Review on Approach Towards Reservoir Wettability and Selective Plugging for Microbial Enhanced Oil Recovery

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Abstract:* *Microbiology plays a vital role in Enhanced Oil Recovery (MEOR), where utilization of microbes is employed to produce various metabolites. Among produced metabolites, biosurfactant has potential to reduced interfacial tension, so that the trapped oil released which are held by high capillary force. Current work was mainly focused on MEOR ex-situ conditions by selective plugging and alteration of rock wettability. In general, biomass is a metabolite produced during fermentation which helps in oil recovery along with biosurfactant. Microbes and its contribution for MEOR application is briefly reviewed.

IndexTerms - MEOR, biosurfactant, biomass, wettability, selective plugging.

I. Introduction

Biosurfactants are naturally occurring compounds produced by bacteria and yeast with various substrates (sugars and hydrocarbon compounds) [2]. Due to the eco-friendly property, the demand for MEOR has been increased to greater extend [9]. MEOR has shown promising result in MEOR application by producing biosurfactant, biopolymer and biomass [6]. The mechanism involved in selective plugging and wettability modification of formation helps to retrieve oil with the aid of produced biosurfactant and biomass. Hence, a review on the above factors are briefly investigated.

1.1 MEOR Mechanism

Bacteria has the potential to produce surfactants, polymers, gases, and solvents that contribute to mobilizing residual oil in a reservoir.

1.2 IFT reduction

Certain bacteria produce biosurfactants that reduce oil-water interfacial tension (IFT). Capillary pressure, which is proportional to the IFT between oil and water, holds the residual oil in porous rocks.

1.3 Selective plugging

A porous rock contains pores of various sizes. When undergoing waterflooding, larger pores receive most of the injected water, while residual oil remains in un-swept small pores. When bacteria flow in reservoir rocks, they also tend to enter large pores. Certain bacteria can generate biopolymers that plug the high-permeability zones with large pores, thus forcing injected water to sweep the oil in low-permeability zones.

1.4 Viscosity reduction

Certain bacteria produce gas and solvents in the reservoir, such as CO_2. Gas and solvents can dissolve in crude oil and reduce crude oil viscosity, leading to an improved mobility ratio and oil recovery. The produced gas can also increase reservoir pressure, which leads to higher producing rates.

1.5 Wettability alteration

Rock wettability greatly influences the distribution of residual oil. In water-wet sandstones, water is in contact with sand grains, and oil droplets are in the centre of the pore space. On the other hand, for oil-wet rocks, oil is in contact with grain surfaces and remains in the small pores. In other words, water wettability is better for oil recovery [1]. Among above mechanism, a detailed review had been done on selective plugging and wettability alteration.

2. Role of Selective Plugging

Selective plugging in microbial enhanced oil recovery involves the use of microbes to grow and produce polymeric compounds, which intern block the high permeability zones and thereby permitting water to flow through the low permeability zones so that increase in oil recovery achieved. The curtail role of selecting plugging is to block and divert the high permeable zone by biomass/biopolymer produced by the microbes [11]. Biopolymers like Aureo asidium are helpful in oil recovery by increasing cell adhesion. At certain conditions indigenous microbes grow and tend to produce biofilm with substrates in porous media and generate colonies and clusters with the help of biomass which is important to clog the thief zones. Biomass produced by microbes has the tendency to modify the wetting properties of rock surface for favourable oil recovery [4]. For high recovery of oil using MEOR applications, it is deemed necessary to make sure that the cells are capable of transported to pores of the rock matrix which could be achieve only by supplementing sufficient nutrients so that biopolymers and biomass are generated to enhance the oil [3]. *Bacillus licheni* were able to produce bio products and retrieved oil [12]. Modelling approaches were applied to estimate the potential contribution of these effects on additional oil recovery. The observations including cell clumping, sorption and polymer production were geometrically quantified and the effect of the modifications on permeability profile and resulting flow characteristics was numerically investigated with fluid dynamic simulations of the petrophysical changes. The results was observed such that changes on EOR capability by conformance control and wettability modification were estimated with analytical approaches [5].

3. Role of Wettability

Petroleum reservoir is categorized into two types based on the wetting property of fluids. They are known as oil wet and water wet. Oil wet with carbonate rock is considered to be difficult in oil recovery. *Acinetobacter, Bacillus, Pseudomonas, and Rhodococcus* produce bio-surfactant to have potential application for MEOR. Using these microbes, several types of biosurfactants can be controlled to improve oil recovery with other chemicals as an ex-situ method [9]. Biosurfactant produced by *Bacillus subtilis* has been injected and validated the potential in core flood experiments [3]. One of the studies investigated and compared three bio-surfactants from different strains for successful ex-situ MEOR application. 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 [10]. Furthermore, several experimental studies have been examined to validate in-situ MEOR. The in-situ bio-surfactant has shown to improve oil recovery up to 15% or more from a recent core flood studies [2]. To apply in-situ biosurfactant more efficiently, a structured mathematical modelling is also required. A number of studies established a three-dimensional, multi-component transport model [4]. Carbonate rocks are naturally water-wet and the surface possesses higher affinity for water than for oil. When crude oil migrates from a source rock and invades an originally water-filled reservoir, the capillary pressure increases and can exceed the force barrier which keeps the water-wetting film in place. As the water wetting film becomes ultra-thin and ruptures, the wetting molecules are displaced and replaced by surface-active polar components in the oil, which adsorbs irreversibly onto the rock surface, effectively altering the wettability towards oil-wet [7]. One of the promising wettability alteration agents for optimal temperature and injection conditions were determined so that wettability alteration were tested on the bitumen (5-9° API-1,600,000 cp) containing Grosmont carbonate sample from Canada [8].

Conclusion

Enhanced oil recovery is a promising technology for residual oil recovery. MEOR is considered as an eco-friendly method using the microbiological which is possible to implement in oil industry due to recovery efficiency. Wettability alteration and selective plugging improves sweep displacement effectively. Discussion on selective plugging and wettability have been discussed briefly in this mini review article which will be helpful for further focus on oil recovery applications.

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