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The Effectiveness of Fir Wood Lignosulphonate Surfactant Stability on Intermediate Oil as Biomaterial Engineering

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Abstract. Indonesia is one of the countries with abundant oil reserve. To be able to produce the oil reserve, decent production methods with the ability to drain remaining oil reserve left in the reservoir is vital. One method that can be implemented is by using surfactant as injection fluid on the reservoir. The objective of this research is to acknowledge the mechanism and suitability of fir wood SLS surfactant on crude oil. This research is also fitted with core flooding test to measure the level of potential recovery factor. Method used in this research was a laboratory research method to test the characteristic and stability of surfactant solution on various concentration. The first test was by conducting aqueous stability to observe solution condition. A decent surfactant is the one that remains clear and does not experience murkiness during aqueous stability process. Surfactant solution sample was inserted into an oven and observed whether there is a change indicated in the surfactant. The next test is the surfactant stability test to acknowledge the suitability between surfactant and formation water from certain reservoir. One of the compatibility tests conducted is the surfactant stability test. Formation water salinity levels utilized in this research are varied between 5,000 ppm and 120,000 ppm, meanwhile the utilized surfactant concentration levels are 1% 1.5% and 2%. Surfactant stability test was conducted for 21 days on 60^o Celsius temperature. As for the core flooding, there are a number of working stages namely brine saturation on the core utilized for core flooding. This stage is conducted after fulfilling surfactant compatibility test requirements. Brine saturation process were implemented by pouring brine solution with different levels of salinity. 200 ml of brine solution and core were poured into a chemical glass until they are covered with brine. After that, insert the solution into a desiccator to conduct saturation with vacuum pump for 2 days. After brine saturation, the next stage was to saturate the oil by using core holder. This oil saturation process was implemented by using 40 ml of intermediate oil. Core was saturated with crude oil by using syringe pump. The core saturated by brine and crude oil was injected with surfactant to obtain the measurement of producible oil. Based on this research, we noticed that the best fir wood lignosulphonate surfactant composition for injection process is the one with 100,000 ppm salinity and 1% surfactant concentration. The injection result by fir wood sodium lignosulphonate surfactant obtained recovery factor percentage of 3.52%. The conclusion of the results shows that the application of fir wood with biomaterial engineering are able to provide benefits as natural surfactant alternative that can be utilized to improve oil production enhancement process.

Keywords: Fir wood SLS surfactant, Compatible, Colloid, Surfactant flooding, Recovery factor.

INTRODUCTION

Naturally, the amount of oil production on a reservoir will decrease along the time until it finally depleted. However, this condition does not represent that the oil reserve is completely produced. If the production activity only relies on primary production method, there is a large possibility that there are still a large amount of unproduced oil in the reservoir. That is why, a secondary production method is imminent to produce the remaining oil volume in the reservoir. Enhanced Oil Recovery (EOR) method will provide the necessary draining solution for

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the remaining oil volume in the reservoir that cannot be produced with primary method [1] [2]. Chemical EOR is a recovery method that utilizes chemical compounds such as polymer and surfactant. Surfactant is a compound that has the ability to lower interface tension of two unsolvable liquids often discovered on solid compounds and liquids attached on rocks. Surfactant addition will lead to decreased interface tension up until the minimum level. Surfactant concentration addition will lead to surfactant aggregation into micelle. In micelle, hydrophobic surfactant group will be pointed into the inside part of the aggregate, and the polar head group will be pointed towards the solvent. Micelle is located within the dynamic balance of the surfactant molecule and influenced by surfactant molecular structure. The early phase before interfacial tension decrease mechanism on surfactant system will previously show decent aqueous stability character, where surfactant remain clear without the formation of colloid or suspense [3].

Surfactant is an active compound with the ability to lower interface tension, which can be produced through both chemical and biochemical synthesis. There are 4 common types of surfactant namely anionic, cationic, nonionic, and ampother surfactants [3]. The main characteristic of surfactant is that the compound possesses both polar and non-polar groups within the same molecule. Sulphonate surfactant possesses negative compound at the end of the polar, because of sulphonate-SO3- presence. Active surface characteristic found in surfactant is able to lower surface tension, interface tension, and improve emulsion system stability. These abilities made surfactant as pre ferredcompound on industries, for example soap, detergent, cosmetics, and pharmacy industries [4]. On oil industry, anionic surfactant are more preferred, especially lignosulphonate surfactant created from lignin as raw material [5].

Lignin are commonly found in most of vegetables starting from the stems up until the leaf. One type of surfactants known to be created from vegetative material is fir wood surfactant synthesized from fir wood. This surfactant is known as fir wood lignosulphonate surfactant. Because of its vegetative material, fir wood surfactant can be categorized as bio surfactant. Wood chemical compound is defined as 50% carbon, 5% hydrogen, 40% oxygen, and the rest consists of nitrogen and metal ion [6]. At this moment, fir wood are commonly utilized in property industry as building materials for example wooden floor. Fir wood is commonly used in Slovakia (due to its decent technical nature, processing, and large domestic source). This compound is largely used in a lot of industrial areas such as building industry and maintenance, package industry, mining industry, transportation construction, erring machinery, furniture, plywood, fiberboard, chipboard, etc. [7]. On oil industry, researches are conducted to acknowledge lignosulphonate surfactant as injection fluid on Enhanced Oil Recovery. This research will be concentrated on chemical injection by utilizing surfactant [8] [9].

Researches on fir wood lignin has been conducted by a number of researchers. Based on FTIR and NMR tests for fir wood characterization, there are four types of commonly known lignin in fir wood namely alkali lignin (AL), klaxon lignin (KL), organosol lignin (OL), and milled wood lignin (MWL) [10].

To clarify the utilization of fir wood lignosulphonate surfactant utilization, this article will be completed with explanations about utilized materials and method. Research data and discussion will also be shown according to the existing theory. In the last part of the article, conclusion will be presented based on the discussion results.

MATERIAL AND METHOD

The materials in this research are fir wood lignosulphonate surfactant and core. The utilized core is a synthetic Berea core consists of homogenous sandstone rock with certain porosity and permeability natures that are measured through laboratory measurement.

Reservoir Rock Characteristic. Formation water salinity composition utilized in this research are 5,000 ppm, 10,000 ppm, 20,000 ppm, 60,000 ppm, 70,000 ppm, 75,000 ppm, 100,000 ppm, 110,000 ppm, and 120,000 ppm. Meanwhile the surfactant concentration utilized in this research are 1%, 1.5% and 2%. The surfactant solution will be measured at 600C temperature and the type of oil used is an intermediate crude oil.

Methodology utilized in this research is an experimental and analytic laboratory research that uses relationship between concentration and salinity to determine causal relationship between the two variables. The surfactant stability test conducted in this research was initiated by pouring 4 cc of surfactant on various concentration levels into pipette tube. The next stage was to insert the tubes into an oven and to check if there are surfactant that changes color (clear or hazy). Surfactant stability test conducted for 504 hours on 60ºC temperature. If the solutions remain clear during the test, they are categorized as compatible with formation water; if there are colloids or suspensions detected, surfactant can be categorized as incompatible with formation water and will affect injection process due to clogging deposits that inhibit rock pores. The test was observed at minute 30, minute 60, hour 2, day 1, day 2, day 7, day 14 and day 21 [11].

For core flooding itself, there are a number of stages to be initiated, starting from brine saturation on desiccator, which is conducted after surfactant compatibility is categorized as compatible for phase behavior test. 200 ml of selected brine solution was poured into a chemical glass and core was added into the glass until it's covered in brine. The solution was then inserted into a desiccator to conduct saturation with vacuum pump for 2 days. For oil saturation with core holder by using intermediate oil on each tube, assisted by syringe pump to insert crude oil into the core.

The flow chart of this research is limited to the generation of solution on fir wood lignosulphonate surfactant compatibility test by applying stability test, phase behavior test, and core flooding test as shown in Fig. 1.

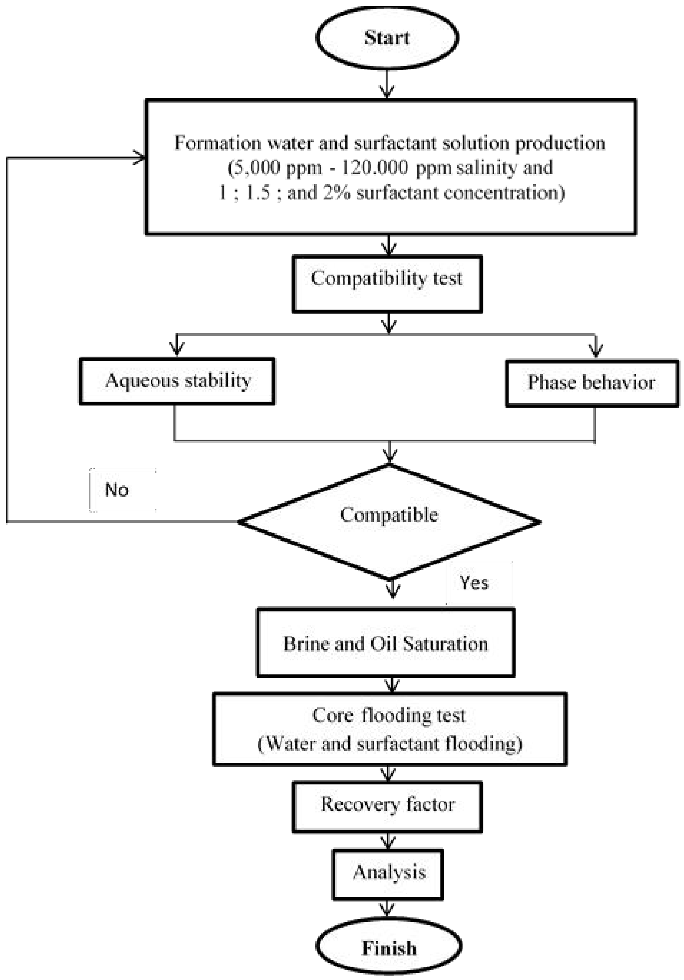

FIGURE 1. Research Flow Chart

Salinity Composition. The compatible surfactant concentration will be used as surfactant solution on fluid injection process. Core flooding is conducted through two stages namely water flooding, where formation water injected into the saturated core by crude oil [12]. Injection was conducted on a number of pore volumes (PV). Water injection process will generate a number of oil compound known as recovery factor by water flooding. If there is no oil left to be generated by this method, water flooding can be stopped and surfactant flooding can begin. Similar as water flooding mechanism, on surfactant flooding surfactant injection is conducted on a number of PV to produce oil out of the core which is known as recovery factor by surfactant flooding.

RESULTS AND DISCUSSION

Surfactant stability test is conducted to observe the clarity and compatibility of surfactant on brine and conduct core flooding on composition and concentration variations that pass the test. In this research, observation was conducted on 27 surfactant solution compositions that consist of 9 salinity and 3 surfactant concentration variations, namely 5,000 ppm, 10,000 ppm, 20,000 ppm, 60,000 ppm, 70,000 ppm, 75,000 ppm, 100,000 ppm, 110,000 ppm and 120,000 ppm salinity levels of formation water. Meanwhile the surfactant concentration utilized in this research are 1% 1.5%, and 2%. Out of the 27 compositions, after 21 days of observation, the aqueous stability was formed on three salinity levels namely 5,000 ppm, 75,000 ppm and 100,000 ppm.

On 5,000 ppm formation water salinity and surfactant concentration of 1% and 2%, colloid or suspension are formed. On 5,000 ppm salinity composition, aqueous stability is generated at surfactant concentration of 1% as seen in the following Table 1.

TABLE 1. 5,000 ppm Water Formation Salinity Surfactant Stability

Surfactant Composition (ppm)	Concentration (%)	Observation (hours)								
		0	0.5	1	2	24	48	168	336	504
5,000	1	Clear	Hazy	Hazy	Hazy	Hazy	Hazy	Hazy	Hazy	Hazy
	1.5	Clear	Clear	Clear	Clear	Clear	Clear	Clear	Clear	Clear
	2	Clear	Hazy	Hazy	Hazy	Hazy	Hazy	Hazy	Hazy	Hazy

After 21 days of observation, the formation water with 75,000 ppm salinity and 2% surfactant concentration appeared to form colloid or suspense, meanwhile on the same level of salinity, the solution with 1% and 1.5% surfactant concentration produces aqueous stability. The aqueous stability result on 75,000 ppm salinity can be seen on the following Table 2.

TABLE 2. 75,000 ppm Water Formation Salinity Surfactant Stability

Surfactant Composition (ppm)	Concentration (%)	Observation (hours)								
		0	0.5	1	2	24	48	168	336	504
75,000	1	Clear	Clear	Clear	Clear	Clear	Clear	Clear	Clear	Clear
	1.5	Clear	Clear	Clear	Clear	Clear	Clear	Clear	Clear	Clear
	2	Hazy	Hazy	Hazy	Hazy	Hazy	Hazy	Hazy	Hazy	Hazy

After 21 days of observation on 100,000 ppm salinity composition, the solution with 2% surfactant concentration formed colloid or suspense, meanwhile aqueous stability is formed on solution with surfactant concentration of 1% and 1.5%. Aqueous stability test is shown in the following Table 3.

TABLE 3. 100,000 ppm Water Formation Salinity Surfactant Stability

Surfactant Composition (ppm)	Concentration (%)	Observation (hours)								
		0	0.5	1	2	24	48	168	336	504
100,000	1	Clear	Clear	Clear	Clear	Clear	Clear	Clear	Clear	Clear
	1.5	Clear	Clear	Clear	Clear	Clear	Clear	Clear	Clear	Clear
	2	Clear	Hazy	Hazy	Hazy	Hazy	Hazy	Hazy	Hazy	Hazy

Surfactant solutions that fulfill compatibility test are often used as chemical compound on surfactant flooding. Characteristics of surfactant that pass the compatibility test are surfactant with clear solution, not hazy, and do not create sediment that can generate Oil in Water (O/W) emulsion [13]. Research result generated from laboratory test shows stable surfactant that met the requirement because the solution is fixated and do not create lumps during storage [4]. This condition act as one of the considerations of surfactant selection as injection fluid on EOR process.

Surfactant can be used on EOR when the solution can be dissolved on water with no sediment formation that has the potential to lower interface tension. the formation of colloid or suspension by surfactant can cover pores on reservoir, and inhibit the remaining oil production [4]. The three best compositions were further tested through phase behavior test to create emulsion. The best phase behavior test result in this research is the solution with 100,000 ppm salinity–1% surfactant concentration composition, and created 25% of middle phase emulsion.

The next stage is to conduct core flooding process on solution with 100,000 ppm salinity and 1% surfactant concentration. The process is conducted through two stages namely water flooding and surfactant flooding. On water injection process in the core, 4 pore volumes (PV) are injected and generated oil production level as shown in the following Table 4.

TABLE 4. Core Water Injection Results

No	**Code**	**PV oil (ml)**	**V oil (ml)**	**%V produced oil**
1	WF 1	2.3	0.5	21.74
2	WF 2	2.3	0.06	2.61
3	WF 3	2.3	0.005	0.22
4	WF 4	2.3	0.003	0.13
Recovery Factor				24.70

As shown in the table above, based on the water injection on core, the additional oil production is at 24.70% of the produced oil volume in the core. Water injection on this core is a standard procedure that must be implemented before chemical injection process. This process is known as secondary recovery process [14] [15]. According to the theory, oil production must be implemented through three stages. The first stage is primary recovery where oil is naturally produced until it reaches optimum production and stop producing, which is known as oil residual saturation parameter (Sor)

[16] [17]. The existing Sor is then further processed to improve oil production by implementing the second stage known as secondary recovery[18] [19]. In this stage, water flooding is implemented as pressure maintenance to further generate oil trapped in the core.

After water injection, surfactant injection is implemented into the core. Surfactant injection is implemented in the 4 pore volume and recovery factor result with 3.52% of injection surfactant, as seen in Table 5.

TABLE 5. Core Surfactant Injection Results

No	Code	PV oil (ml)	V oil (ml)	%V produced oil
1	SF 1	2.3	0.017	0.728
2	SF 2	2.3	0.019	0.826
3	SF 3	2.3	0.024	1.032
4	SF 4	2.3	0.022	0.936
		Recovery Factor		

As seen in The Table above, the core surfactant injection process represents 100,000 ppm salinity composition with 1% concentration and core, there is a 3.52% recovery factor improvement of the oil volume in the core.

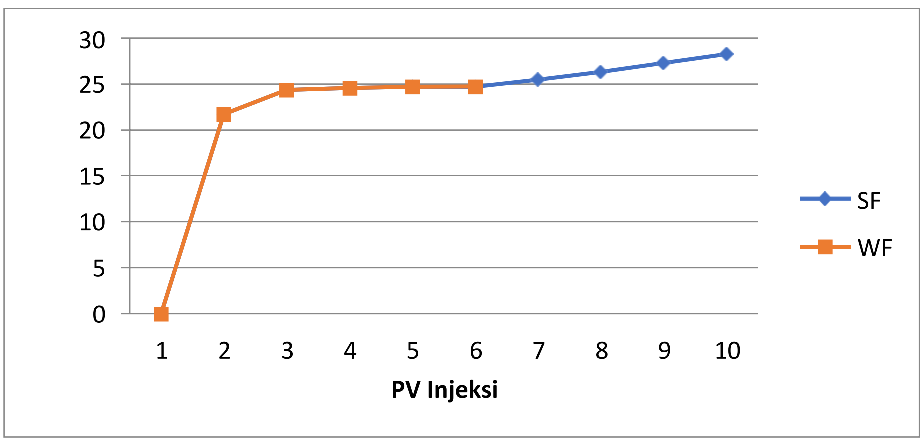

FIGURE 1. Research Flow Chart

Based on Table 4 and Table 5, the total RF of oil production from the core is at 28.26% of the total oil volume trapped in core. From the whole research data, to facilitate comparison of core flooding results, core flooding characteristic table that interprets the summary of the final testing data is generated as shown below.

TABLE 6. Core Flooding Characteristic Results

Salinity (ppm)	100.000
Concentration (%)	1
Core	Berea
Crude oil	Intermediate
Permeability (mD)	171.05
Produced water (ml)	2.2
Water Injection RF (%)	24.74
Surfactant Injection RF (%)	3.52
RF total (%)	28.26

On the table above, we also discovered that the surfactant concentration and core permeability influence recovery factor value. The higher the surfactant concentration, the higher the core permeability will be that would lead to higher oil volume generated from rock pores [20]..

CONCLUSION

Based on the research and the laboratory test results, it is evident that bagasse has the potential to be synthesized to produce sodium lignosulfonate (SLS) anionic sBased on the research data, we can conclude that fir wood lignosulphonate surfactant can be utilized in intermediate crude oil enhanced oil recovery process. The best lignosulphonate surfactant performance is produced on 100,000 ppm salinity and 1% surfactant concentration composition, by generating 3.52% of recovery factor. The higher the salinity level during fir wood lignosulphonate surfactant stability test, the higher the potential of colloid or suspension generation during the test. Similarly, the higher the surfactant concentration, the higher the chance of the solution generates colloid will be. Aqueous stability optimization on fir wood lignosulphonate surfactant was obtained on 1% surfactant concentration level. Based on that, surfactant concentration and formation water salinity influence fir wood lignosulphonate surfactant stability. As bio material, a suitable technic and composition design in lignosulphonate surfactant utilization on intermediate crude oil is important.

REFERENCES

1. A. Barati-Harooni, A. Najafi-Marghmaleki, A. Tatar, and A. H. Mohammadi, "Experimental and modeling studies on adsorption of a nonionic surfactant on sandstone minerals in enhanced oil recovery process with surfactant flooding," Journal of Molecular Liquids, vol. 220, pp. 1022- 1032, Aug. 2016, doi: 10.1016/j.molliq.2016.04.090.
2. Ansyori, M.R. (2018). Get to know Enhanced Oil Recovery (EOR) as a Solution to Increase Oil Production. Swara Patra, PPSDM Migas Scientific Magazine, Vol. 8, No. 2, 16.
3. Setiati, R. (2017). Synthesis and Characterization of Sugarcane Bagasse Lignosulfonate Sodium Lignosulfonate: Effect of Concentration and Salt Solution on Oil Pressure Performance in Core Rock. Dissertation, Bandung Institute of Technology.
4. Taiwo et al. 2016, Characterization of surfactant flooding for light oil using Gum Arabic
5. Taber, J. J., Martin, F. D., & Seright, R. S. (1997). EOR screening criteria revisited-Part 1: Introduction to screening criteria and enhanced recovery field projects. SPE reservoir engineering, 12(03), 189-198.
6. Priyanto., et al, 2021. Synthesis of Sodium Ligno Sulfonate (SLS) Surfactant from Black Liquor Waste and The Potential Test for EOR in Ledok Field Cepu
7. Zamrodah 2016, Impact of Surfactants as Detergent and Soap Manufacturer on The Environment and Health
8. Fattahanisa, A., R. Setiati, S. Kasmungin, and A. Ristawati. 2019. "The Alternative Solutions of Bagasse to Improve Indonesian Oil Production in Low Salinity." Journal of Physics: Conference Series 1402(3).
9. Abu Ghalia and Dahman 2017, Synthesis and utilization of natural fiber-reinforced poly (lactic acid) bionanocomposites
10. Yang, W., Lu, J., Wei, B., Yu, H. & Liang, T., 2021, Micromodel Studies of Surfactant Flooding for Enhanced Oil Recovery: A Review, ACS Omega, 6(9), 6064-6069
11. Ružinská et al. 2015, The Evaluation of Specific Environmental and Degradation Characteristics of Surface Treated Wood
12. Ahmad, Nasirudin Mahmud, and Lestari Said. 2015. "Analysis of Formation Water in Determining the Tendency of Scale Formation in Wells X, Y and Z." National Seminar of Scholars: 317-25.
13. Setiati, R., Aryani, E., Putri, M., & Wahyuningrum, D. (2016). Sulfonation of bagasse lignin to sodium lignosulfonate surfactant, 35-41.
14. Zhu, Youyi, Zhang, Yi, Hou, Qingfeng, Liu, Hualong, Jian, GuoqingEffect Of Oil And Water Interfacial Tension On Oil Recovery Of Surfactant-Polymer Flooding
15. Alli, Yani Faozani, Letty Brioletty, Hestuni Eni, and Yan Irawan. 2017. "Co-Surfactant Polyethylene Glycol Mono-Oleate in the Formulation of Natural Based-Surfactant for Chemical EOR." Scientific Contributions Oil and Gas 40(1): 1-8.
16. Song, Kao Ping, Wang, Cheng Cheng, Fu, Cheng, Wu, Xiao Hui, 2014. The Research of Water Flooding Measures in Late High Water Cut Period of Secondary Reservoirs
17. James G. Speight, Chapter 6 - Nonthermal Methods of Recovery, Editor(s): James G. Speight, Enhanced Recovery Methods for Heavy Oil and Tar Sands, Gulf Publishing Company, 2009, Pages 185-220, ISBN 9781933762258, https://doi.org/10.1016/B978-1-933762-25-8.50011-0
18. Shao, Xian Jie, Kang, Yuan Yuan, Wang, Cai Feng, Gao, Er Shuang, 2013. Technologies for Reusing Resources in Abandoned Oilfield after Tertiary Oil Recovery
19. Campbell CB, Denslow TA, Gabriel P, Adam CJ. 2009. Enhanced Oil Recovery Surfactant Formulation and Method of Making the Same. Chevron Coorporation. US Patent 2009/0111717 A1.
20. Ristawati, A., R. Setiati, S. Kasmungin, and A. Fattahanisa. 2019. "The Alternative Solutions of Bagasse Waste Utilization to Improve Recovery Factors in Reservoir with High Salinity." Journal of Physics:

Conference Series 1402(3).
21. Yang et al. 2012, Advance water-flooding to reduce the stress sensitivity affect on low permeability reservoir development

Paper

by Muhammad Taufiq Fathaddin

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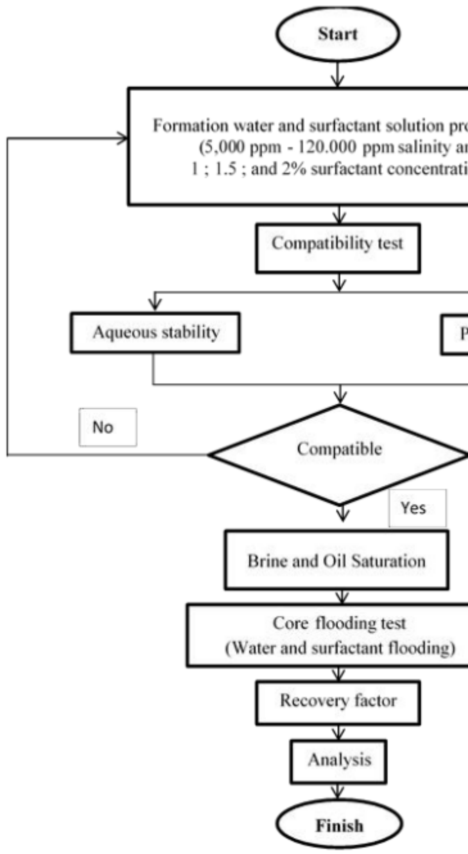

FIGURE 1. Research Flow Chart

Salinity Composition. The compatible surfactant concentration will be used as surfactant solution on fluid injection process. Core flooding is conducted through two stages namely water flooding, where formation water injected into the saturated core by crude oil [12]. Injection was conducted on a number of pore volumes (PV). Water injection process will generate a number of oil compound known as recovery factor by water flooding. If there is no oil left to be generated by this method, water flooding can be stopped and surfactant flooding can begin. Similar as water flooding mechanism, on surfactant flooding surfactant injection is conducted on a number of PV to produce oil out of the core which is known as recovery factor by surfactant flooding.

RESULTS AND DISCUSSION

Surfactant stability test is conducted to observe the clarity and compatibility of surfactant on brine and conduct core flooding on composition and concentration variations that pass the test. In this research, observation was conducted on 27 surfactant solution compositions that consist of 9 salinity and 3 surfactant concentration variations, namely 5,000 ppm, 10,000 ppm, 20,000 ppm, 60,000 ppm, 70,000 ppm, 75,000 ppm, 100,000 ppm, 110,000 ppm and 120,000 ppm salinity levels of formation water. Meanwhile the surfactant concentration utilized in this research are 1% 1.5%, and 2%. Out of the 27 compositions, after 21 days of observation, the aqueous stability was formed on three salinity levels namely 5,000 ppm, 75,000 ppm and 100,000 ppm.

On 5,000 ppm formation water salinity and surfactant concentration of 1% and 2%, colloid or suspension are formed. On 5,000 ppm salinity composition, aqueous stability is generated at surfactant concentration of 1% as seen in the following Table 1.

TABLE 1. 5,000 ppm Water Formation Salinity Surfactant Stability

Surfactant Composition	Concentration	Observation (hours)								
(ppm)	(%)	0	0.5	1	2	24	48	168	336	504
5,000	1	Clear	Hazy	Hazy	Hazy	Hazy	Hazy	Hazy	Hazy	Hazy
	1.5	Clear	Clear	Clear	Clear	Clear	Clear	Clear	Clear	Clear
	2	Clear	Hazy	Hazy	Hazy	Hazy	Hazy	Hazy	Hazy	Hazy

After 21 days of observation, the formation water with 75,000 ppm salinity and 2% surfactant concentration appeared to form colloid or suspense, meanwhile on the same level of salinity, the solution with 1% and 1.5% surfactant concentration produces aqueous stability. The aqueous stability result on 75,000 ppm salinity can be seen on the following Table 2.

TABLE 2. 75,000 ppm Water Formation Salinity Surfactant Stability

Surfactant Composition	Concentration	Observation (hours)								
(ppm)	(%)	0	0.5	1	2	24	48	168	336	504
75,000	1	Clear	Clear	Clear	Clear	Clear	Clear	Clear	Clear	Clear
	1.5	Clear	Clear	Clear	Clear	Clear	Clear	Clear	Clear	Clear
	2	Hazy	Hazy	Hazy	Hazy	Hazy	Hazy	Hazy	Hazy	Hazy

After 21 days of observation on 100,000 ppm salinity composition, the solution with 2% surfactant concentration formed colloid or suspense, meanwhile aqueous stability is formed on solution with surfactant concentration of 1% and 1.5%. Aqueous stability test is shown in the following Table 3.

TABLE 3. 100,000 ppm Water Formation Salinity Surfactant Stability

Surfactant Composition	Concentration	Observation (hours)								
(ppm)	(%)	0	0.5	1	2	24	48	168	336	504
100,000	1	Clear	Clear	Clear	Clear	Clear	Clear	Clear	Clear	Clear
	1.5	Clear	Clear	Clear	Clear	Clear	Clear	Clear	Clear	Clear
	2	Clear	Hazy	Hazy	Hazy	Hazy	Hazy	Hazy	Hazy	Hazy

Surfactant solutions that fulfill compatibility test are often used as chemical compound on surfactant flooding. Characteristics of surfactant that pass the compatibility test are surfactant with clear solution, not hazy, and do not create sediment that can generate Oil in Water (O/W) emulsion [13]. Research result generated from laboratory test shows stable surfactant that met the requirement because the solution is fixated and do not create lumps during storage [4]. This condition act as one of the considerations of surfactant selection as injection fluid on EOR process.

Surfactant can be used on EOR when the solution can be dissolved on water with no sediment formation that has the potential to lower interface tension. the formation of colloid or suspension by surfactant can cover pores on reservoir, and inhibit the remaining oil production [4]. The three best compositions were further tested through phase behavior test to create emulsion. The best phase behavior test result in this research is the solution with 100,000 ppm salinity–1% surfactant concentration composition, and created 25% of middle phase emulsion.

The next stage is to conduct core flooding process on solution with 100,000 ppm salinity and 1% surfactant concentration. The process is conducted through two stages namely water flooding and surfactant flooding. On water injection process in the core, 4 pore volumes (PV) are injected and generated oil production level as shown in the following Table 4.

TABLE 4. Core Water Injection Results

No	Code	PV oil (ml)	V oil (ml)	%V produced oil
1	WF 1	2.3	0.5	21.74
2	WF 2	2.3	0.06	2.61
3	WF 3	2.3	0.005	0.22
4	WF 4	2.3	0.003	0.13
		Recovery Factor		24.70

As shown in the table above, based on the water injection on core, the additional oil production is at 24.70% of the produced oil volume in the core. Water injection on this core is a standard procedure that must be implemented before chemical injection process. This process is known as secondary recovery process [14] [15]. According to the theory, oil production must be implemented through three stages. The first stage is primary recovery where oil is naturally produced until it reaches optimum production and stop producing, which is known as oil residual saturation parameter (Sor)

[16] [17]. The existing Sor is then further processed to improve oil production by implementing the second stage known as secondary recovery[18] [19]. In this stage, water flooding is implemented as pressure maintenance to further generate oil trapped in the core.

After water injection, surfactant injection is implemented into the core. Surfactant injection is implemented in the 4 pore volume and recovery factor result with 3.52% of injection surfactant, as seen in Table 5.

TABLE 5. Core Surfactant Injection Results

No	Code	PV oil (ml)	V oil (ml)	%V produced oil
1	SF 1	2.3	0.017	0.728
2	SF 2	2.3	0.019	0.826
3	SF 3	2.3	0.024	1.032
4	SF 4	2.3	0.022	0.936
		Recovery Factor		

As seen in The Table above, the core surfactant injection process represents 100,000 ppm salinity composition with 1% concentration and core, there is a 3.52% recovery factor improvement of the oil volume in the core.

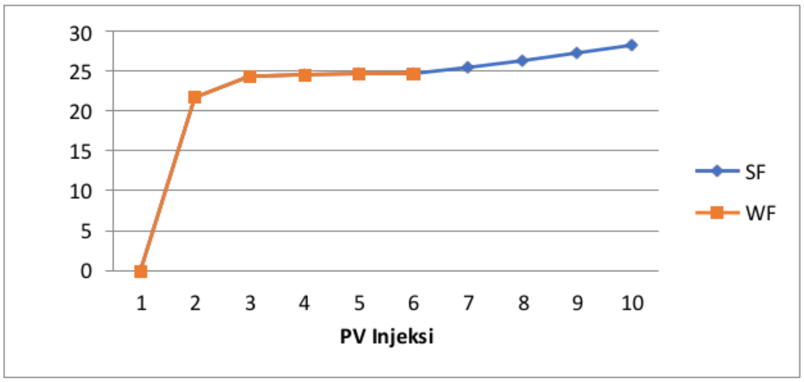

FIGURE 1. Research Flow Chart

Based on Table 4 and Table 5, the total RF of oil production from the core is at 28.26% of the total oil volume trapped in core. From the whole research data, to facilitate comparison of core flooding results, core flooding characteristic table that interprets the summary of the final testing data is generated as shown below.

TABLE 6. Core Flooding Characteristic Results

Salinity (ppm)	100.000
Concentration (%)	1
Core	Berea
Crude oil	Intermediate
Permeability (mD)	171.05
Produced water (ml)	2.2
Water Injection RF (%)	24.74
Surfactant Injection RF (%)	3.52
RF total (%)	28.26

On the table above, we also discovered that the surfactant concentration and core permeability influence recovery factor value. The higher the surfactant concentration, the higher the core permeability will be that would lead to higher oil volume generated from rock pores [20]..

CONCLUSION

Based on the research and the laboratory test results, it is evident that bagasse has the potential to be synthesized to produce sodium lignosulfonate (SLS) anionic sBased on the research data, we can conclude that fir wood lignosulphonate surfactant can be utilized in intermediate crude oil enhanced oil recovery process. The best lignosulphonate surfactant performance is produced on 100,000 ppm salinity and 1% surfactant concentration composition, by generating 3.52% of recovery factor. The higher the salinity level during fir wood lignosulphonate surfactant stability test, the higher the potential of colloid or suspension generation during the test. Similarly, the higher the surfactant concentration, the higher the chance of the solution generates colloid will be. Aqueous stability optimization on fir wood lignosulphonate surfactant was obtained on 1% surfactant concentration level. Based on that, surfactant concentration and formation water salinity influence fir wood lignosulphonate surfactant stability. As bio material, a suitable technic and composition design in lignosulphonate surfactant utilization on intermediate crude oil is important.

REFERENCES

1. A. Barati-Harooni, A. Najafi-Marghmaleki, A. Tatar, and A. H. Mohammadi, "Experimental and modeling studies on adsorption of a nonionic surfactant on sandstone minerals in enhanced oil recovery process with surfactant flooding," Journal of Molecular Liquids, vol. 220, pp. 1022- 1032, Aug. 2016, doi: 10.1016/j.molliq.2016.04.090.
2. Ansyori, M.R. (2018). Get to know Enhanced Oil Recovery (EOR) as a Solution to Increase Oil Production. Swara Patra, PPSDM Migas Scientific Magazine, Vol. 8, No. 2, 16.
3. Setiati, R. (2017). Synthesis and Characterization of Sugarcane Bagasse Lignosulfonate Sodium Lignosulfonate: Effect of Concentration and Salt Solution on Oil Pressure Performance in Core Rock. Dissertation, Bandung Institute of Technology.
4. Taiwo et al. 2016, Characterization of surfactant flooding for light oil using Gum Arabic
5. Taber, J. J., Martin, F. D., & Seright, R. S. (1997). EOR screening criteria revisited-Part 1: Introduction to screening criteria and enhanced recovery field projects. SPE reservoir engineering, 12(03), 189-198.
6. Priyanto., et al, 2021. Synthesis of Sodium Ligno Sulfonate (SLS) Surfactant from Black Liquor Waste and The Potential Test for EOR in Ledok Field Cepu
7. Zamrodah 2016, Impact of Surfactants as Detergent and Soap Manufacturer on The Environment and Health
8. Fattahanisa, A., R. Setiati, S. Kasmungin, and A. Ristawati. 2019. "The Alternative Solutions of Bagasse to Improve Indonesian Oil Production in Low Salinity." Journal of Physics: Conference Series 1402(3).
9. Abu Ghalia and Dahman 2017, Synthesis and utilization of natural fiber-reinforced poly (lactic acid) bionanocomposites
10. Yang, W., Lu, J., Wei, B., Yu, H. & Liang, T., 2021, Micromodel Studies of Surfactant Flooding for Enhanced Oil Recovery: A Review, ACS Omega, 6(9), 6064-6069
11. Ružinská et al. 2015, The Evaluation of Specific Environmental and Degradation Characteristics of Surface Treated Wood
12. Ahmad, Nasirudin Mahmud, and Lestari Said. 2015. "Analysis of Formation Water in Determining the Tendency of Scale Formation in Wells X, Y and Z." National Seminar of Scholars: 317-25.
13. Setiati, R., Aryani, E., Putri, M., & Wahyuningrum, D. (2016). Sulfonation of bagasse lignin to sodium lignosulfonate surfactant, 35-41.
14. Zhu, Youyi, Zhang, Yi, Hou, Qingfeng, Liu, Hualong, Jian, GuoqingEffect Of Oil And Water Interfacial Tension On Oil Recovery Of Surfactant-Polymer Flooding
15. Alli, Yani Faozani, Letty Brioletty, Hestuni Eni, and Yan Irawan. 2017. "Co-Surfactant Polyethylene Glycol Mono-Oleate in the Formulation of Natural Based-Surfactant for Chemical EOR." Scientific Contributions Oil and Gas 40(1): 1-8.
16. Song, Kao Ping, Wang, Cheng Cheng, Fu, Cheng, Wu, Xiao Hui, 2014. The Research of Water Flooding Measures in Late High Water Cut Period of Secondary Reservoirs
17. James G. Speight, Chapter 6 - Nonthermal Methods of Recovery, Editor(s): James G. Speight, Enhanced Recovery Methods for Heavy Oil and Tar Sands, Gulf Publishing Company, 2009, Pages 185-220, ISBN 9781933762258, https://doi.org/10.1016/B978-1-933762-25-8.50011-0
18. Shao, Xian Jie, Kang, Yuan Yuan, Wang, Cai Feng, Gao, Er Shuang, 2013. Technologies for Reusing Resources in Abandoned Oilfield after Tertiary Oil Recovery
19. Campbell CB, Denslow TA, Gabriel P, Adam CJ. 2009. Enhanced Oil Recovery Surfactant Formulation and Method of Making the Same. Chevron Coorporation. US Patent 2009/0111717 A1.
20. Ristawati, A., R. Setiati, S. Kasmungin, and A. Fattahanisa. 2019. "The Alternative Solutions of Bagasse Waste Utilization to Improve Recovery Factors in Reservoir with High Salinity." Journal of Physics:

Conference Series 1402(3).
21. Yang et al. 2012, Advance water-flooding to reduce the stress sensitivity affect on low permeability reservoir development

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