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Microbial enhanced oil recovery (MEOR) using ultra sonic wave

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ABSTRACT

Microbial Enhanced Oil Recovery is a technology to increase petroleum recovery using biosurfactants as a result of bacterial metabolites. The purpose of this study was to examine the effect of ultrasonic waves, NaCl concentration, and pH on recovered oil yield. Ultrasonic waves were emitted for 1-5 minutes (SKU 929154620, 20 kHz) with 1-5% NaCl concentrations at pH 5.5, 6, 6.5, and 7. The highest recovered oil yield reached 80.37% using *Pseudomonas peli* with NaCl 6% without pH variation for 3 minutes of ultrasonic transmission. These findings reveal that ultrasonic waves and NaCl concentrations have a major effect in increasing the recovery of petroleum using bacteria.

Key words : *Bio-surfactant, Crude oil, NaCl, Pseudomonas, Ultrasonic*

Introduction

Despite the promotion of renewable energy, oil and gas remain the world's main energy sources. Maximizing oil recovery due to high global energy demand must be achieved (Gbadamosi *et al.*, 2019). There are three stages of oil recovery improvement technology to meet the increasing needs every year. In the first stage, the process is directly based on natural flow-air formation using very high pressure with yield of 10-20%, so that there is still a lot of oil left in the reservoir (Geetha *et al*., 2018). The technology has developed into secondary oil recovery using the water flooding method. This method can successfully recover 30-40% of oil, but high energy is required (Dong *et al.*, 2016). The primary and secondary oil recovery is considered not optimal in increasing oil recovery. The third stage of oil recovery then emerges which is known as enhanced oil recovery (EOR).

EOR increases the efficiency of hydrocarbon production by changing the physicochemical properties of rock (Shafiai and Gohari, 2020). EOR aims to reduce the interfacial tension of oil and water, capillary pressure, and the ratio of oil and water mobility through increasing water viscosity (Thomas, 2008). In its application, EOR is divided into two methods, conventional and non-conventional (Mozafari and Nasri, 2017). Conventional EOR consists of chemical methods (Abidin, Puspasari, and Nugroho, 2012), thermal (Gurgel *et al*., 2008), and gas (Bachmann *et al*., 2014; Gao, 2018)

Currently, EOR is developing towards using bacteria to recover oil which is called microbial enhanced oil recovery (MEOR). The use of bacterial activity known as microbial enhanced oil recovery (MEOR) with its metabolites which can interact in the oil reservoir to increase the mobility of petroleum through decreasing oil viscosity and surface tension (Ke *et al*., 2018; Song *et al*., 2015). In general, this process uses bacteria or nutrients that are injected into wells to multiply bacteria below the surface, resulting in increased bacterial activity and increased fluidity and oil recovery (Cai *et al*., 2015; Omoniyi and Abdulmalik, 2015). Not all bacteria can be used as MEOR bacteria, it requires the right relationship between the microbial structure and the oil reservoir (Xingbiao *et al*., 2015).

Bacteria in MEOR produce biosurfactants that have an amphiphilic side, can interact with the surface tension of the oil, and reduce surface tension so that they are easier to mobilize (Ashish and Debnath (Das) 2018). Various bacteria from previous studies have been used in MEOR such as *Bacillus safensis*(de Araujo *et al*., 2019), *Geobacillus strains* (Lin *et al*., 2019), *Bacillus mojavensis* (Ghazala *et al*., 2019), *Chelatococcu sdaeguensis* (Ke *et al*., 2019) and other bacteria.Throughout our best search, MEOR using Pseudomonas group bacteria especially *Pseudomonas peli*, *Pseudomonas citronellolis*, and *Pseudomonas fluorescens* and *Burkholderia glumae* has never been done.

Ultrasonic waves have been used in MEOR technology to separate solid particles, separate solid/liquid particles in high concentrations of suspensions, and can also reduce the stability of oil/water emulsions (Ye *et al*., 2008). The study of ultrasonic waves for oil recovery applications first occurred in the 1950s after an earthquake, with a study of water levels caused by earthquakes (Arabzadeh and Amani 2017; Wang, Fang, and Guo 2020). The application of ultrasonic waves in the EOR method has advantages. It is easy and fast in its application, protects the borehole from damage, low operating costs, and high profitability (Abramova *et al*., 2014). Ultrasonic waves have weaknesses at long distances so further research is needed to overcome them (Wang, *et al*., 2020).

Studies related to the relationship of bacterial biosurfactants, the salt concentration of NaCl, and pH on oil recovery using ultrasonic waves have been carried out separately so that the simultaneous effect of ultrasound and microorganisms on emulsion stability has not been fully investigated. Therefore, the main objective of this study is to investigate the synergistic effect of combined ultrasonic waves and microorganism-producing biosurfactants on water stability in oil emulsion and recovered oil yield.

Materials and Methods

Bacterial rejuvenation, Zobell medium and starter making, and biosurfactant extraction

The research consisted of rejuvenating bacteria, making Zobell medium, starting bacteria, and extracting biosurfactants according to the standards by (Yudono, Fatma *et al*., 2017; Yudono, Said, *et al*., 2017). The nutrient agar (NA) 3.6 g medium is mixed with distilled water until a total volume of 180 ml is then put into several test tubes of 5 ml each. The mouth of the test tube was then clogged with cotton. The test tube containing NA was then sterilized using an autoclave at 121 °C 1 atm for 15 minutes. The NA medium after being distilled was tilted and allowed to solidify for 24 hours. Each bacterium was inoculated with a zigzag motion into solid NA media. The cultures were then incubated at 37 °C for 24 hours.

Zobell media is made by dissolving 5 g of peptone, yeast extract 1 g. 0.012 g K2HPO4, and 0.01 g FeSO4 in distilled water with a solution volume of 1000 mL. The mixture is boiled on a hotplate and homogenized with a magnetic stirrer. After boiling the mixture is sterilized by autoclave at 121°C 1 atm for 15 minutes. To make a bacterial starter, two test tubes of bacterial culture were subcultured by aeration for 24 hours in an Erlenmeyer containing 100 mL of Zobell medium then added 150 mL of Zobell medium with a total volume of 250 mL. The mixture is aerated according to the shortest bacterial culture time.

The nutritional elements of bacteria, namely carbon, nitrogen, phosphate, and calcium (C: N: P: K) were prepared in a ratio of 100: 10: 1: 0.1 with a concentration of 5%. The 250 mL bacterial starter is mixed into the chamber which already contains the nutrients then aerated according to the shortest time of bacterial culture. The bacteria used consisted of *Pseudomonas peli*, *Pseudomonas citronellolis*, and *Pseudomonas fluorescens* and *Burkholderiaglumae*.

Total petroleum hydrocarbon (TPH)

Total petroleum hydrocarbons were measured by extracting Soxhlet n-hexane as a solvent. The percentage of total petroleum hydrocarbon (TPH) of petroleum is calculated using equation 1.

$$\%TPH = \frac{W_o - W_f}{W_0} \times 100\% \quad .. (1)$$

where Wo is sludge weight (g) while Wf is sludge weight after treatment (g). The recovered oil is calculated using equation 2 where the TPHo and TPHf are the total starting and ending petroleum hydrocarbon values, respectively.

$$\%\text{recovered oil} = \frac{TPHo}{TPHf} \times 100\% \quad (2)$$

Ultrasonic waves are emitted using digital ultrasonic SKU 929154620 at 20 kHz.

Results and Discussion

Effect of ultrasonic waves on oil recovery

The oil has been recovered successfully using four types of bacteria at five different times of ultrasonic wave transmittance (Figure 1). The recovered oil increased along with increasing the time for each bacteria which is used. Based on the length of time the ultrasonic wave was transmitted, *Bhurkholderia glumae* recovered the highest oil in 3 minutes at 71.42%. When the time was increased to 4 and 5 minutes, the oil recovery power by *Bhurkholderia glumae* decreased considerably (65.68% and 61.5%). This is also in line with what happened to the *Pseudomonas peli* bacteria, the oil was also successfully recovered with the highest yield at 3 minutes the ultrasonic wave was emitted (65.94%) and decreased the next time. Oil recovered by *Pseudomonas peli* was not as good as that of *Bhurkholderia glumae* although at the same time both bacteria showed their maximum performance.

In oil recovery using *Pseudomonas fluorence*, the highest percentage of recovered oil occurred when ultrasonic waves were emitted for 3 and 4 minutes, namely 73.91% and 67.97%. Unlike the ultrasonic wave emission at *Pseudomonas citronellolis*, at 1 and 2 minutes, the oil recovered the most, but when the radiation time was increased, the results obtained decreased drastically. This is because these bacteria reach their maximum limit of recovering oil. The bacteria then lose their ability as the ultrasonic wave emission time increases (Wolski, 2020).

Effect of NaCl variations on oil recovery

Oil recovery on the variation of NaCl for each bacterium is illustrated in Figure 2. Since the best time for ultrasonic wave transmission is 3 minutes, then variations in NaCl concentration have been carried out. The highest oil recovered by *Bhurkholderia glumae* was obtained with 6% NaCl of 74.98% yield. Furthermore, *Pseudomonas peli* reached the highest of oil recovery when concentration of NaCl was 6% as well (80.37%), indeed the *Pseudomonas fluorence* (76.96%). In contrast, *Pseudomonas citronellolis* achieved the optimum of oil recovery when the ultrasonic wave was emitted for 2 minutes, but the highest recovered oil was still obtained with 6% NaCl (71.84%). It can be described that the increase of NaCl concentration will increase the oil recovered. This result was in good agreement with (Kumar and Mandal, 2016) that there is a synergistic effect of a mixture of NaCl and surfactant which causes a decrease in the surface energy of crude oil in the presence of a surfactant solution to increase salinity.Halotolerant bacteria can accumulate organic substances in the cytoplasm to prevent loss of fluid in the cells due to the high concentration of NaCl outside the cells so that high oil recovery is achieved *et al*., 2018).

Effect of pH on oil recovery

In order to know the yield of oil recovered by each bacterium, the variation of NaCl was done. Figure 3 shows that *Pseudomonas citronellolis* achieved the

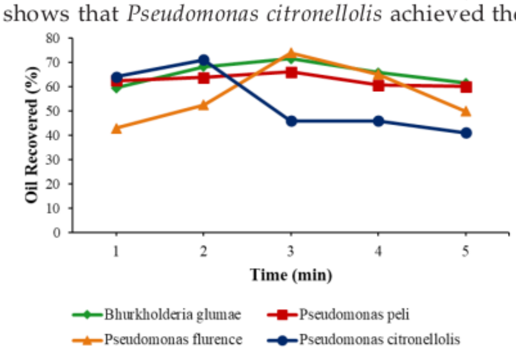

Fig. 1. Transmitting ultrasonic waves on oil recovery

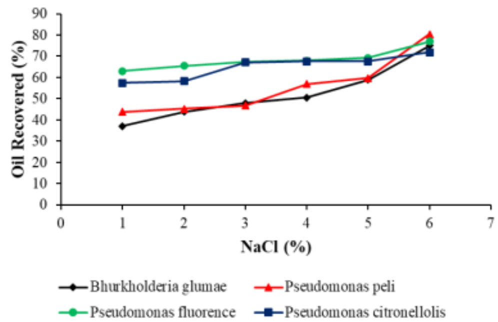

Fig. 2. Variations of NaCl concentration on oil recovery

highest oil recovered of all other bacteria at all variations of pH. The highest was obtained when the pH was 7 with yield 66.67%. This occurs to all bacteria at the same pH, but *Pseudomonas peli* was the lowest (27.68%).

The interesting thing here is oil recovery by *Pseudomonas citronellolis* conducted at 2 minutes of ultrasonic wave transmission rather than 3 minutes as though the other three bacteria. This is caused by

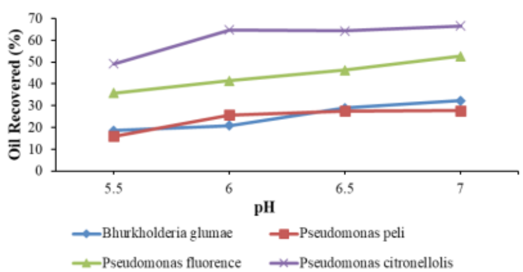

Fig. 3. Oil recovery yield affected by pH variations

bio-surfactant in moderately strong acidic conditions is in the form of the proton, so that the solubility in water is reduced and the oil recovered increases (Ikhwani *et al.*, 2017).

Conclusion

Oil recovery by combining several methods, namely ultrasonic waves, microbes, and NaCl concentration has been successfully carried out. Biosurfactants from the three types of bacteria are able to recover oil with high yields. The best ultrasonic wave transmission time is 3 minutes, while the best NaCl concentration and pH are at 6% and 7 respectively. This condition succeeded in making *Pseudomonas peli* recover 80.37% of oil.

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