Advances in
Biotechnology & Microbiology
ISSN 2474-7637

Juniper PUBLISHERS key to the Researchers

Mini Review
Volume 13 Issue 1 - March 2019
DOI: 10.19080/AIBM.2019.13.555854

Adv Biotech & Micro

Potential of Bacterial Profile Modification in Enhanced Oil Recovery in Depleted Oil Reservoir

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Submission: January 28, 2019; **Published:** March 05, 2019

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Abstract

Due to lack of natural drives in most of the oil reservoir has led to supplementation of the artificial drive viz injection of displacement fluid (either water or gas) within the reservoir. These recoveries are unable to channel the oil from high permeable zones therefore, results in poor sweep efficiency of the oil. Bacterial profile modification is process where growth of indigenous micro-organism was thrived by nutrient formulation for targeted community responsible for production of biomass; secondary metabolites (gases, volatile fatty acids, biosurfactant) led to incremental oil recovery in depleted oil reservoir. Produced biomass & metabolites would clog the high permeable zones and block the water streaks which further restrict the unwanted liquid. Hence, displace the un-swept oil from the reservoir. This study represents the potential of microbial consortium towards modifying the permeability profile of the reservoir.

Keywords: High permeable zones; Biomass; Secondary metabolites

Introduction

In present scenario, most of the world' energy is derived from crude oil. A large proportion of this valuable and non-renewable resource is left behind in the ground after the application of conventional methods of oil extraction. Among secondary recovery, water flooding is one of the most common process. Due to the reservoir heterogeneity, the injected water flow preferentially along the high permeable zones that cause these fluids to by-pass oil saturated areas of the reservoir. Therefore, large amount of water rises with the oil that led to decrease the overall oil to water ratio [1]. Bacterial profile modification is an innovative technique that involves the utilization microbial biofilm that clog the high permeable zones, thus restricting the water to pass through it and diverting its path to low permeable zones. This tends to improve the sweep efficiency of the reservoir. The process involves the injection of selected microbes along with the nutrient mixture in the injection well. So, the microbes migrate through the high permeable zones and grow within the reservoir. These microbes further divert the water path towards the low permeable zones and facilitate the displacement of un-swept hydrocarbon [2].

Figure 1 depicts the activity of microbial consortia that will grow in the high permeable zones of the reservoir and facilitate the diversion of the water path. These microbial consortia are capable of producing biomass and secondary metabolites in-situ under harsh reservoir conditions (temperature, pressure, salinity, pH). A secondary metabolic product includes biosurfactant, biopolymer, gases and solvents, which increase the mobility of crude oil and subsequently leads to the recovery of oil [3-5]. These microbial metabolites reduce the oil-water interfacial tension, oil viscosity and also alter the wettability [6]. Bacterial profile modification involves the use of such microbes that are capable of producing the same type of metabolites under harsh conditions [7].

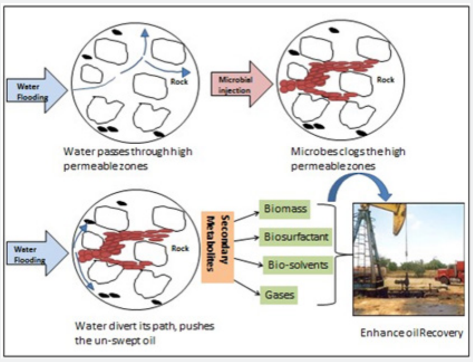

Figure 1: Mechanism of bacterial profile modification.

Bio-surfactants

Biosurfactants are amphipathic molecules with both hydrophobic and hydrophilic parts that are produced by varieties of micro-organisms. They have the ability to reduce the surface and interfacial tension by accumulating at the interface of immiscible fluids and increase the mobility of hydrophobic compounds. Biosurfactants are biodegradable, have low toxicity [8]. Biosurfactant are able to tolerate extreme conditions (pH, temperature, and salinity) and appeared to be efficient over chemically synthesized surfactant [9]. The application of biosurfactants in oil reservoirs occur in three ways: injection of biosurfactant producing microorganisms into the reservoirs; injection of nutrients into the reservoir that facilitate the growth of indigenous surfactant producing micro-organisms; ex-situ production of biosurfactants and subsequent injection in the oil reservoir [10].

Biopolymers

Biopolymers are polysaccharides that are secreted by many strains which will protect them against temporary desiccation and assist in adhesion to surfaces. The biopolymers mainly bring about the selective plugging of high permeability zones and redirect the water to oil-rich channels [11]. Another role of biopolymer is that it has the tendency to increase the viscosity of the displacing water hence improves the mobility ratio and the sweep efficiency.

Bio-solvents

Bio-solvents include ethanol, acetone and butanol that are produced by various microbial strains during the fermentation process. There are various anaerobic bacterial species (*Clostridium sp, Enterobacter aerogens*) that are capable of producing bio-solvents. Bio-solvents help in reducing oil viscosity and can also contribute as a surfactant in reducing interfacial tension between oil- water interphase [12].

Gases

Various anaerobic bacteria such as Clostridia, *Thermoanaerobacter* and Methanogens can produce hydrogen, carbon dioxide and methane by carbohydrate fermentation during the growth 73 phase. In an oil reservoir, these gases are produced in-situ which dissolves in the crude oil that 74 reduces the viscosity of oil and capillary forces contributing to oil retention [13,14] (Table 1).

Table 1: Application of microbial metabolites in MICROBIAL Enhanced Oil Recovery (MEOR).

Microbial product	Example microbes	Application in MEOR
Biomass	*Bacillus, Leuconostoc, Xanthomonas*	Selective plugging, and wettability alteration
Biosurfactants	*Bacillus, Pseudomonas, Acinetobacter, Arthrobacter, Clostridium*	Emulsification and de-emulsification activity through reduction of interfacial tension, viscosity reduction
Biopolymers	*Bacillus, Brevibacterium, Xanthomonas, Leuconostoc, Enterobacter sp.*	Viscosity reduction, selective plugging
Biosolvents	*Clostridium, Klebsiella sp.*	Oil viscosity reduction, dissolution of rock (enhance permeability)
Gases	*Clostridium, Methanobacterium, Enterobacter sp.*	Increase pressure, oil dwelling and viscosity, interfacial tension reduction

Case study

As the oil fields aged it tends to produce little to insignificant quantities of oil. Thousands of oil wells in such fields fall in the category of stripper wells. To enhance the production of oil from these stripper wells, joint research of ONGC, IRS & TERI lead to improved Microbial technology of cultured set of microbes that could survive at high temperatures (90 ºC), air pressure (up to 140 kilograms per square centimeter), and salinity lies between 4% to 8%. These microbes were successfully field tested in oil wells of Gujarat and Assam and the application of this technology is through Huff & Puff method where microbial injection & oil production is done through the same well [15].

Maudgalya et al. [16] reviewed 407 MEOR field trials worldwide. The field trails depends on various parameters: reservoir lithology, properties, micro-organisms, nutrients, type of test and type of recovery mechanisms. Among 407 field trails, 333 were applied through well stimulation; 26 field trials were performed through water flooding and remaining was conducted through huff- puff scheme. The study showed that microbes alter the permeability profile, either increases the

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production of secondary metabolites (biosurfactants, polymers, gases and acids), degrade the crude oil components. The main mechanism for oil recovery reported by DuPont involves the permeability modification due to the formation of a biofilm on the rock surface and wettability modification. A successful field trials conducted by DuPont indicate that oil recovery from mature fields can be increased up to 25% [17]. The successful MEOR application in a mature water flooded reservoir in Canada has been reported [18]. The MEOR application involves the stimulation of indigenous bacteria through the injection of the nutrient mixture. The results indicate higher oil production rates, incremental oil recovery, and decreased water cuts (up to 10%), which decreased operating costs due to reduced lifting and water treatment costs.

Conclusion

Bacterial profile modification makes use of indigenous and exogenous microbial strains to enhance the recovery of oil. These microbes are capable of producing metabolites: biosurfactants tend to reduce the oil viscosity, biomass clog the high permeable zones of reservoirs, gases help in reducing the viscosity and further pressurize in oil mobility, solvents also reduces the interfacial tension. This process has the potential to recover oil reserves that otherwise would remain immobile and unrecoverable. Profile modification is safe and environmentally friendly.

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