude due to micelles formation.

4. CONCLUSION

Based on the evidence accumulated during the experimental investigation process, the following conclusions were drawn from the study;

i. The recovery efficiency of oil with respect to each local surfactant was seen to improve significantly however, the detergent has the optimal recovery efficiency at the same dosage with other surfactants
ii. The pH of different local surfactant moved towards a more alkaline state with increase in dosage of the surfactant implying the local surfactants were less toxic and more environmentally friendly.
iii. The effect of the local surfactant on viscosity shows viscosity increases with dosage of surfactant.

In conclusion, the detergent is the best surfactant with the highest recovery efficiency in this study.

Moving forward, the following recommendations are recommended for further research.

i. Further investigation is required to access the salinity effect on local surfactants in fractured reservoirs.
ii. The research recommends the use of local surfactant for improved oil recovery as it is easily modifiable based on region.
iii. Crude oil used for any experimental research should be screened for contamination. Crude oil of interfacial tension less than 10 mN/rn is an indication of contamination.
iv. The effect of temperature on local surfactant should be investigated in further studies.
v. To recover oil from oil-wet sandstone core, spontaneous imbibition with detergent surfactant solution should be considered.
vi. More studies should also be directed at establishing a distinct relationship between brine salinity and crude oil type.

NOMENCLATURE

EOR – Enhanced oil recovery
OOIP – Oil initially in place

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