

Prospects for Industrial and Microbial Biotechnology in Oil Industry



Biotechnology

KEYWORDS : Biotechnology, MEOR, oil industry, bioremediation

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ABSTRACT

Biotechnology plays a predominant role in discovery and production of hydrocarbon for energy security of the world and thereby plays a pivotal role in oil industry. Oil industry have performed substantial amount of research and applied bioprocesses as complementary technologies on diverse platforms in order to reduce investment and maintenance costs while promising to overcome technological barriers concerning the upgrading of petroleum and gas. The petroleum industry includes biodesulfurization of gasoline and diesel as technical areas of greatest concern and requirement on academic and private efforts on research are to be increased. The roadmap and research on Microbial Enhanced Oil Recovery (MEOR) can provide attention on the potentiality of biotechnology to others fields for the oil industry.

INTRODUCTION

The implementations of biological processes in the oil industry are important to search, generate, refine and transform petroleum and other oils into valuable derivatives. Microbial enhanced oil recovery (MEOR) is a new technology that represents the use of microorganisms to extract and recover the remaining oil derivatives from reservoirs [1]. These derivatives can clean the pollution refers as new dimensions of biotechnology in oil industry. During the last few years, biotechnology has fortified its position as the assembly of technologies with focusing on the production of goods and services by means of biological systems or its products [2,3]. The fast-paced technological progression derived from the modification of DNA allowed the industrialization of new processes. Hence in recent times, biotechnology in food, agrochemical, environmental, chemical, and pharmaceutical has a broad and diverse impact at industrial level [4]. Oils are indeed complex amalgamations of hydrocarbons are present at largest source of energy next to natural gas. These are the valuable substrates for microorganisms.

MICROBIAL ENHANCED OIL RECOVERY (MEOR)

Microbial Enhanced Oil Recovery (MEOR) is a new technology that can be potentially implemented with an exceptionally low operating cost [5]. The technique utilizes microorganisms and their biological products to enhance the oil recovery. Bacteria are the microorganisms used in the production of metabolic compounds like acids, biosurfactants, biopolymers, gases, solvents and biomass that increase their sources to be used for EOR purposes [6]. Industrial processes for MEOR made to classify the mechanisms of bacteria that can be calculated and applied in environmental problems like hydrogeophysics [7,8].

The three bacterial species (*Bacillus subtilis*, *Clostridium acetobutylicum* and *Pseudomonas putida*) is highly permeable in porous rock has been conducted by Jang et al., 1983 [9]. These microbes have also provided a quantitative screening criterion for selecting proper potential bacterial strains for in situ MEOR applications. *Bacillus* and *Clostridium* species are the most common species used for MEOR purposes since they can form dormant with resistant endospores that can survive under stressful and drought environmental conditions. During these conditions, the species can produce various kinds of useful bioproducts for MEOR [10-12]. A partial list of bacteria has been compiled that have been used in the MEOR experiments through field studies [13].

MEOR is considered as an inexpensive process that has to be implemented with minor modifications to the existing field and facilities [14]. Considerable research in the area of MEOR using

microbes is important to be performed in the present decades.

MICROBIAL TREATMENT

The application of bacterial in the production of oil was first suggested by Beckman in 1926 [15]. Since 1946, Extensive experimental work on the potential of microbes for MEOR and process for secondary recovery of petroleum using anaerobic bacteria, hydrocarbon utilizing, and sulfate reducing bacteria purposes was conducted by various scientists. The promising results and the research in this area lost its interest due to economic reasons during 1970s. During 1980 to 1990, the global decline in oil prices raised the need for a cost effective process that is both technically and economically feasible [16].

OIL RECOVERY MECHANISM IN MEOR

MEOR offers a multiple mechanism to be applied inside the reservoir and recover additional oil from depleted reservoir. MEOR encompasses a multiplicity of methods ranging from those of inoculation of microbes from single reservoir treatment to field-wise treatments. During the process, bacteria grow on the nutrients inoculated in the reservoir and produce useful metabolic products (or metabolites) for enhancement of oil recovery machinery by aerobic or anaerobic microbes [17]. The process induces the microbes to become oleophilic (to seek and attach them to oil droplets) and induces the microbes to perform an activity within the oil reservoir as to produce bio-gas, bio-surfactant or bio-polymers.

Oil recovery using MEOR usually requires three stages:

Stage 1: Primary Oil Recovery

Nearly 12% to 15% of the oil in the reservoir can be recovered without the need to introduce other substances into the well.

Stage 2: Secondary Oil Recovery

The oil reservoir is flooded with water or other substances to drive out an additional 15% to 20% more oil from the reservoir

Stage 3: Tertiary Oil Recovery

This stage may be accomplished different methods like MEOR to recover additional oil (nearly 11%) more oil from the reservoir.

Various mechanisms involves in the process of MEOR shows reduction of oil viscosity and facilitate microorganisms break down the complex molecular structure of crude oil, makes more fluid for easy recover of oil from the reservoir [18]

Table 1: Types of Microbial Processes for Oil Recovery

Process	Production Problem	Types of Activity or Product Needed
Cleanup of reservoir	Paraffin and matter deposits	Biosurfactants, hydrocarbon degradation, Emulsifiers, solvents, acids
Stimulation of reservoir	High water production, Formation damage, pore damage	Biosurfactants, Gas, acids, solvents, Biomass and polymer production
Enhancement of water flooding	Poor displacement efficiency, Poor sweep efficiency, Coning, Scouring	Biosurfactants, Biomass and polymer production, solvents, polymers, Nitrate reduction

MICROBIAL CANDIDATES FOR MEOR

In terms of their oxygen intake, microbes can be classified into two main classifications: aerobes and anaerobes. Successful field experiments mostly used the anaerobic bacteria rather than aerobes. The anaerobes do not contain the appropriate complement of enzymes in network system that is necessary for the growth in an aerobic environment. The work conducted by Lazar et al., 2007, found predominantly spore-forming cocci and bacilli in deep reservoir and non spore-forming bacilli in shallow ones [16]. There are many sources from which bacterial species that are MEOR candidates can be isolated. These shows the formation of waters, sludge from biogas operations and effluents from sugar refineries, sediments from formation water purification plants (gathering stations) and oil contaminated soil could be used as a good source of isolation of microbes for MEOR. Isolation of MEOR from hot water streams was also been reported in previous studies [14,19].

MICROBIAL NUTRIENTS FOR MEOR

Nutrients are the largest expense in the MEOR processes where 30% of the cost for a microbial fermentation is processed on fermentation medium. The microbes require mainly three nutritive components for growth and metabolic productions. They are carbon, nitrogen and phosphorous sources like C,N and P that are generally in the ratio of 100: 10: 1 [20]. The optimization of the media is very important since the types of bioproducts that are produced by different bacteria are highly dependent on concentrations and components of the nutrients provided for growth. Cheap raw materials like molasses, whey, beef extract, cheese etc., are also used as nutrients in MEOR technology that contain all the necessary nutritional components [21].

MICROBIAL BIOPRODUCTS

Microorganisms produce a variety of bioproducts as metabolites that are potentially useful for oil recovery [14]. There are six main bioproducts or metabolites produced by microbes.

Table 2 shows a summary of these bioproducts and their application in oil recovery.

IN SITU AND EX SITU MEOR

There are two processes for MEOR technology depending on the site of the bioproducts production. They are ex situ and in situ processes [22, 23]. The major oil recoveries are now exploring in the more conventional EOR processes and considering as potential in both MEOR ex situ and in situ methods. The ex situ process involves the production of the biological products at the surface outside the reservoir by inoculating bacteria separately either with or without separation of the bacterial cells. The in situ process involves the production of the bacterial products within the reservoir by enhancing the indigenous reservoir microbes or inoculating the selected bacteria (exogenous microbes) that produce specific metabolic products within the reservoir.

Table 2: Microbial bioproducts and their applications in oil recovery

Product	Microorganism	Application in oil recovery
Biomass	Bacillus sp., Leuconostoc mesenteroides, Xanthomonas campestris	Selective plugging, viscosity reduction, oil degradation, wettability alteration
Biopolymers	Bacillus polymyxa, Brevibacterium viscogenes, Xanthomonas campestris, Leuconostoc mesenteroides, Enterobacter sp.	Control of mobility, viscosity changes
Bio-acids	Enterobacter aerogenes, Clostridium sp.,	Emulsification, increase of Permeability
Bio-solvents	Clostridium sp., Zymomonas mobilis	Emulsification, reduction of viscosity
Biosurfactants	Bacillus strains, Clostridium sp., Pseudomonas sp., Acinetobacter calcoaceticus, Arthrobacter paraffineus	Emulsification, interfacial tension reduction, viscosity reduction
Biogases	Clostridium sp., Enterobacter aerogenes, Methanobacterium sp.	Pressure increase, oil swelling, interfacial tension reduction, reduction in viscosity, increased permeability

FUTURE RESEARCH

There is a strong need to provide a general overview of the present biotechnology situation and its future impact on the oil industry. This industrial sector has shown importance in petroleum products with experiences and challenges due to decreasing oil reserves, increasing demand of petroleum, fuels and petrochemicals, fluctuating oil prices with more environmental regulations. The challenges in MEOR will strengthen and persist MEOR technology in the upcoming years. MEOR is well-proven technology in implementation to select the selective microbes to understand their growth requirements and production conditions. Conducting toxicity tests on the microbes is recommended in various fields to assure safe handling and does not show threat to humans or the environment. The use of bioremediation in various countries is increasing. The scientific, public perception, regulatory and economic limitations are the barriers to MEOR a decade ago still exist. Hence the use of bioengineered microorganisms for environmental cleanup is to be applied for the benefit of society should be done in the near future.

CONCLUSIÓN

Biotechnology has several potential environmental applications, these include: agriculture, pollution control, mining and MEOR. The rationale for using micro-organisms to degrade pollutants and toxic substances provides experience with nature. Micro-organisms have a variety of capabilities in production of MEOR products like Biomass, Biopolymers, Bio-acids, Bio-solvents, Biosurfactants and Biogases which can be exploited for waste management and disposal of toxic products.

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