Eco. Env. & Cons. 27 (May Suppl. Issue) : 2021; pp. (S231-S235)

ISSN 0971–765X

Consortium bacteria application for ultrasonic wave microbial enhanced oil recovery

Yuliani[1, 5]*, Bambang Yudono[2], Eddy Ibrahim[3] and Hary Widjajanti[4]

[1]Doctoral Program of Environmental Science, Graduate School, Universitas Sriwijaya, Jl. Padang Selasa No. 524 Bukit Besar, Palembang, South Sumatera, Indonesia
[2] Department of Chemistry, Faculty of Mathematics and Natural Science, Universitas Sriwijaya Sriwijaya, Palembang, Indonesia
[3] Department of Mining Engineering, Faculty of Engineering, Universitas Sriwijaya, Palembang, Indonesia
[4] Department of Biology, Faculty of Mathematics and Natural Science, Universitas Sriwijaya Sriwijaya, Palembang, Indonesia
[5] Mechanical Engineering Department, Faculty of Engineering, Universitas Islam Ogan Komering Ilir (UNISKI) Kayuagung, Ogan Komering Ilir, South Sumatera, Indonesia

(Received 16 November, 2020; Accepted 11 December, 2020)

ABSTRACT

The Microbial Enhanced Oil Recovery process using several bacteria or consortium of bacteria is a potential method of obtaining crude oil in a reservoir. Biosurfactants as secondary metabolites of consortium I bacteria (*Bhurkholderiaglumae*, *Pseudomonas fluorescence*, *Pseudomonas citronellolis*) and consortium II bacteria (*Bhurkholderiaglumae*, *Pseudomonas peli*, *Pseudomonas citronellolis*) with time variations of ultrasonic, NaCl and pH in a temperature range of 70 °C and 90 °C is applied to recover oil. The sonication process uses digital ultrasound at 20 kHz. The best results were obtained from the results of oil recovery at 2 minutes of ultrasonic transmission, 6% NaCl, and pH 7 for consortium I bacteria (59.28%). The best temperature was 70 °C for consortium II bacteria (52.76%). Consortium bacteria in ultrasonic wave emission have the potential to increase oil recovery.

Key words : *Consortium bacteria, Ultrasonic, Oil recovery*

Introduction

Crude oil is still the main fuel source in several regions of the world. Approximately 66% of crude oil reserves have not been discovered since the recovery technique using pressure from the reservoir, and water infusion was carried out (conventional methods) (Bhattacharya *et al*., 2019). Energy consumption and rising oil prices have made oil recovery methods continue to be developed. Tertiary oil recovery techniques using surfactants, polymers, and solvents (chemical processes) have been developed (Dang *et al*., 2018). Although most of the oil can be recovered from the reservoir, it cannot be denied that the use of these chemical compounds is harmful to the environment, expensive, and leaves the remaining materials accumulated and difficult to remove (Gudiña *et al*., 2012).

Microbes are an oil recovery option with minimal oil spill effects compared to physical and chemical oil recovery methods. Most insoluble oil hydrocarbons cause microbes to produce biosurfactants to supply available carbon sources (Saravanan *et al.*, 2020). The biodegradation that occurs is higher by using microbes, but the toxicity is much lower compared to using chemical compounds (Logeshwaran *et al.*, 2018). Certainly, this is very acceptable for environmental sustainability and has the potential to be further developed at the industrial level (She *et al.*, 2019).

Microbial Enhanced Oil Recovery (MEOR) is an environmentally friendly tertiary oil recovery method. Injection of exogenous microorganisms and nutrients produces various bacterial metabolites such as biosurfactants (Niu *et al.*, 2020). Furthermore, more oil can be recovered through the injection of the resulting microbial products into the reservoir. Combining process using consortium bacteria with different properties. This is an improved recovery technique. Several studies have been reported regarding MEOR using a microbial consortium to increase the biodegradation rate of hydrocarbons. Environmental factors such as pH and temperature affect oil recovery. In this study, MEOR uses a consortium of bacteria combined with ultrasonic waves.

Materials and Methods

The consortium formula containing three types of bacteria aims to obtain the total petroleum degraded by the indigenized bacterial mixed culture. Bacteria Consortium I consists of *Bhurkholderia glumae, Pseudomonas fluorescence, Pseudomonas citronellolis*, while the bacteria Consortium II consists of *Bhurkholderia glumae, Pseudomonas peli, Pseudomonas citronellolis*. The formula for the bacterial consortium that is best in degrading petroleum (potentially beneficial in the short term, lasts longer with less environmental impact) will be determined by inserting 1000 mL of sludge into the blank (aquades) (w/v).

Then, the mixture was put into each 2.5% biosurfactant and bacterial cell culture with a variation of 1% NaCl salt content; 2%; 3%; 4%; 5%; 6% (w/v against biosurfactants and indigenized bacterial cell culture), a variation of pH 5.5; 6; 6.5; 7 by transmitting 20 kHz ultrasonic waves for 1 to 5 minutes at a temperature of 70 °C, 80 °C and 90 °C to a total volume of 4000 mL. Then aeration is carried out for 10 days. The calculation of recovered oil is calculated, according toYudono *et al.* (2017).

Results and Discussion

This study, using a bacterial consortium I (K1) consisting of the bacteria *Bhurkholderia glumae. Pseudomonas fluorescence, Pseudomonas citronellolis*, and consortium II (K2) bacteria consist of *Bhurkholderiaglumae, Pseudomonas peli, Pseudomonas citronellolis*.

Effect of the ultrasonic wave on consortium bacteria

The results of oil recovery at variations in the time of using ultrasonic waves on bacteria consortium I (K1) and consortium bacteria II (K2) can be seen in Figure 1.Oil recovered has increased with increasing time for ultrasonic wave transmitting in bacteria consortium I (K1) and bacteria consortium II (K2) (Figure 1). When observed, there are similarities in the bacteria consortium I and consortium II oil recovery pattern in the same time span (1-5 minutes). In the oil recovery process by transmitting waves for 1 minute, the recovered oil was obtained by 33.816% using the bacterial consortium I (K1). At the same time, using the bacteria consortium II, the oil obtained was 13.48%.

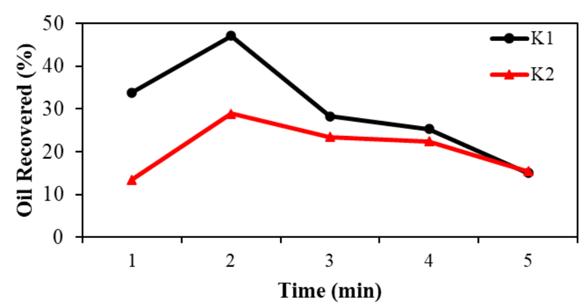

Fig. 1. Effect of ultrasonic time on consortium bacteria on oil recovered

The highest recovered oil was achieved during two minutes of wave transmission using bacteria consortium I and bacteria consortium II. The bacteria consortium I showed good results because the oil recovered was 47.063%, while the bacteria consortium II was only able to recover 28.93%. The oil recovery process has decreased after a wave casting time of more than two minutes. After a significant increase in the second minute, the oil recovery continued to fall to 15.056% and 15.470% for bacteria consortium I and bacteria consortium II, respectively.

Effect of variations in the concentration of NaCl on the consortium bacteria on oil recovery

The oil recovery process with various concentrations of NaCl in each bacterial consortium I (K1) and bacteria consortium II (K2) is shown in Figure 2. From the results of the recovery process, in each of the K1 and K2 consortium bacteria, it was found that the ultrasonic wave emission time best happens for 2 minutes. Therefore, to increase oil recovery, NaCl was tested in a concentration variation of 1-6%. In various NaCl concentrations, the two bacteria performed quite well in recovering the oil. It can be seen that the bacteria consortium II (K2) experienced a significant increase when the NaCl concentration was 5-6%, with a yield of 47.92%. Initially, consortium I bacteria managed to recover more oil than consortium II bacteria. Still, in the end, consortium bacteria II surpassed the achievements of consortium bacteria I. Consortium I bacteria recovered the highest oil at a concentration of 6% NaCl of 40.07%, which indicates a decrease.

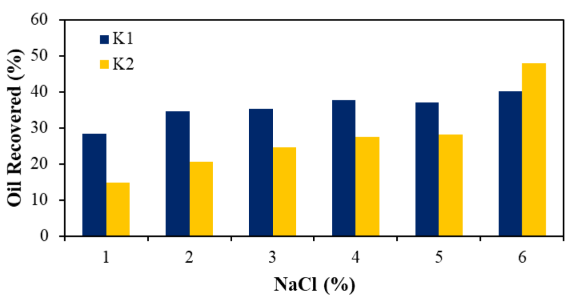

Fig. 2. Effect of NaCl concentration on consortium bacteria on oil recovered

The addition of NaCl to the biosurfactant will affect the hydrophilic group of the biosurfactant so that the hydrophobic group will easily release nonpolar compounds that are attached to the hydrophobic group and will dissolve with the hydrophilic group in the biosurfactant (Sari *et al.*, 2020). This indicates that the bacterial consortium is effective in recovering crude oil because the resulting biosurfors can increase the solubility of hydrophobic compounds to increase and accelerate the rate of degradation by microbes (El-Sheshtawy and Doheim, 2014).

Effect of pH variations on oil recovery by consortium bacteria

Variations in pH were carried out to obtain the best oil recovery conditions by consortium bacteria in the ultrasonic wave transmitting time. The best NaCl concentration was carried out, as shown in Figure 3. Oil recovery has continued to increase since the best variable has been determined. At variations in NaCl concentration, the bacteria consortium II (K2) recovered the most oil, while when the pH variation was carried out, the bacteria consortium I (K1) were more dominant.

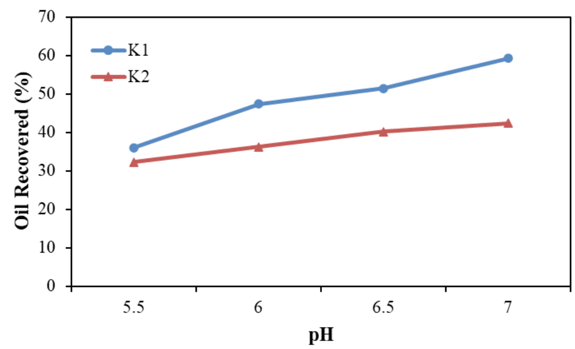

Fig. 3. Effect of pH on the consortium bacteria

The pH variation starts from 5.5 (acidic atmosphere) to pH 7 (neutral). Both consortium bacteria have a positive effect along with increasing pH. The lowest recoverable oil was at pH 5.5 for bacteria consortium I and consortium II (36.01% and 32.23%, respectively). The best results were obtained when the pH was neutral, namely 59.28% and 42.41% for bacteria consortium I and bacteria consortium II, respectively. At neutral conditions, the interface voltage is the highest, so the emulsion is easy to form. The higher the pH (closer to neutral pH), the higher the recovered oil (Al-Sahhaf *et al.*, 2008). This shows that bacteria can thrive in neutral pH conditions. Enzymes that work on the formation of biosurfactants work better than other pH to produce the most biosurfactants (Ikhwani *et al.*, 2017).

Effect of temperature variations on oil recovery by consortium bacteria

Crude oil that was successfully recovered in each consortium bacteria with temperature variations at the ultrasonic time, the best NaCl concentration and pH obtained previously is illustrated in Figure 4.

The recovered oil has decreased after increasing the temperature. Both consortium I and consortium II bacteria were only able to recover the highest oil at 70 °C (56.39% and 52.76). The increase in metabolic activity in breaking down hydrocarbons, espe-

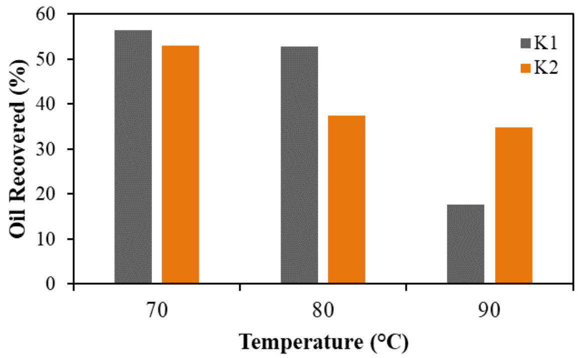

Fig. 4. Effect of temperature variations on the consortium bacteria

cially short-chain alkane compounds, is most effective at 70 °C (Rojo, 2010). Bacteria enter the stationary phase towards the death phase after the temperature rises 80-90 °C so that the oil recovered decreased. The concentration of biosurfactants secreted in the death phase has reached maximum because more bacteria have died than living cells (Alkan *et al*., 2019; Ptaszek *et al*., 2020).

It can be concluded that 70 °C is the best temperature in the variation. Overall, the variation concerning temperature is only beneficial for consortium II bacteria because in the previous best conditions (2 minutes of ultrasonic emission, 6% NaCl, and pH 7), the oil recovered was 59.28%. by consortium I bacteria. After being applied at 70 °C, there was a decrease in oil by 2.89% in consortium I bacteria, but it is different from consortium II bacteria, where there has been an increase in bacteria consortium II by 10.35%.

Conclusion

Consortium bacteria I (K1) have recovered oil up to 59.28% in the best conditions, namely during 2-minute wave radiation, 6% NaCl, and pH 7. Temperature variations in consortium I bacteria have a negative impact by reducing oil recovery. The consortium bacteria II (K2) recovered the highest oil in 2 minutes wave emission, 6% NaCl, pH 7 at 70°C at 52.76%. An increase in temperature has a positive impact on consortium bacteria II (K2).

References

Al-Sahhaf, T., Elsharkawy, A. and Fahim, M. 2008. Stability of water-in-crude oil emulsions: Effect of oil aromaticity, resins to asphaltene ratio, and pH of water. *Petroleum Science and Technology*. 26 (17) : 2009–2022. https://doi.org/10.1080/10916460701428904

Alkan, H., Szabries, M., Dopffel, N., Koegler, F., Baumann, R. P., Borovina, A. and Amro, M. 2019. Investigation of spontaneous imbibition induced by wettability alteration as a recovery mechanism in microbial enhanced oil recovery. *Journal of Petroleum Science and Engineering*. 182 (June), 106163. https://doi.org/10.1016/j.petrol.2019.06.027

Bhattacharya, M., Guchhait, S., Biswas, D. and Singh, R. 2019. Evaluation of a microbial consortium for crude oil spill bioremediation and its potential uses in enhanced oil recovery. *Biocatalysis and Agricultural Biotechnology*. 18 (October 2018), 101034. https://doi.org/10.1016/j.bcab.2019.101034

Dang, C., Nghiem, L., Nguyen, N., Yang, C., Chen, Z. and Bae, W. 2018. Modeling and optimization of alkaline-surfactant-polymer flooding and hybrid enhanced oil recovery processes. *Journal of Petroleum Science and Engineering*. 169 : 578–601. https://doi.org/10.1016/j.petrol.2018.06.017

El-Sheshtawy, H. S. and Doheim, M. M. 2014. Selection of Pseudomonas aeruginosa for biosurfactant production and studies of its antimicrobial activity. *Egyptian Journal of Petroleum*. 23 (1) : 1–6. https://doi.org/10.1016/j.ejpe.2014.02.001

Gudiña, E. J., Pereira, J. F. B., Rodrigues, L. R., Coutinho, J. A. P. and Teixeira, J. A. 2012. Isolation and study of microorganisms from oil samples for application in Microbial Enhanced Oil Recovery. *International Biodeterioration and Biodegradation*. 68 : 56–64. https://doi.org/10.1016/j.ibiod.2012.01.001

Ikhwani, A. Z. N., Nurlaila, H. S., Ferdinand, F. D. K., Fachria, R., Hasan, A. E. Z., Yani, M., Setyawati, I. and Suryani. 2017. Preliminary study: optimization of pH and salinity for biosurfactant production from Pseudomonas aeruginosa in diesel fuel and crude oil medium. *IOP Conf. Series: Earth and Environmental Science*. 58 : 1–7. https://doi.org/10.1088/1755-1315/5

Logeshwaran, P., Megharaj, M., Chadalavada, S., Bowman, M. and Naidu, R. 2018. Petroleum hydrocarbons (pH) in groundwater aquifers: An overview of environmental fate, toxicity, microbial degradation and risk-based remediation approaches. *Environmental Technology and Innovation*. 10 : 175–193. https://doi.org/10.1016/j.eti.2018.02.001

Niu, J., Liu, Q., Lv, J. and Peng, B. 2020. Review on microbial enhanced oil recovery: Mechanisms, modeling and field trials. *Journal of Petroleum Science and Engineering*. 192 : 107350. https://doi.org/10.1016/j.petrol.2020.107350

Ptaszek, N., Pacwa-Plociniczak, M., Noszczynska, M. and Plociniczak, T. 2020. Comparative study on multiway enhanced bio- and phytoremediation of aged petroleum-contaminated soil. *Agronomy*. 10(7):

1–19. https://doi.org/10.3390/agronomy10070947

Rojo, F. 2010. Carbon catabolite repression in Pseudomonas: Optimizing metabolic versatility and interactions with the environment. *FEMS Microbiology Reviews.* 34 (5) : 658–684. https://doi.org/10.1111/j.1574-6976.2010.00218.x

Saravanan, A., Kumar, P. S., Vardhan, K. H., Jeevanantham, S., Karishma, S. B., Yaashikaa, P. R. and Vellaichamy, P. 2020. A review on systematic approach for microbial enhanced oil recovery technologies: Opportunities and challenges. *Journal of Cleaner Production.* 258 : 120777. https://doi.org/10.1016/j.jclepro.2020.120777

Sari, C. N., Hertadi, R., Harahap, A. F. P., Ramadhan, M. Y. A. and Gozan, M. 2020. Process optimization of palm oil mill effluent-based biosurfactant of Halomonas meridiana BK-AB4 originated from bledug kuwu mud volcano in central java for microbial enhanced oil recovery. *Processes.* 8 (6). https://doi.org/10.3390/PR8060716

She, H., Kong, D., Li, Y., Hu, Z. and Guo, H. 2019. Recent Advance of Microbial Enhanced Oil Recovery (MEOR) in China. *Geofluids*. https://doi.org/10.1155/2019/1871392

Yudono, B., Fatma, Estuningsih, S. P. and Suganda, L. 2017. Oil recovery of soil contained petroleum oil by using bio surfactant of mixed cultures bacteria (Brevundumonas diminuta, *Pseudomonas fluorescens, Pseudomonas aeroginosa, Pseudomonas citronelis*) at vary pH conditions (5-9). *International Journal on Advanced Science, Engineering and Information Technology*. 7 (3) : 858–864. https://doi.org/10.18517/ijaseit.7.3.2154