The utilization of Surfactant on enhanced oil recovery chemical injection to maintain energy in Indonesia

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Abstract. The needs of oil in the world for the transportation, industry, power plant and other fields drive us to be more consumptive in the utilization. Oil needs in Indonesia that keeps on increasing along the years is unequal with the number of oil exploration activity, which further create a scarcity on fossil energy fuel source availability. If Indonesia is unable to discover new oil sources as soon as possible, Indonesia is predicted to become oil importer in 2025. Oil production is known to be practiced through three steps which are primary recovery, secondary recovery, and tertiary recovery. At this moment, several oil wells in Indonesia have reached final stages of secondary recovery. If the production activity on these wells is continued, the recovered oil will never be able to reach optimum result and will unable to cover the production cost. Because of that, oil development and production management projects will never be able to run. The offered solution to fulfill this energy needs is by conducting tertiary recovery method known as Enhanced Oil Recovery (EOR). EOR method is known to be able to optimize oil recovery as much as 30% of total remaining reserve on an oil or gas field. One of EOR method that will be the focus in this research is chemical injection or chemical flooding, where a certain chemical compound is injected into the reservoir with an objective of reservoir physical or chemical manipulation to facilitate oil production to the surface. The material required for chemical flooding are surfactant, alkali, and polymer. On the previously conducted research at EOR Laboratory Universitas Trisakti is aimed to observe the impact of surfactant concentration on water formation salinity on phase and interfacial tension (IFT) tests to improve surfactant performance on EOR process to optimize recovery factor (RF) or oil production. Chemical ingredients used in this research are anionic surfactants which are Alpha Olein Sulfonate (AOS) and paraffin oil. The utilization of surfactant solution concentration is 0.5%, 1%, 1.5% and 2%. Meanwhile formation salinities are at 10,000 ppm, 15,000 ppm, and 20,000 ppm. The emulsion formed from the phase test is an upper phase. The factor of emulsion phase formation is high interfacial tension and the utilized surfactant basic ingredient is a petroleum based ingredient. The result of IFT measurement on surfactant solution possess a value range of 16 dyne/m to 41 dyne/m. Based on the research result and conducted analysis, the utilized AOS surfactant in this research is proven to be able to lower significant IFT of water and oil on emulsion percentage formed and stable at 18.75% on 1.5% concentration with water salinity of 15,000 ppm.

1. Introduction
The needs of energy are very crucial, especially on industrial and public transportation fields. The dependency of oil energy source has depleted our oil reserve. Because of that, it is important to find the
best solution to improve oil production. One of which is by increase oil production by Enhanced Oil Recovery method (EOR).

The definition of EOR is a method of oil production improvement through gas injection, chemical injection, or thermal injection techniques. The method is proven to be able to improve oil production. In this research, we will discuss chemical injection conducted on EOR step or as known as chemical flooding and stable emulsion formation. The chemical compounds used in chemical flooding are surfactant, polymer, and alkali.

2. Literature review
The chemical compound used in the application of chemical flooding method is surfactant. The definition of surfactant (surface active agent) is a molecule that possesses hydrophilic polar group and lipophilic non-polar group [1]. Perkins explains that surfactant utilization is highly popular because its ability to influence surface and interface natures of two phases that are unable to come together. We can see in Figure 1 an illustration of polar and non-polar groups contained by surfactant [2].

Setiati explains that the function of surfactant is to lower interfacial tension (IFT) that would break interfacial tension of oil and water, and create an emulsion which is a surfactant that would dissolved in water or oil. The formed emulsion will facilitate oil to move outside the rock pores [4]. Perkins explains that surfactant aggregate molecule in the water is grouped and create a micelle. Micelle is started to form on critical micelle concentration (CMC) situation. Micelle consists of hydrophobic interior upper area, where hydrophobic tails are coming together. In this area, the lipophilic tails are surrounded by hydrophilic, which is a place where surfactant molecule heads interact with water [2].

Sheng in his book titled Modern Chemical Enhanced Oil Recovery: Theory and Practice, explains his research on laboratory scale EOR. Sheng explains that the most basic part of EOR research is the phase test [5]. Sandersen further explains that the most influencing parameters of a phase test are surfactant concentration, co-surfactant, salinity, oil type and temperature [6]. Kayali explains that phase test is conducted to acknowledge IFT information on surfactant produced from microemulsion formation in surfactant system, formation water and oil. This is highly connected with IFT as an important factor of oil production through microemulsion formed on chemical flooding process [7].

Microemulsion classification introduced by Winsor in 1948 and as quoted from Surfactants Chemistry book written by Eastoe which identifies three types of microemulsion formation starting from type I that explains when surfactant is mixed with oil, the result tends to form oil microemulsion on
water (O/W) or as known as Winsor type I. Microemulsion formed is a lower phase because of the surfactant nature that easily dissolved in water if compared to oil. Type II explains that when surfactant is mixed with oil, the inclination is that microemulsion water on oil is formed (W/O) or known as Winsor type II. The formed microemulsion is an upper phase, which is caused by the nature of surfactant that more easily to dissolved into oil than water. Type III explains when surfactant is mixed with oil, the result is the formation of three phases. This condition is known as middle phase because the formed microemulsion is stable between oil and water [8].

Based on Figure 2, as quoted from a book written by Sheng [5], when a surfactant solution with a series of formation water salinities are mixed with oil, it will produce microemulsion formation. There are three types of microemulsion formations namely Winsor I (oil in water) microemulsion, Winsor II (water in oil) microemulsion, and Winsor III microemulsion.

![Figure 2. Microemulsion formed by phase test on surfactant-formation water-oil system](image)

There are many researches or papers that analyze the impact of chemical flooding on oil production with certain rock formation. Based on a number of literatures that report laboratory scale researches, this type of research has been regularly conducted. However researches that covers its application on Indonesian oil field is very rarely done. In Indonesia, the national oil field owned by Chevron and Tac field owned by Pertamina are examples of fields that already conducted surfactant injection [10].

As written by Oman Energy Services, the utilization of surfactant on a field scale has been implemented all over Western Canadian Sedimentary Basin areas on limestone, shale and sandstone rock formation to produce heavy paraffin and asphaltenes crude oil [11].

Chemical flooding process is commonly used on polymer injection, surfactant-polymer injection, and alkali-surfactant-polymer injection (ASP). The polymer injection technology utilizes the nature of polymer to improve water injection viscosity and more efficient on thick oil. The addition of surfactant is intended to lower IFT value. The addition of alkali is aimed to lower surfactant retention on rock formations [12].

Kristanto and Bintarto wrote a paper on surfactant utilization concept development. Their first concept is low concentration of surfactant solution injection. The objective of this activity is to lower IFT value on oil and water. The second concept is high concentration solution injection into the reservoir with a relatively low volume. In this concept micelles with stable dispersion nature are formed in both water on hydrocarbon and hydrocarbon on water [13].
3. Research methodology
This research is conducted through several stages that include surfactant solution production and formation water with different concentration and salinity, phase test, and IFT measurement. The following Figure 3 shows the flow of research scheme.

![Figure 3. Research scheme.](image)

4. Results and discussion
The observation of solution based surfactant characteristics which includes phase test is one of the most basic areas in EOR research and surfactant injection test to recover remaining oil reserves. AOS surfactant is utilized as solution sample with 0.5%, 1%, 1.5%, and 2% concentration levels and 10,000 ppm, 15,000 ppm and 20,000 ppm water formation salinity. This research is expected to be able to produce a surfactant that is able to lower interfacial tension between oil and water while also form a stable emulsion.

4.1. Phase test
Phase testing was conducted by using pipette tubes, ovens, and surfactant solution samples to observe the emulsion content formed within 0 hours, 0.5 hours, 1 hour, 2 hours, 24 hours, 48 hours, and 168 hours at a constant temperature of 60°C. The phase test is expected to produce a stable emulsion. The phase test on twelve surfactant samples resulted in formation of the top phase emulsion. This can occur because of the high IFT value and the more dominant AOS surfactant properties to mix with oil. The results in Figure 4 show a surfactant sample with a concentration of 1.5% and a formation water salinity of 15,000 ppm. After heating in the oven for 24 hours, the surfactant, emulsion and oil in the pipette tube are clearly visible.
Figure 4. Illustration of Surfactant Solution Phase Test with 1.5% concentration and 15,000 ppm salinity.

Phase test is continued by using pipet tube and oven on the twelve surfactant solution with different concentration and formation water salinity. The objective is to acknowledge the characteristic of surfactant used in this research and the limit of emulsion formation inside 0 hour, 0.5 hour, 1 hour, 2 hours, 24 hours, 48 hours, 504 hours and 168 hours on a constant 60°C temperature. Phase test activity is expected to be able to form a stable emulsion on certain time period. The phase test on twelve surfactant solution produces an upper phase emulsion. This can happen because IFT value of surfactant solution, high formation water salinity and AOS surfactant characteristic used in this research is more dominant to mix with oil. This result, as can be seen in Figure 4, shows that the formed emulsion on the upper water formation line is more dominant to be mixed with oil, after 0.5 hour of measurement activity. After being heated in an oven for 2 hours, we can clearly see the line of surfactant, emulsion and oil in pipet tube.

On a range of 24 hour, the formation of emulsion line is drastically decreasing in the pipet tube although it is still categorized as upper phase. The phase test on 2 hours for 0.5% surfactant solution with 15,000 ppm formation water salinity have shown 42.5% or 1.7 ml of emulsion out of 4 ml surfactant solution with paraffin oil in pipet tube. The next phase test on 24 hour of time, the emulsion line formed experiences lower decrease than the previous condition which is at 32.5% or 1.3 ml of total 4 ml. The emulsion line formed on 48 hour is at 27.5% or 1.1 ml of total 4 ml mixture of surfactant solution with paraffin oil in pipet tube.

During phase test on the 168 hour, the emulsion decrease still happening at 13.8% or 0.55 ml of the total 4 ml. Based on the observation results, we can say that the emulsion formed in this research is still unstable. During the 504 hour phase test, emulsion decrease was identified although it is at a very low level which is at 0.5 ml or 12.5% of the total 4 ml. After that, during phase test on the 672 hour, emulsion decrease is unidentified because emulsion level is the same as before which is at 12.5% or 0.5 m of total 4 ml. This event can indicate that the emulsion is already stable. The emulsion decrease line of total 1.5% total surfactant with formation water salinity at 15,000 ppm respectively at 0 hour, 0.5 hour, 1 hour, 2 hours, 24 hours, 48 hours, 504 hours and 168 hours is at 2.3 ml, 2.1 ml, 1.63 ml, 1.2 ml, 0.85 ml, 0.8 ml, 0.75 ml, or in percentage is respectively at 57.5%, 52.5%, 50%, 40.8%, 30%, 21.3%, 20%, 18.75%, and 18.75%. The emulsion at 1.5% concentration with formation water salinity of 15,000 ppm
can be said as a stable condition during phase test at 672 hours with emulsion limit of 18.72% or 0.75 ml of total 4 ml.

4.2. Injection test

Based on the injection test conducted by using nine types of sandpack and nine surfactant solutions, we obtain the results as presented in the following Table 1.

| No. | Formation Water (ppm) | Surfactant (%) | Total RF (%) | SOR (%) |
|-----|------------------------|----------------|--------------|--------|
| 1   | 10,000                 | 1%             | 73.33        | 15.8   |
| 2   | 10,000                 | 1%             | 75           | 13.2   |
| 3   | 10,000                 | 2%             | 73.33        | 15.8   |
| 4   | 15,000                 | 1%             | 71.88        | 17     |
| 5   | 15,000                 | 1.5%           | 73.75        | 15.6   |
| 6   | 15,000                 | 2%             | 70           | 18.4   |
| 7   | 20,000                 | 1%             | 68.75        | 19.4   |
| 8   | 20,000                 | 1.5%           | 71           | 17     |
| 9   | 20,000                 | 2%             | 69           | 21.1   |

Based on the test conducted on nine surfactant solutions with different concentrations and salinities, we obtained variations of RF values. As we can see in Table 1, the RF value is influenced by surfactant concentration and formation water salinity. Up until surfactant 1.5%, oil production reaches optimum level with similar water salinity and formation. If we compare the RF value result, the solution with similar concentration tends to experience decrease. Figure 5 shows the highest RF value at 75% on 1.5% surfactant concentration formation water salinity 10,000 ppm.

![RF graphic on Surfactant injection result.](image)

On 1.5% surfactant concentration with formation water salinity of 15,000 ppm, RF value is produced at 73.75%. The value is further decreased with lowest RF percentage of 71% on 1.5% surfactant concentration with 20,000 ppm salinity. Based on the result of surfactant injection observation, we obtain optimum RF value at 75% from 2% surfactant concentration with formation water salinity of
20,000 ppm. The finding explains that oil pumping effort through surfactant injection is influenced by surfactant concentration and formation water salinity.

In an effort to maintain energy in Indonesia, the use of surfactants must achieve optimum oil recovery conditions. The largest oil recovery occurred in the use of 1.5% surfactant with an RF value of 75%, which means that up to 75% of oil reserves could still be produced with the use of only 1.5% surfactant. This applies to oil fields that have a formation water salinity of 10,000 ppm. If the oil field has a salinity of 15,000 ppm, the largest oil recovery is only achieved at an RF value of 73.75%, while in an oil field that has a salinity of 20,000 ppm, the largest oil recovery only reaches 71%.

5. Conclusion
Based on the results of research and analysis, the optimization of AOS surfactant of 1.5% used in this study was able to produce an increase in oil recovery by 71% - 75% adjusted to the salinity of the oil field. So the use of AOS surfactants is able to increase the recovery factor of oil in an effort to meet energy needs in Indonesia.

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