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Promising Biotechnology on Selective Plugging and Wettability Alteration for Enhanced Oil Recovery

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Abstract

Biotechnology can play an important role in enhanced oil recovery (EOR) process employing physical and chemical features of microbes. The process, known as microbial enhanced oil recovery (MEOR), includes injecting *ex-situ* bioproducts or stimulating indigenous microbes to generate specific metabolites for oil recovery. This paper focuses on the most actively research area of MEOR involving selective plugging and wettability alteration. The role of biomass and biopolymers for oil recovery is briefly described. Biosurfactants for wettability alteration are also represented. The review describes how to utilize the biotechnology in EOR process and shows the potential of MEOR.

Keywords: Microbial enhanced oil recovery (MEOR); Biosurfactan; Biopolymer; Wettability alteration; Selective pluggin

Introduction

Though renewable energy resources are growing in the market recently, crude oil is still used as a major resource [1]. Such trends motivate efforts to find environment-friendly alternative methods to enhance oil recovery. To meet the rising demand of these alternatives, microbial enhanced oil recovery (MEOR) has shown potential [2,3]. MEOR has similar mechanisms with chemical enhanced oil recovery (CEOR) as it applies biologically-produced surfactant or polymer to improve oil recovery. The main advantages of MEOR compared to CEOR are that these bio products are generally not only biodegradable but cheap. Earlier studies have shown that MEOR is sufficient to be a tertiary enhanced oil recovery tool with these advantages [4]. There are two major areas of research that have been most actively studied such as selective plugging and wettability alteration. These two major mechanisms will be briefly investigated through this review.

Meor strategies

Selective plugging: One of the most crucial problems in oil recovery is the existence of highly permeable regions called thief zones. In this circumstance, the control of fluid path is an important factor for successful oil production. Selective plugging attempts to selectively clog the thief zones to divert the fluid path. This method is often implemented by using the biomass or biopolymers.

When indigenous microbes grow in oil reservoirs, bacteria tend to create a biofilm with substrates in the porous media [5]. These microbes generate colonies and clusters with biomass which have an evolutionary advantage [6]. Some MEOR studies have focused on utilizing the biomass. The biomass accumulates in high permeability zones and diverts the injected water to remaining oil zones [7]. Furthermore, such biomass can alter the wettability of rock surface to more favorable condition for oil recovery [5]. The method needs the stimulation of indigenous bacteria or injection of selected bacteria. It also improves sweep efficiency by increasing accessible regions [1]. For the successful use of biomass in MEOR process, some criteria should be satisfied. During MEOR process, cells can be transported through the rock pore, proper nutrients are supplied, bioproducts are generated adequately, and the growth rate of bacteria must not be so fast that it blocks the well [8]. A previous study showed that *Bacillus licheniformis* BNP29 satisfies the criteria and generates suitable bioproducts for MEOR [9].

Various organisms produce polymers which can be used in oil recovery process. *Xanthomonous, Aureobasidium*, and *Bacillus* are considered for EOR [2]. Xanthan gum and curdlan are focused as important biopolymers. Some biopolymers function to increase cell adhesion and preserve the cells from predation and desiccation [10]. Others, such as xanthan gum, are utilized as thickening agents for water in MEOR process [2,9,11]. Because of high tolerance to high temperature and salinity, xanthan gum is an established polymer in oil industry [12]. It increases the viscosity of injected water and improves recovery efficiency over simple water flooding. Curdlan mixture with acid-producing bacteria can reduce the permeability [13]. Dextran produced by *Leuconostoc* is also studied as permeability reduction agent for MEOR [14,15]. Typically, the biopolymers have directly mixed with injected water as opposed to *in-situ* generating by stimulating the indigenous microbes [16]. In addition, emulsions and other bioproducts can selectively plug to make better channeling for oil recovery [17].

Wettability alteration: Most of oil reservoirs have the characteristic of mixed and oil-wet with fractured carbonate rock [18]. It causes the difficulty of oil to produce, contributing to lower displacement efficiency. Problems posed by mixed and oil wet condition of reservoir rock can be solved by biosurfactant [19]. Biosurfactant has significant effect on lowering surface and interfacial tension [20]. It affects adsorbed oil on reservoir rock by changing the interfacial tension between oil and water. Several studies have been shown that oil recovery is improved by this mechanism [21-33].

Acinetobacter, *Bacillus*, Pseudomonas, and *Rhodococcus* produce bio surfactant to have potential application for MEOR. Using these microbes, several types of bio surfactants can be controlled to improve oil recovery with other chemicals as an ex-situ method [2]. Bio surfactant produced by *Bacillus* subtilis has been injected and validated the potential in core flood experiments [21-23]. One of the studies investigated and compared three bio surfactants from different strains for successful ex-situ MEOR application [24]. Since it is important to produce stable bio surfactant, a number of studies have been conducted to optimize the bio surfactant production process by adjusting environmental parameters such as temperature and pH [25]. Furthermore, several experimental studies have been examined to validate *in-situ* MEOR [26-28]. The *in-situ* bio surfactant has shown to improve oil recovery up to 15% or more from a recent core flood studies [29].

To apply *in-situ* bio surfactant more efficiently, a structured mathematical modeling is also required. A number of studies established a three-dimensional, multi-component transport model [30,31]. The results show that bio kinetic model has potential to apply oil industry. In addition, recent studies have quantitatively examined the impact of environmental factors to improve accuracy [32,33]. From these results, it is identified that the analysis of environmental factor is important and the optimal injection design is needed.

Conclusion

MEOR is considered as an eco-friendly and cost-effective method using the microbiological techniques to replace the traditional EOR processes. While various MEOR processes exist, not all of them are possible to implement in oil industry due to recovery efficiency. Selective plugging and wettability alteration, however, are representative methods that increase sweep and displacement efficiency. These methods have tremendous promise for oil recovery. Nevertheless, some problems such as inconsistency and uncertainty of *in-situ* performances, which retard extensive field applications of MEOR, still remain. In addition, there is no one universal solution for MEOR operations because each reservoir has different characteristics. Therefore, future study should focus on not only mitigating the uncertainty problems but also optimizing the MEOR strategies.

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