International Journal of Current Science Research and Review
ISSN: 2581-8341
Volume 07 Issue 07 July 2024
DOI: 10.47191/ijcsrr/V7-i7-83, Impact Factor: 7.943
IJCSRR @ 2024
www.ijcsrr.org

The Effect of Alpha Olefin Sulphonate (AOS) Surfactant Injection on Sandstone Rock on Increasing Oil Recovery with Variations in Salinity, Concentration, and Temperatures: A Laboratory Study

Widia Yanti[1], P. Pauhesti[2], Dharma Setiawan S. Mokoapat[3], Reno Pratiwi[4], Arinda Ristawati[5]
[1,2,3,4,5] Department of Petroleum Engineering, Faculty of Earth Technology and Energy, Universitas Trisakti, Jl. Kyai Tapa No. 1 Grogol Jakarta Barat, Jakarta, Indonesia
[1] PhD Student, Graduate School, Chulalongkorn University, Soi Chula 12 Phaya Thai Rd, Bangkok, Thailand

ABSTRACT: In this study, Alpha Olefin Sulphonate (AOS) surfactant was injected. This laboratory test aims to verify the correlation between a surfactant solution's low IFT value and its ability to yield a high oil recovery value. The salinity used in this research was 5000 ppm and 15000 ppm. Then it was mixed with AOS surfactant at concentrations of 0.5%, 1%, and 2%. At the same time, the temperatures used are 30 °C and 60 °C. After testing, it was found that a solution with a salinity of 15,000 ppm and a surfactant concentration of 2% had the lowest IFT value and was proven to have a total RF of 73%.

KEYWORDS: AOS, oil recovery, surfactant injection, sandstone rock, RF, laboratory study

INTRODUCTION

According to the BP Statistical Review of World Energy in 2013, there has been a notable reduction in oil production in Indonesia since 1995 [1]. Nevertheless, oil consumption continues to rise annually as a result of economic expansion. This phenomenon gives rise to an imbalance between the demand for and supply of oil [2]. Hence, in order to establish a state of stability, it is imperative for the Indonesian government and oil firms to collaborate in augmenting the production of oil from the presently operational oil fields within Indonesia [3]. One potential technological solution for mitigating the decline in natural reservoir pressure is Enhanced Oil Recovery (EOR). One of the EOR techniques employed in this investigation is chemical injection, sometimes referred to as chemical flooding [4].

Chemical flooding, an EOR technique, is gaining significance in the industry for its ability to recover residual oil that remains trapped after primary and secondary recovery methods have been employed. The current study has implemented a chemical flooding technique known as surfactant injection, or surfactant flooding. Various chemical compositions and combinations were employed in the oil recovery process following traditional waterflooding [5]. Through the use of primary and secondary methods of oil recovery, such as artificial lift and waterflooding, the average oil recovery remains within the range of 5–30% [6]. Nevertheless, subsequent to the implementation of primary and secondary recovery techniques, the quantity of original oil in place remains substantial, estimated to be over 50 billion barrels [7]. The application of EOR presents a potential opportunity for implementation, wherein the recovery of oil can range from 5% to 65% of the original oil in place [6].

Enhanced oil recovery (EOR), also known as tertiary recovery, is a potential solution to address the generally poor recovery efficiency associated with petroleum production systems [8]. According to estimates provided by the United States Department of Energy, the complete implementation of improved oil recovery techniques within the United States has the potential to yield an additional 240 billion barrels of oil [9].

According to the US Department of Energy's findings, thermal recovery, gas injection, and chemical injection are the three main methodologies for using EOR. In this investigation, the reservoir will undergo surfactant injection, which is a chemical injection procedure. The rationale for choosing this particular technique lies in the fact that the addition of surfactants has garnered significant interest due to their capacity to diminish the surface/interfacial tension (IFT) between fluids that are not mutually soluble.

The significance of interfacial tension is of great importance in the enhanced oil recovery process. The IFT decreases as the concentration of surfactant increases [9].

International Journal of Current Science Research and Review
ISSN: 2581-8341
Volume 07 Issue 07 July 2024
DOI: 10.47191/ijcsrr/V7-i7-83, Impact Factor: 7.943
IJCSRR @ 2024
www.ijcsrr.org

Surfactants refer to chemical compounds that have the ability to adsorb onto surfaces or concentrate at the interface between two fluids, thereby causing major modifications to the interfacial characteristics. Notably, one of their key effects is the reduction of IFT [10]. The classification of surfactants is determined by the hydrophilic component, which can be categorized as anionic, cationic, amphoteric or zwitterionic, and nonionic [9]. This investigation will utilize AOS surfactants.

Alpha Olefin Sulfonate (AOS) surfactants are classified as anionic surfactants and are extensively utilized in EOR procedures because of their favorable characteristics, such as their limited adsorption on sandstone rocks that possess a negative surface charge [5]. In addition, it is worth noting that AOS surfactants exhibit exceptional detergency capabilities, have a high level of compatibility with hard water, and possess favorable wetting and foaming qualities when used in conjunction with CO_2, even in situations where the porous medium is only partially saturated with oil. The aforementioned characteristics render AOS surfactants highly suitable for use in enhanced oil recovery (EOR) initiatives, which seek to augment oil production from subterranean reservoirs [11]. In addition, it has been observed that AOS surfactants exhibit favorable stability even at elevated temperatures [12].

The economic considerations surrounding surfactant injection are of significant importance due to the substantial expenses associated with the chemicals involved. Therefore, it is necessary to construct and consider an optimal injection method [13]. This study aims to to verify the correlation between a surfactant solution's low IFT value and its ability to yield a high oil recovery value.

MATERIALS AND METHODS

The present investigation is conducted at a laboratory scale. Conducting laboratory scale studies is of paramount importance prior to using a certain approach or technology in real-world field settings. The oil utilized in this investigation is characterized as light oil with an American Petroleum Institute (API) gravity of 43.34. The salinity levels employed in this investigation were 5000 and 15000 parts per million (ppm). Subsequently, it was combined with AOS surfactant at varying concentrations of 0.5%, 1%, and 2%. The temperatures employed in this study are 30 and 60 °C. To obtain further information, it is necessary to adhere to the experimental procedure outlined in this study. This procedure encompasses the following steps: (a) The preparation of brine solutions; (b) The preparation of the surfactant; (c) The measurement of physical properties of the core, specifically porosity and permeability; (d) The measurement of physical properties of the brine and surfactant solution, including density, specific gravity (SG), viscosity, and interfacial tension (IFT); and (e) The injection process of the brine and surfactant into the reservoir model.

The research conducted in this laboratory commenced with the initial step of creating a brine solution. This involved combining 5 grams of NaCl with 1 liter of distilled water to achieve a brine concentration of 5000 ppm. Dissolve 15 grams of sodium chloride (NaCl) in 1 liter of distilled water to obtain a concentration of 15000 parts per million (ppm). Next is the process of injecting the surfactant solutions into the brines. The AOS surfactants that were injected into brine are at concentrations of 0.5%, 1%, and 2%. Subsequently, the solution's physical characteristics, including specific gravity, interfacial tension, viscosity, and density, were assessed at temperatures of 30 and 60 °C. Choose the injection solution with the lowest IFT value, since this study aims to verify the correlation between a surfactant solution's low IFT value and its ability to yield a high oil recovery value. The subsequent step involves desiccating the core specimens and determining their weight once the moisture has been removed. Additionally, the dimensions of the samples, specifically their length and diameter, should be measured. Next, the core sample is fully immersed in the chosen brine solution until it becomes completely saturated. Then, the weight of the sample is measured while it is still wet. This is to ascertain the porosity value of the core specimen. First, the rock sample is infused with oil, and the resulting water (V_{oil}) is measured. Then, the core sample is soaked in oil for a period of one day. After that, the core sample is injected with water (a process known as waterflooding), and the value of Recovery Factor (RF) brine ($V_{oilprod}$) is determined. Finally, the core sample is injected with a chosen surfactant solution, and the resulting RF surfactant is recorded. Combining the results of both waterflooding and surfactant injection will yield the cumulative RF value. Figure 1 is the flowchart of the research.

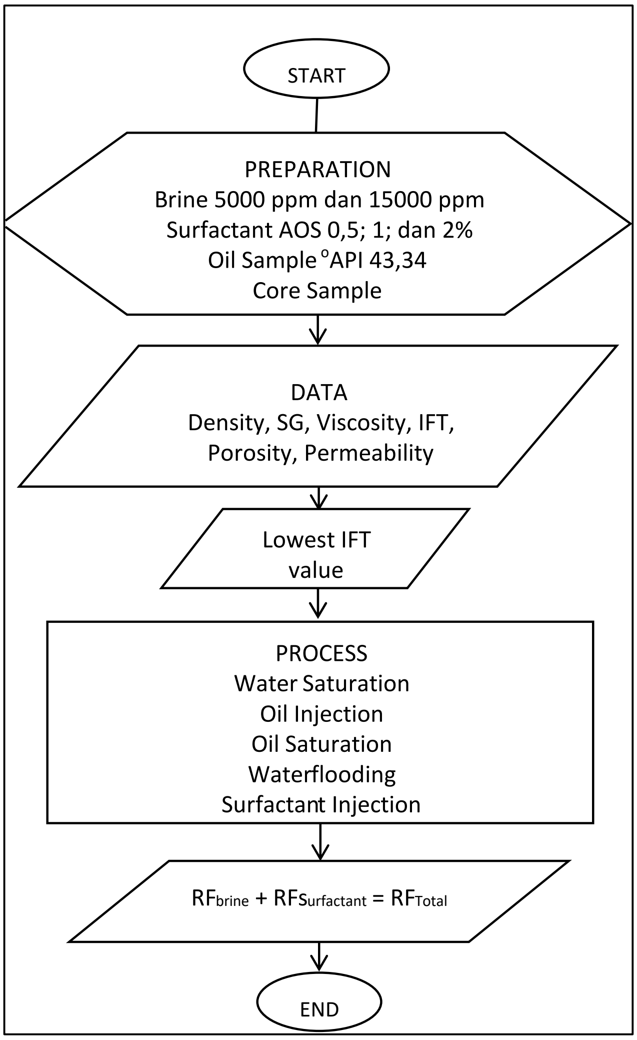

Figure 1. Research flowchart

RESULT AND DISCUSSIONS

As previously mentioned, the brine solution used in this study was brine with a salinity of 5000 and 15000 ppm. Meanwhile, the surfactant solution used is made by mixing the AOS concentration into a previously made brine solution with a concentration of 0.5, 1, and 2%. It means the AOS surfactants are each 5 ml, 10 ml, and 20 ml. For more details, see Table 1 below.

Table 1. Salinity and concentrations of the brine and surfactant solution

Salinity, ppm	AOS Concentration, %
5000	0.5
	1
	2
15000	0.5
	1
	2

International Journal of Current Science Research and Review
ISSN: 2581-8341
Volume 07 Issue 07 July 2024
DOI: 10.47191/ijcsrr/V7-i7-83, Impact Factor: 7.943
IJCSRR @ 2024
www.ijcsrr.org

After preparing the brine and surfactant solutions, we conducted the measurement of the physical properties of the solutions. The physical properties of the solution to be counted were viscosity (brine and surfactant solutions), density at temperatures 30 and 60°C (brine and surfactant solutions), and surface tension (brine and surfactant solutions). The viscosity is measured using a viscometer Oswald. Then the density is measured using density meter. Meanwhile the surface tension is measured using tensionmeter Du Nouy.

Table 2 is the result of physical property measurements of the brine solutions. Meanwhile, Table 3 is the result of the physical property measurements of the surfactant solutions. It can be seen that chemical injection into brine solutions will have an effect on their physical properties.

Table 2. The result of physical property measurements of the brine solutions

Salinity, ppm	Temperature, ºC	Density, gr/cm^3	Specific Gravity	Viscosity, cP
5000	30	0.9986	1.0030	3.50
	60	0.9811	0.9965	2
15000	30	1.0051	1.0095	3.60
	60	0.9876	1.0032	2.70

Based on the density measurement results in Table 3, increasing the surfactant concentration can increase the density value. Conversely, an increase in temperature will reduce the density value. This is caused by expansion when the temperature is increased. Based on the results of measurements of specific gravity (SG) in Table 3, an increase in temperature can affect the SG value; the greater the temperature, the smaller the SG value. This is because the SG formula is the fluid density divided by the water density. Based on the viscosity measurement results in Table 3, the viscosity value decreases as temperature increases. This is because the higher the temperature, the more dilute a solution will be. Meanwhile, increasing concentrations will increase the viscosity value. This is because the more solution that is mixed, the thicker the solution will become.

Table 3. The result of physical property measurements of the surfactant solutions

Salinity, ppm	Temperature, ºC	AOS Concentration, %	Density, gr/cm^3	Specific Gravity	Viscosity, cP
5000	30	0.5	0.9979	1.0023	3
		1	0.9982	1.0026	3.87
		2	0.9985	1.0029	4.05
	60	0.5	0.9836	1.0001	2.15
		1	0.9860	1.0007	2.50
		2	0.9864	1.0012	2.95
15000	30	0.5	1.0056	1.0100	2.08
		1	1.0061	1.0105	2.88
		2	1.0067	1.0116	3.9
	60	0.5	0.9831	1.0023	2.50
		1	0.9912	1.0081	2.70
		2	0.9914	1.0086	3

To see the effect of surfactant injection on interfacial tension (IFT), IFT testing was carried out. IFT testing in this study was carried out using a Du Nouy tensiometer. Tested five times at various salinity concentrations and temperatures. The results of this test are shown in Table 4.

As this research aims to verify the correlation between a surfactant solution's low IFT value and its ability to yield a high

International Journal of Current Science Research and Review
ISSN: 2581-8341
Volume 07 Issue 07 July 2024
DOI: 10.47191/ijcsrr/V7-i7-83, Impact Factor: 7.943
IJCSRR @ 2024
www.ijcsrr.org

oil recovery value, then we chose the injection solution with the lowest IFT value. Based on the IFT measurement results in Table 4, it can be seen that the solution with a salinity of 15,000 ppm and a surfactant concentration of 2% had the lowest IFT value. Hence, a surfactant with a brine concentration of 15,000 ppm and a 2% concentration was selected for use in the core flooding test.

Table 4. The result of IFT measurement on the variation of concentration, salinity, and temperature

Salinity, ppm	Temperature, ºC	AOS Concentration, %	1	2	3	4	5	IFT (average)
5000	30	0.5	17	18	19	23.5	23	20.1
		1	17	18	17	16	16	16.8
		2	19	12	19	17	16	16.6
	60	0.5	9	15	15	17	11	13.4
		1	10	12	9	10	10	10.2
		2	9	8	7	9	12	9
15000	30	0.5	15	17	11	8	15	13.2
		1	11	8.5	10.5	8,5	17	11.1
		2	10	11	9	12	10	10.4
	60	0.5	19	18	17	15	16	11.3
		1	9.5	15.5	17	15	10	10.2
		2	9.5	6	5.5	6.5	5	6.5

Next, the porosity and permeability of the rock cores used in this study were tested, respectively, at 26.78% and 521.57 mD. Finally, the results of brine and surfactant injection were tested on the core to see the effect of surfactant injection. For more details, see Table 5.

Table 5. The result of surfactant injection

No.	Brine (mL)	Surfactant (mL)
1	1,55	0
2	0	0
3	0	0,2
4	0	0,1
5	0,05	0,1
Total	1,6	0,4

Table 5 shows the outcome of the core flooding test. For this experiment, two solutions were employed. Specifically, Solution I consisted of brine with a salinity of 5000 ppm and a concentration of 0.5%. On the other hand, Solution II is a highly concentrated saltwater solution with a salinity of 15,000 parts per million and a surfactant content of 2%. The results of the fluid interfacial tension test, which produced low values, guided the selection of these surfactant solution concentrations.

Testing was carried out in several stages. The first stage was testing the core sample, whose dry weight had been measured, and then it was saturated with brine water for one day. Next, the wet weight of the core sample was weighed. The core was inserted into the core holder and injected with oil. The water produced was then recorded. This produced water represented the oil stored in the core (Voil). The Voil value of this core was 2.7 mL. After the core had been saturated with oil, it was soaked in oil for one day. Next, the core, which was saturated with oil, was injected with water (waterflooding). The oil produced was then recorded as production Voil. The recovery factor resulting from this process was then recorded. After the waterflood testing was complete, the injection fluid was replaced with surfactant. As in the previous process, the amount of oil produced and the resulting recovery factor were also recorded. Finally, the recovery factor (RF) of the core was calculated using the Recovery Factor formula [14].

International Journal of Current Science Research and Review
ISSN: 2581-8341
Volume 07 Issue 07 July 2024
DOI: 10.47191/ijcsrr/V7-i7-83, Impact Factor: 7.943
IJCSRR @ 2024
www.ijcsrr.org

RF Solution = $\frac{V_{oilprod}}{V_{oil}}$ (1)

By implementing formula (1), we could calculate the RF Brine and RF Surfactant.

RF Brine = $\frac{1{,}6\ mL}{2{,}7\ mL} = 59\%$

RF Surfactant = $\frac{0{,}4\ mL}{2{,}7\ mL} = 14\%$

The RF brine is the value of RF that resulted from the waterflood testing. Meanwhile, the RF surfactant is the value of RF that resulted from the surfactant injection testing. The RF for 15,000 ppm brine solution with a concentration of 2% was 59% for the waterflooding testing and 14% for surfactant testing. The overall RF of this solution was determined by adding together the RF of the brine and the RF of the surfactant, resulting in a value of 73%.

CONCLUSION

Based on the results and analysis in the previous section, we can conclude that:

1. The brine solution, containing 15,000 ppm of salinity and a surfactant concentration of 2%, exhibits the lowest IFT value. This solution has been demonstrated to have a surfactant RF of 14% and a cumulative RF value of 73%.
2. It has been empirically demonstrated that the inclusion of temperature significantly impacts the outcomes of the physical characteristics of the injection fluid. This is evident from the findings of density, viscosity, and specific gravity tests, which exhibited a decrease following testing at a temperature of 60 °C. At a temperature of 30 °C, the density of a salinity solution with a concentration of 2% and a salinity level of 15,000 ppm is measured to be 1.0067 g/cc. However, when the temperature is increased to 60 °C, the density decreases to 0.9914 g/cc.
3. The IFT calculation findings indicate that a significant rise in surfactant concentration leads to a corresponding reduction in IFT, resulting in high values. The brine concentration can be observed through the measurements of 0.5%, 1%, and 2%. The IFT value drops from a concentration of 0.5% to 11.3 dyne/cm. The concentration of 1% corresponds to a surface tension of 10.2 dyne/cm. The minimum concentration of 2% is 6.5 dyne/cm.

Due to the preliminary study of this research, additional calculations and testing are required to examine the influence of AOS surfactant concentration on oil recovery using surfactant injection technology, including defining the critical micelle concentration (CMC) point.

REFERENCES

1. BP Statistical Review of World Energy in 2013. Accessed on October 29, 2023. http://crudeoilpeak.info/peak-oil-and-fuel-subsidies-in-indonesia
2. Abdurrahman, M., Bae, W., Novriansyah, A., and Khalid, I. 2016. Enhanced oil recovery (EOR) challenges and its future in Indonesia. In Proceedings of The IRES 28th International Conference.
3. Yanti, W., Kasmungin, S., Adawiyah, R., and Kolanus, B. 2017. Laboratory study of salinity and surfactant concentration effects on oil recovery. MATEC Web of Conferences.
4. Pauhesti, P., Kasmungin, S., and Hartono, K.F. 2017. Uji Laboratorium untuk meningkat perolehan minyak menggunakan injeksi surfaktan AOS konsentrasi rendah. PETRO Jurnal Ilmiah Teknik Perminyakan 4(2): 66-70.
5. Samanta, A., Bera, A., Ojha, K., and Mandal, A. 2012. Comparative Studies on Enhanced Oil Recovery by Alkali-Surfactant and Polymer Flooding. Journal of Petroleum Exploration and Production Technology Vol. 2: 67-74.
6. Lake, L.W. 1989. Enhanced Oil Recovery. Prentice Hall.
7. SKK Migas Annual Report 2012. Accessed on July 10, 2024. https://www.scribd.com/doc/163061954/SKK-Migas-Annual-Report-2013
8. Curbelo, F.D.S., Garnica, A.I.C., Dantas, T.N.C., and Neto, E.L.B. 2008. Oil recovery by ionic surfactant and sweep efficiency study in sandstones. Brazil Journal of Petroleum and Gas 2(1): 9-16
9. Xavier, J. 2011. Effect of varying surfactant concentration on interfacial tension in tertiary recovery of crude oil. MSc Thesis. Dalhousie University.
10. Green, D.W. and Willhite, G.P. 1998. Enhanced oil recovery. Society of Petroleum Engineers Textbook Series Vol. 6.

11. Farajzadeh, R., Krastev, R., and Zitha, P.L.J. 2008. Foam films stabilized with alpha olefin sulfonate (AOS). Colloids and Surfaces A Physicochemical and Engineering Aspects 324: 35-40.
12. AOS definition. Accessed on November 1, 2023. http://jpchemicals.in/a-o-s
13. Babadagli, T., Al-Bemani, A., Boukadi, F., and Al-Maamari, R. 2002. A laboratory feasibility study of dilute surfactant injection for the Yibal Field Oman. Journal of Petroleum Science and Engineering 48(1-2): 37-52.
14. Fadilah, M. (2021). Pemanfaatan minyak jelantah untuk bahan surfaktan dalam proses peningkatan perolehan minyak bumi. Final Assignment. Trisakti University Jakarta.

Cite this Article: Widia Yanti, P. Pauhesti, Dharma Setiawan S. Mokoapat, Reno Pratiwi, Arinda Ristawati (2024). The Effect of Alpha Olefin Sulphonate (AOS) Surfactant Injection on Sandstone Rock on Increasing Oil Recovery with Variations in Salinity, Concentration, and Temperatures: A Laboratory Study. International Journal of Current Science Research and Review, 7(7), 5577-5583