Initial screening of AOS, its performance in EOR to improve oil recovery

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Abstract. Continuous increasing of fuel need in Indonesia, at least in the last ten years, is the reason for improving domestically crude oil production. Exploitation in the form of oil drainage activities needs to be investigated further. Surfactants as an agent that believed can reduce interfacial tension, need to be determined the formulation and compatibility in their use for oil drainage from reservoirs. Screening of the conditions of surfactant operation needs to be done in order to provide optimal oil recovery. In this study a surfactant behavior test was carried out on AOS (Alpha Olephin Sulfonate) in a laboratory scale, using sandpack as a sandstone reservoir rock prototype, measured the effect of salinity and concentration on oil recovery in chemical flooding, where interfacial tension (IFT) as the main variable. From the measurements, it was found that a surfactant concentration of 1.5% worked optimally in formation water with a salinity of 10,000 ppm, by producing IFT of 16.75 mN/m and recovery factor of 7.5%. This is compatible with the properties of AOS surfactants which can work well in solutions with low salinity. The emulsion formed shows that the surfactant works in the upper phase, or tends to dissolve in oil, correlates with the basic ingredients of surfactant which is an oil base.

1. Introduction
Energy sources based on fossils are still the excellent in their use in various fields of life. Because their needs tend to increase, efforts need to be made to obtain more optimal petroleum. One of the activities to increase oil production is the Enhance Oil Recovery (EOR). This method is considered to optimize the acquisition of oil by approximately 30% of the remaining reserves in an oil and gas field [1-3]. One of the EOR methods that will be the subject of this research is chemical injection or chemical flooding. Certain chemicals that are injected into the reservoir will manipulate the physical and chemical properties of the reservoir so that oil will be more easily produced to the surface [4,5].

Surfactant is a molecule that has a polar and non-polar group, which is widely used because it has the ability to affect the surface properties and interfaces of two-phase layers that are not mutually insoluble. The function of this surfactant is to reduce the interfacial tension (IFT) which has an impact on the breakdown of the oil-water interfacial tension so that oil in water or water in oil emulsion is formed [5,6]. If the emulsion can be formed, it is believed that oil will move more easily and out of the pores of the rock. The surfactant aggregate molecules can form micelle if the surfactant concentration used reaches its critical limit (CMC) [7]. Micelle consists of a hydrophobic interior area, where the hydrophobic tails join together. In this area, the lipophilic tail is surrounded by hydrophilic, where the head of the surfactant molecule interacts with water [4,8].
Surfactants for EOR applications in the petroleum industry require certain characteristics. The characteristics of the surfactant needed include resistance to formation water conditions which have high levels of salinity and hardness, good detergency in hard water, high temperature resistance (103 - 115 °C), IFT 10⁻³ to 10⁻¹ dyne/cm, adsorption <0.25%. The importance of surfactants that are resistant to salinity and hardness is high considering that most of the formation water in Indonesian oil wells have high salinity (5,000 - 30,000 ppm), and hardness > 500 ppm [9-11].

Selection of surfactants for certain reservoir types must be based on laboratory testing. Several factors that influence the selection of surfactants for EOR are produce low interfacial O/W tension, compatibility of surfactants with other chemicals such as polymers, stability of the conditions in the reservoir include temperature and pressure, performance resistance of surfactants to ionic brine conditions and certain salinity, as well as the characteristics of the surfactant solution in the oil and water phase [7,12].

Compatibility and solubility stability can be seen when dissolving the surfactant in brine solution. The best solution to be injected into the reservoir is a clear solution, not cloudy and does not form deposits. Sheng explains that the most fundamental thing in the EOR study is the phase test [1,13]. Sandersen then explained that the parameters that greatly affect the phase test include surfactant concentration, cosurfactant, salinity, composition of oil, and temperature [5].

According to Kayali, the phase test was carried out to determine the IFT information on surfactants from microemulsions formed in a system of surfactant, brine, and oil [14]. This is closely related to IFT which is an important factor in the acquisition of oil with microemulsions formed in the chemical flooding process.

Alpha Olefin Sulfonate (AOS) surfactants with general chemical formula of R-CH=CH-(CH₂)ₙ-SO₃Na, R=C₁₀₋₂₀ commercially recognized as sodium linear alpha olefin sulfonate was studied by researchers. Their research outcome showed that this family of surfactant performs particularly well in the presence of divalent ions and has a high biodegradation rate. The advantage of this surfactant is that it has good performance in a wide enough pH range, and shows good foaming and detergent ability even in high hardness solutions. In addition, it provides a reasonable acid resistance and can be consumed in emulsion polymerization [15,16].

Meanwhile, AOS have shown outstanding detergency, lower adsorption on porous rock, high compatibility with hard water and good wetting and foaming properties. This property makes AOS an excellent candidate of foam application in enhanced oil recovery [17,18].

2. Methods
The study was conducted on laboratory scale, using Alpha Olefin Sulfonate surfactant as a chemical flooding material. Making surfactant solution is carried out with various concentrations (0.5, 1.0, 1.5 and 2.0%). A solution that represent formation water is made using a NaCl solution with several variation of concentration (10,000; 15,000; and 20,000 ppm).

In each brine solution with a certain salinity value, the surfactant is dissolved with various concentrations. IFT measurement is done to get the smallest value and is considered as the best condition for the use of surfactants in brine.

By using the best surfactant and salinity concentration values, then a phase behavior test is carried out in a system containing brine-surfactant-oil, to see how far and how long the emulsion formed can maintain its condition.

Sandpack is made as a representation of sandstone type reservoir rock, using a PVC pipe filled with sand and clay with a ratio of 98:2. According to the composition commonly found in sandstone rocks [10]. Porosity and permeability tests were carried out to test the suitability of rock conditions with rock characteristic that meet the requirements of chemical flooding.

Injection of chemical flooding into the sandpack is a way to observe how far the AOS surfactant in its best composition can increase the value of the recovery factor.

Recovery factor is defined as the ratio of the amount of oil or gas that can be taken to the amount of oil or gas in place (in place).
3. Result and discussion

Based on IFT measurements on various surfactant concentrations and solvent salinity, we can determine the best conditions for using AOS to obtain a minimum IFT value. In the figure, it can be seen that the best condition is achieved at 1.5% AOS concentration with a salinity of 10,000 ppm.

![Figure 2. Correlation between surfactant concentration and IFT in various salinity.](image)

In the figure 2, it can be seen that the addition of surfactant concentrations greater than 1.5% can add IFT, but not in a significant amount. At a concentration value of 1.5% it can be considered as the formation point of CMC, where the surfactant forms an aggregate known as a micelle [10,19,20].
The main purpose of using surfactants in EOR is the formation of emulsions between oil and water, which indicate the mixing of the two non-soluble phases. Reduced IFT and finally the formation of micelles are the effects seen from the onset of the emulsion [3,21].

By using this condition as a reference, a phase behavior test is performed to see how long the solution can have a good emulsion effect. In addition, it was also observed the effect of using surfactant solutions in increasing oil yield, through the amount of recovery factor.

**Figure 3.** AOS surfactant 1.5% behavior test in a mixture of oil and brine with 15000 ppm salinity.

As shown in the figure 3, the use of AOS surfactants in brine causes dissolved oil in the form of upper phase emulsions, which indicates that surfactants tend to form water in oil emulsions. This is indicated by dissolving the surfactant into oil which is the upper phase.

However, this condition can only last a short time, and then begin to separate between the oil phase and the emulsion. From 28 days of monitoring (672 hours), it was seen that the emulsion still remained as much as almost 20% of the mixed volume. It needs to be done in a long time to find out how long the surfactant has the ability to form an emulsion under optimal salinity and concentration conditions.

**Figure 4.** Recovery Factor at various salinity and surfactant concentration.
The effect of salinity on the performance of surfactants in increasing oil yield can be seen in Figure 4. It was observed that the recovery value of the best factor was obtained in the use of AOS with a concentration of 1.5%, where an optimal value was achieved in all tested salinity.

This correlates with the ability of surfactants to reduce interfacial tension indeed at the concentration level.

Meanwhile, if observed the effect of salinity on the presentation of oil recovery, it can be seen that the AOS surfactant can work well at 10,000 ppm salinity, which in that condition results in an optimal increase in oil recovery.

The study that has been carried out is the initial screening test, which needs to be followed up with further tests. Its include observing surfactant compatibility with other additives such as polymers, the resistance of surfactants to pressure and temperature in a certain range, as well as the behavior of surfactants in the presence of ions alkali which affects the nature of the solution [2,3,18].

The initial screening test is the starting point that can narrow the scope of the observations that will be carried out in the next screening observation [11,22,23].

4. Conclusion
From studies that have been conducted on AOS surfactants in their use as chemicals in EOR activities, it can be concluded that AOS surfactants can work well at a concentration of 1.5% in solutions with 10,000 ppm salinity. The reduction in interfacial tension that can be achieved is 16.75 mN / m. The emulsion formed can last up to 20% by volume for 28 days, and the emulsion formed is an upper phase which indicates that the surfactant is soluble in the oil phase.

Further studies are needed to further determine the compatibility of AOS surfactants in their use in EOR.

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