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Uses of Microorganisms in The Recovery of Oil and Gas

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Abstract

Microscopic organisms are the only single-celled organisms proposed for the advancement of techniques for Estimation of Oil Recovery (EOR) because they have numerous desirable properties, including a simple structure and an unsustainable growth rate when supplied with vital nutrients, resulting in the release of metabolic chemicals like Aerosols, acids, minimum lubricants, surfactants, and polymers.

Clostridium acetobutylicum was isolated from intensive rice cultivation soil and has the ability to use polysaccharides such as starch and carboxylmethyl cellulose to produce biobutanol, while *Desulfovibrio hydrocarbonoclasticus* was isolated from marine sediment in Iraq and grows in anaerobic synthetic seawater medium with the addition of a trace element solution. These bacteria can also withstand difficult conditions High salinity, high pressure, and high temperature play roles and contribute to underground geological formations. An aqueous mixture of nutrients, *Clostridium acetobutylicum*, *Desulfovibrio hydrocarbonoclasticus*, and molasses with nutrient and bacterial spore injection into a reservoir. As a result, these microorganisms are capable of considerable catalytic reactions.

production of a diverse spectrum of products (biosolvents, bioacids, biogases, and biosurfactants) from relatively simple nutritional compounds, multiply vigorously under favourable conditions, and have resulted in increased oil release from reservoir rock. The well began producing 70 days after the medication was started. 80 to 90 days after the injection began, relatively brief polyunsaturated fats, Carbon dioxide, and residues of ethanol, 1-butanol, and acetone were detected. Because of their highly resistant endospores, *Clostridium* are the most ideal of the several microbes used in MEOR (Microbial enhanced oil recovery). *Desulfovibrio* strains capable of producing biosurfactants in situ, which are beneficial to the MEOR process, are also valuable. Nutrients are often supplied as fermentable carbs to promote microbial metabolism.

Keywords: Enhancement of Oil Recovery, *Clostridium acetobutylicum, Desulfovibrio hydrocarbonoclasticus,* biosurfactants and MEOR.

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استخدامات الكائنات الحية الدقيقة في استعادة الغاز والنفط

الخلاصة:

البكتيريا هي الميكروبات الوحيدة التي تم اقتراحها حتى الآن لتطوير عمليات تحسين استخلاص الزيت (EOR) ، لأنها تمتلك العديد من الخصائص المهمة: الحجم الصغير، ومعدل النمو عند إمدادها بالمغذيات الأساسية ويؤدي ذلك إلى إنتاج المركبات الأيضية، مثل الغازات والأحماض والمذيبات منخفضة الوزن الجزيئي والمواد الخافضة للتوتر السطحي والبوليمرات.
تم عزل كلوستريديوم أسيتوبوتيليكوم من التربة المستخدمة في زراعة الأرز في العراق والتي لديها القدرة على استخدام السكريات مثل النشا وكربوكسيل ميثيل السليلوز لإنتاج البيوبوتانول وتم عزل البكتيريا ديسولفوفيبريو من الرواسب البحرية في العراق والتي تنمو في وسط مياه البحر. وتتحمل هذه الأنواع من البكتيريا أيضًا البيئات القاسية المشابهة لتلك التي توجد في التكوينات الجيولوجية الجوفية، مثل الملوحة العالية والضغط العالي ودرجة الحرارة المرتفعة.
وتم عمل خليط مائي من العناصر الغذائية، كلوستريديوم أسيتوبوتيليكوم و ديسولفوفيبريو هيدروكاربونوكلاستيكس، وتم الحقن بالعناصر الغذائية والجراثيم البكتيرية في الخزان. وبالتالي كانت هذه الكائنات الحية الدقيقة لها قدرة كبيرة على التخليق الكيميائي.
تم الحصول على مجموعة واسعة من المنتجات (المذيبات الحيوية، والأحماض الحيوية، والغازات الحيوية، والمواد الحيوية السطحية) بشكل عام من مركب مغذي بسيط نسبيًا، وتنتشر بقوة في ظل ظروف مواتية، مما أدى إلى تحسين إطلاق الزيت من صخور المكمن. ولاحظنا أن بئر الإنتاج بعد 70 يومًا من بدء الحقن ملئ بالأحماض الدهنية قصيرة السلسلة، وثاني أكسيد الكربون وآثار من الإيثانول، 1-بيوتانول، والأسيتون بعد 80 إلى 90 يومًا من بدء الحقن.
نستنتج ان الكلوستريديوم هو الأكثر مثالية من بين العديد من الكائنات الحية الدقيقة المستخدمة في MEOR (استخلاص الزيت المعزز الميكروبي) بسبب أنواعها الداخلية شديدة المقاومة. وسلالات Desulfovibrio يمكن لها أن تنتج عوامل خافضة للتوتر السطحي في الموقع ، والتي تكون مفيدة لعملية MEOR ، مفيدة أيضًا. لتشجيع التمثيل الغذائي الميكروبي ، يتم إعطاء المغذيات عادة على شكل كربوهيدرات قابلة للتخمر.

1. Introduction:

Despite the fact that Rapidly expanding economies like China, India and Brazil are forecast to compensate for more than 0.5 of the growing demand for energy; both worldwide energy needs and expenditure are expected to increase. Despite the fact that coal and oil (oil, gas, and coal) will eventually overtake energy sources, contributing for more than three-quarters of global energy infrastructure in 2035, demand for renewables will surge (such as nuclear, solar, and wind) as well as desire for geothermal, wave, and biofuels has increased concurrently. Secondary oil recovery can boost recovery by 15-25%, and up to 55% remaining unrecoverable in petroleum reservoirs [1].The industry is motivated to maximize oil recovery efficiency by the current low but volatile oil price, the maturation of major oil fields (such as the North Sea) and the decline in the number of freshly produced oil fields [2]. EOR is a tertiary recovery technique which employs diverse thermo, biochemical, and microbiological techniques to recover a supplemental 7-15percent of the overall of oil from underperforming and depleted oil wells at an efficient and cost-effective production rate [3]. Microorganisms expanded oil

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regeneration (MEOR) is an alternative oil rebuilding technique that has been shown in the literature to retrieve up to 50% of residual oil. MEOR processes entail injecting native or suitable exogenous microorganisms (primarily bacteria) and nutrients into an oil tank to promote in situ microbial growth or byproducts of aerobic treatment compounds that can affect the physicochemical characteristics of crude oil and catchment area conditions, thereby raising oil production [2].

1.1 Types of Enhanced oil regeneration methodologies

Enhanced oil recovery techniques can be categorized broadly into thermal and non-thermal categories, as indicated in Figure (1) Thermal procedures involve combustion, steam flooding, and hot water injection. Non-thermal processes have a wider range of applications than thermal ones. Gas (carbon dioxide, nitrogen, and stack gas) and chemical (polymers, surfactants, and alkaline) examples include MEOR and foam flooding injection. To recover oil from lighter oils, miscible gas instillation, water alternating gas (WAG) injection, polymer or surfactant flooding, and changes in apparent viscosity can all be used. Thermal activities such as cyclic steam injection and in vitro dissolution would be preferable for heavier oils [4]. Because carbon dioxide is abundant and has low price to extract, and Mudstone have been studied on both a prototype and levels of the value chain, thermal and gas injection techniques, greenhouse Gases such as carbon, are the most regularly used for sandstone reservoirs [5].

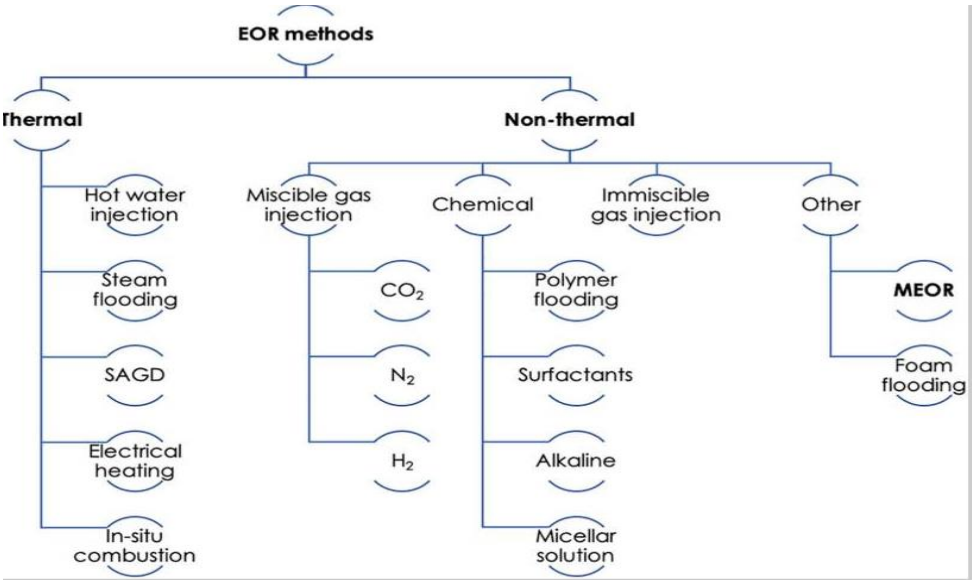

Fig. (1): Methods for enhancing oil recovery (EOR) are summarised. MEOR, microbial enrichment oil regeneration; SAGD, steam assisted gravity drainage [4]

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1.2 Microbial Enhanced Oil Recovery (MEOR)

The injected microorganisms could generate an extensive EOR-relevant metabolic products are selected. A range of characteristics, including reservoir pressure, porosity, permeability, temperature, pH, dissolved solids, and salinity, as well as the availability of nutrients for the bacteria and specific microorganisms injected into the reservoir, according to [3], influence microorganism growth and outcomes. When both primary and secondary recuperation techniques have been applied, it is thought that MEOR can recover up to fifty percent of the remaining oil in a pond. Metabolite production and growing bacteria to achieve this increased recovery typically include changing the physical and chemical attributes petroleum products and deposit rocks [1]. As a result, MEOR could overcome the fundamental barriers to effective oil regeneration, High crude oil stiffness, poor aquifer accessibility, and maximum oil IFTs, for example, provide flow resistance strong enough to trap the oil in the pores of the reservoir rock. Mixes or formulations of mixed bacterial diversity bacteria and archaea— The use of metabolic products as like solvents, acids, or gases to improve recovery and extend the life of oil wells is prevalent. *Clostridium, Zymomonas, and Klebsiella*, for example, utilise acetone, butanol, and propan-2-diol to create. Greenhouse gas emissions are evidenced by methane and hydrogen gas. synthesized by the *archaeon Methanobacterium* as well as the bacterial species Clostridium and Enterobacter. Fermentation gases can repressurize wells, causing light crude oil to be displaced and so improving recovery [6]. *Clostridium* are the most ideal microbes for MEOR (microbial enhanced oil recovery) because of their extremely resistant endospores that allow life in difficult environments [7]. Some Bacillus strains are indeed very effective because they may create biosurfactants that aid in the MEOR process in situ [8]. Nutrients, most commonly in the form of fermentable carbohydrates, are administered to boost microbial metabolism.

2. Devices and experimental works

2.1 Location of samples and diagnosis:

Sampling locations *Clostridium acetobutylicum* was isolated from the soils of Iraq at...., the submerged soil samples were inoculated after collection in sterilized Reinforced Clostridia Medium (RCM) in 100 mL serum bottles with a working volume of 50 mL, which were flushed with nitrogen to impart anaerobic conditions. The RCM medium was thereafter incubated at 30 °C, and the gas production was observed for 5 days. This isolate can also produce biobutanol from polysaccharides like starch and carboxylmethylcellulose. Certain Bacillus strains are

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extremely successful because they can produce biosurfactants that promote the MEOR process in situ [8]. To stimulate microbial metabolism, nutrients, most often in the form of fermentable carbohydrates, are administered [1]. *Clostridium acetobutylicum* morphological and cytological alterations during the formation of acetone, butanol, and ethanol in an industrial fermentation medium were found and linked with growth and physiological changes. Clostridial forms that were inflated and cigar-shaped were engaged in the conversion of acids to neutral solvents, and there was a correlation between the number of clostridial forms and the synthesis of solvents. Solvents were not produced by sporulation mutants that were unable to establish clostridial stages (cls mutants). Solvent levels were intermediate in oligosporogenous mutants with reduced clostridial stage development. Sporulation mutants that were unable to generate mature spores (spo mutants) produced normal quantities of solvents after the clostridial stage. The absence of chromosomal gene transfer methods in obligate anaerobes has impeded genetic research in these medicinal and industrially significant bacteria. We examined protoplast fusion and reported the isolation of chromosomal recombinants in order to build a genetic system for the industrially important Clostridium acetobutylicum strain P262, which manufactures acetone and butanol. Although plasmid transformation of the anaerobic pathogen Clostridium perfringens was recently described [21], this is the first account of a chromosomal genetic recombination mechanism in clostridia, as well as the first report of protoplast fusion in an obligate anaerobe.

Desulfovibrio hydrocarbonoclasticus was isolated from marine sediment in Iraq and The microorganisms were propagated in 160-ml serum vials with fifty or hundred ml of anaerobic synthetic seawater substrate, in order to enrich dechlorinators rather than sulphate reducers, the medium was changed from conventional saltwater media to remove sulphate and achieve an approximate seawater-like Na^+ content of 0.46 M. With the addition of a trace element solution, the final concentrations (in milligrams/liter) were as follows: The comparable values are Manganese chloride • $6H_2O$, 5, H_3BO_3, 0,5, Zinc- chloride, 0,5, Cobalt chloride, 0,6, nikl sulphate, 0,5, Copper chloride, 0,3, and $NaMoO_4$ • $2H_2O$, 0. Also, each litre includes 10 mg of resazurin, 0.003 mg of $NaSeO_3$, and 0.008 mg of Na_2WO_4. The medium was brought to a boil with oxygen-free N_2, then cooled with nitrogen and carbon dioxide (95:5). Following that, final concentrations of 1 mM sodium sulphate (as a reductant) and 30 mM $NaHCO_3$ were added. By adjusting the carbon dioxide level in the headspace, the pH of the medium was elevated to seven to seven and half. The medium was deposited in nitrogen and carbon dioxide -flushed serum

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bottles before subculturing and securing them with butyl rubber stoppers. Thiamine, 1,4-naphthoquinone, nicotinamide, hemin, and lipoic acid were added to the sterile medium at concentrations of 0.05, 0.2, 0.5, 0.05, and 0.05 mg/liter, respectively, along with an anaerobic sterile Wolin vitamin solution. To prevent precipitation, sterile anaerobic stock solutions of Magnesium chloride and Calcium chloride were added. ten gram of sediment was transferred to 160 ml serum vials under anaerobic environments, together with 100 cc of saltwater medium adjusted to a final concentration of 250 M using 2-CP. The cultures were kept stationary in a dark, 25°C incubator [9]. After 60 hours of incubation, the BACTEC 9240 blood culture equipment (Becton Dickinson) highlighted the two sets of blood cultures taken by the emergency department as positive in anaerobic Lytic-10 medium. Gramme stains revealed gram-negative spiral bacilli, and wet mounts created from centrifuged concentrates demonstrated that the organisms moved. Positive vial contents were subcultured to chocolate and blood agars incubated at 35°C in 6% CO2, MacConkey agar aerobically incubated at 35°C, and CDC anaerobic blood agar anaerobically incubated at 35°C. Small transparent colonies developed on the anaerobic media after 4 days, whereas the aerobic plates remained negative. The isolate was transported to the laboratory to be identified. The morphology, motility, and obligate anaerobic nature of the organism led to its classification as a Desulfovibrio species. the lack of saccharolytic activity, a positive desulfoviridin test, and the production of H_2S. Identification of the species was performed by Quest Diagnostics (San Juan Capistrano, Calif.) with a MicroSeq 500 16S ribosomal DNA sequencing kit (Applied Biosystems, Foster City, Calif.), which sequences the first 500 bp of the 16S rRNA gene. The DNA was first amplified by PCR, purified, and then sequenced by the dideoxy chain termination cycle sequencing method. The sequenced products were purified and resolved by capillary electrophoresis on an ABI 3700 DNA sequencer and analyzed with ABI Sequencing Analysis software. The resulting DNA sequence was compared by means of MicroSeq analysis software to Applied Biosystem's library of 16 ribosomal DNA bacterial sequences. In addition, the sequences were also compared against those in public databases. The isolate was identified as *D. desulfuricans* [21]. The methods of MEOR presented as follow [11] as showed in Figure (2):

1- The generation of acids capable of dissolving carbonates, thereby liberating the imprisoned oil in situ (OIP).

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2- The generation of gases that can swell the OIP or reduce its viscosity while also increasing reservoir pressure.
3- The creation of organic solvents that can alter rock wettability, lower OIP viscosity, or enhance water viscosity.
4- The creation of biofilms or other biopolymers that enhance the viscosity of water or block exhausted canals, hence boosting sweep efficiency.
5- The synthesis of surface active chemicals (SAC) that lower the interfacial tension between oil and water.
6- Methane generation from oil.
7- MEOR may necessitate the injection of a microbial inoculum, which is a nutritional broth containing microorganisms. Nutrients alone may also be supplied to boost the growth of specific members of the indigenous microbial population. In most cases, additional carbon sources would be required for inoculation [6].

Zobell in 1946 [10] patented *Desulfovibrio hydrocarbonoclasticus,* an anaerobic, hydrocarbon-using, sulfate-reducing bacteria. A soluble mixture of nutrients, including Clostridium acetobutylicum, Desulfovibrio hydrocarbonoclasticus, and molasses, resulted in the formation of hydrogenase by bacterial microorganisms. This enzyme, hydrogenase, was assumed to have potential for hydrogenase production given that certain of these items have a reputation for improving oil release from reservoir rock. nutrient and bacterial spore injection into a reservoir The spores grew in the reservoir, allowing the oil to be freed from the rock more easily. A sand-packed, oil-soaked column was used to test the theory in a laboratory setting. After passing an aqueous solution containing molasses and *Clostridium* spores down the column, oil release enhanced (by roughly 30%) [11].
Over a 6-month period, 25 200-gallon containers of broth containing *Clostridium acetobutylicum* and two percent solution of beet syrup in fresh water were inserted [12]

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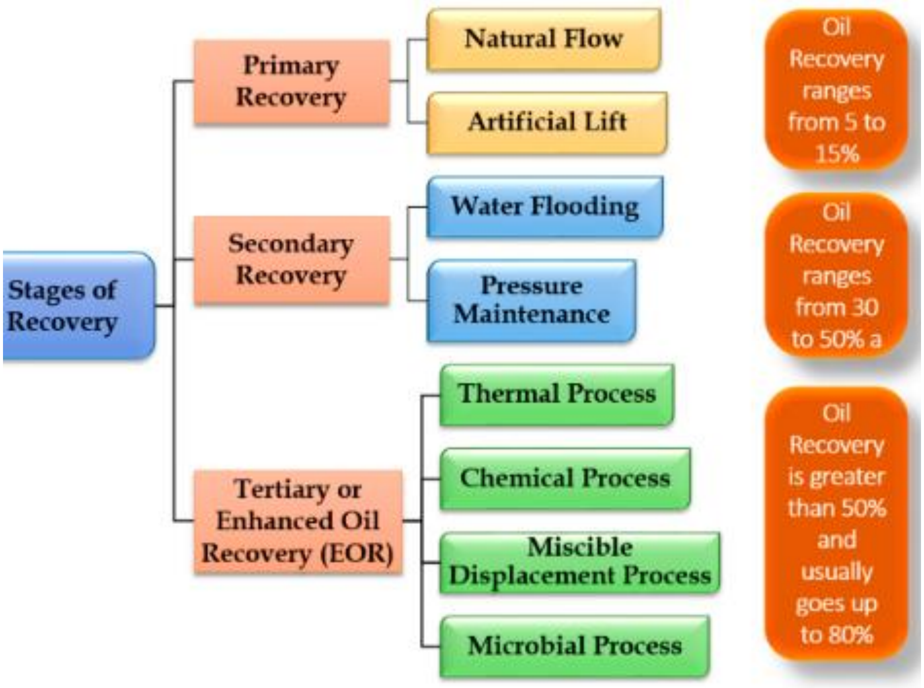

Fig. (2): Methods of Microbial enhanced oil recovery

3. Results and Discussion:

Clostridium acetobutylicum is the most ideal because of its highly resistant endospores, which allow it to survive in harsh settings [7]. *Desulfovibrio hydrocarbonoclasticus* is also useful because it may produce biosurfactants in situ, which are beneficial to the MEOR process, and nutrients, which are often in the form of fermentable carbohydrates, encourage microbial metabolism [8]. Figure (3)

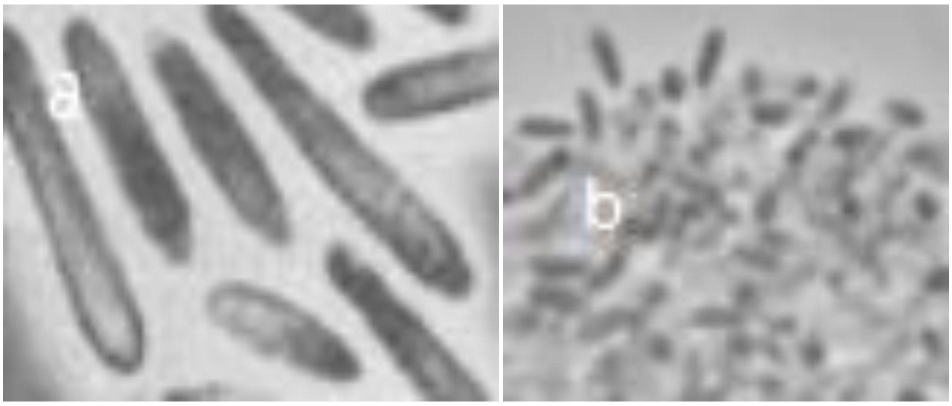

Fig. (3): Microorganisms used in enhancement of oil recovery. (a) is Clostridium acetobutylicum and (b) is Desulfovibrio hydrocarbonoclasticus.

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MEOR is an alternate method of oil recovery. MEOR is frequently defined as injection of living microorganisms containing important nutrients into an injection well. When the reservoir's environmental conditions are favourable, the introduced microbes multiply rapidly, and their metabolic products mobilise the leftover oil [3]

-production of chemicals for Enhanced Oil Regeneration like gases, oils, acids, solvents, and surfactants, using microorganisms that consume injected polymers and CO2 flood byproducts. The organisms that are inserted into polymer floods consume the polymer that has adsorption on the reservoir rock. The bacteria in CO2 floods consume the soluble carbon, nitrogen, and sulphur components that the CO2-crude oil slug leaves behind.

Seventy days after the injection began, freshwater milestone was achieved at the producing well. Relatively brief fatty acids, carbon dioxide, and trace quantities of ethanol, 1-butanol, and acetone were identified eighty to ninety days after the injection started. Sugars began to appear as well. The hydrogen content remained unchanged. Oil production grew from 0.9 to 3.3 barrels per day. Despite the fact that the study was pronounced effective, no additional field tests were carried out.

3.1 Mechanisms involved in MEOR:

MEOR is frequently defined as in order to foster the growth of indigenous microorganisms, live microorganisms containing necessary nutrients are placed into an injection well. As a carbon source, the bacterium consumes crude oil and turn it from its complicated to its simple form when the inorganic salts are supplied. On the other hand, the addition of exogenous carbon sources including sucrose, glucose, and molasses resulted in the production of additional metabolites [11].

The MEOR mechanism is split into two components. Using microorganism biomass or biopolymers to selectively block high permeability zones and enhance oil recovery is one technology; another is to use solvents or biosurfactants to minimize Within the reservoir, there is frictional tension. If only the viscosity of crude oil is addressed, regeneration can be accomplished in two ways: either by lowering the oil-water contact resistance or by augmenting the oil-water tension between surfaces or by using bacteria or enzymes that degrade the heavy part of the oil, such as alkyl-monooxygenase/ hydroxylase [3]

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3.1.1. Selective plugging

The increased the availability of the medium in the reservoirs is the underlying issue with recovery. The medium is saturated with oil, which has collected in inaccessible locations; these areas are referred to as "thief zones". Selective plugging involves blocking high permeability medium that prevents oil buildup in order to meet the process's purpose of releasing trapped oil from thief zones. Furthermore, after flooding with water, oil-rich zones are directly flooded, forcing trapped oil from the reservoir. The biomass and biopolymers that are stuck to the top of the media, where they grow, are used. This resulted in the formation of biofilm and clusters, which restrict oil seepage into high permeability zones [8].

A variety of bacteria digest biopolymers, which are high molecular weight molecules with hydroxyl groups that make them dipole, ion-dipole, and hydrogen link with other substances to form the network-like structure. Recent research indicates that these networks function as a barrier to improved oil recovery [16].

3.1.2. Interfacial tension (IFT)

Biopolymers, which are nonpolar molecules containing both hydrophobic and hydrophilic moieties, can be created by microorganisms. Biosurfactants have the ability to extract oil from difficult deposits. Biosurfactants can ameliorate poor oil regeneration by decreasing the tension that exists between the liquid media and oil saturation. This is due to either the high permeability of the oil or the poor permeability of the rock formation [14].

Biosurfactants have the capability of reducing the capillary forces that prevent oil from flowing through rock pores. The viscous forces oppose the capillary forces that favour flow in the reservoir. A capillary number is used to describe the parameter between the two forces and determine the possibility of any leftover oil in the reservoir being mobilised. The capillary number and the amount of oil mobilised are directly connected. The biosurfactant can improve capillary number to allow increased oil recovery [7].

3.1.3. Biogases, solvents, and biogenic acids

Solvents, gases, and organic acids are among the metabolites used in the MEOR process. In a core flood test, a variety of thermophile bacteria that can synthesis volatile fatty acids, biomass, and gases were reported to aid in the recovery of around 19% of the oil. Many gases were produced as a result of the fermentation of carbohydrates and other hydrocarbons, including

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CO_2, H_2, CH_4, and others. These gases assist in pressurizing the crude oil and making it less viscous. [16].

Microscopic organisms produced low-molecular-weight organic acids such as formic acid and acetic acid propionate during the fermentation process. While crude oil's dissolved gases and solvents may reduce viscosity, secondary metabolites can dissolve carbonate rocks, raising reservoir permeability [15]. Table (1) summarises these bioproducts and their related technologies.

Table (1): Microbial bioproducts and their applications in oil recovery.

products	Microorganisms	Application in oil recovery
Biosolvent (acetone, butanol and propan-2-diol)	*Clostridium acetobutylicum*	Encapsulation, viscosity, and weight loss
Bioacids Formic acid and acetic acid	*Clostridium acetobutylicum*	Increase exfoliation and permeability
Biogases Carbon dioxide, methane and hydrogen	*Clostridium acetobutylicum Desulfovibrio hydrocarbonoclasticus*	Oil swelling, lower interfacial tension, decreased viscosity, and higher permeability are all caused by increased pressure.
Biosurfactants Lipopeptides, phospholipids, glycolipids	*Desulfovibrio hydrocarbonoclasticus*	Surface and interfacial tensions are lowered, and the Increased solubility and mobility of hydrophobic or insoluble biomolecules.

The amount of molasses that is added to the injection water can vary. We've discovered that adding 100–2,000 parts of molasses to a million parts of water causes more fast proliferation and more rapid and full release of petroleum oil from oil-bearing soil elements than is possible without such an added nutrition. Yet given that the molasses' carbohydrate percentage might fluctuate, larger or smaller amounts of molasses can be added to the injection water as required.

3.1.4. Bio-Solvents

Solvents are sometimes created as a byproduct of microbial metabolism. Propan-2-diol, acetone, and butanol are examples. They may also help to reduce oil viscosity and function as a co-surfactant in the reduction of oil-water electrostatic repulsion [17].

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3.1.5. Bio-Acids

When fed proper nutrients, certain bacteria can create acids such as formic acid and acetic acid. These acids may be useful in carbonate reservoirs or carbonate-cemented sandstone formations. because they can dissolve carbonate rock and so increase its porosity and permeability. Anaerobic carbohydrate fermentation frequently involves a phase in which bacteria create organic acids. Clostridium sp., for example, may produce 0.0034 moles of acid for every kilogram of molasses [15].

3.1.6. Biogases

Gases like carbon dioxide, hydrogen, and methane can be produced by bacteria through the fermentation of carbohydrates. By taking advantage of the principles of reservoir re-pressurization and reduced viscosity in heavy oil, these gases can be exploited to improve oil recovery. In pressure-depleted reservoirs, these gases may help to increase pressure. In addition, they might dissolve in crude oil and lessen its viscosity.

According to reports, *Clostridium, Desulfovibrio,* and certain methanogens are among the genera that produce gas. Methanogens create a mixture of around 60% methane and 40% carbon dioxide, with the methane partitioning into the oil and gas phase and the carbon dioxide partitioning into the water phase, improving the mobility of the oil [16].

3.1.7. Biosurfactants

A variety of microorganisms produce amphipatic compounds with both hydrophilic and hydrophobic components. They can lower surface and Congregating at the interface of immiscible fluids reduces friction coefficient and promotes the solubility and mobility of repellent or intractable organic molecules. Lipids include lipopeptides, phospholipids, glycolipids (including biosurfactant, glycosaminoglycan lipids, and sophorolipids), essential fats, and neutral lipids [7].

3.1.8. Bioremediation

One of the most intriguing mechanisms in the MEOR process is biodegradation. The viscosity, fluidity, and other qualities of crude oil are fundamentally altered during this process, and the heavy fraction is broken down into lighter components, increasing oil recovery. Anaerobic and aerobic biodegradation are the two forms of degradation. Aerobic biodegradation begins when bacteria consume crude oil that has been oxidised by oxygenase and peroxidase enzymes [17].

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Clostridium are the most ideal microbes for MEOR because of their extremely resistant endospores that allow life in difficult environments [7]. Desulfovibrio strains are also useful because they may produce biosurfactants in situ, which are beneficial to the MEOR process. To enhance microbial metabolism, nutrients, most typically in the form of fermentable carbohydrates, are introduced [8]. The first MEOR field test was done in 1954 at Lisbon Field in Union County, Arkansas. Upwards of 400 MEOR field experiments had been completed by 2003 as a result of more field testing. In addition to several additional field tests conducted around the world, just one [18] has been completed in the United States. MEOR field applications have two basic goals: single well treatment and complete field treatment.

This is similar to the huff and puff procedure, however in this instance the microbial influence is used. The well is first inoculated with the desired bacteria, and nutrients are injected to promote the indigenous microbes. The well is then shut off for a period of time to allow microbial growth and the generation of the required metabolites surrounding the well bore. Ultimately, the well is made effective and ready for drilling. The majority of effective field trials recorded were single well treatments in the United States, China, Romania, India, Russia, and Argentina, with incremental oil varying from no influence to 20% [19].

Port wood, on the other hand, collected data from 322 US projects that were all managed using the MEOR technique. One of the goals was to identify any reservoir characteristics that would be dominant in determining whether the MEOR technique could be adopted. He observed that reservoir lithology had no discernible impact on MEOR efficiency because 73% of the operations were executed in sandstone reservoirs and 27% in carbonate reservoirs. He also stated that MEOR technology might be used in reservoirs with a wide temperature range because microorganisms can endure the temperatures encountered in most oil reservoirs [15].

He also noted that when porosity grew, so did incremental oil output. Even at the highest porosity levels (26-30%), the incremental production was nearly 20%. As a result, porosity was not considered to be a limiting issue in the MEOR approach. Another breakthrough was the revelation that low oil gravity reserves (those with an API of 30 or even below, indicating heavier oil) are appropriate for MEOR applications. It is crucial to understand that microbial EOR is not a single technique or approach, but rather the adaptation of microbial systems to unique issues with oil recovery from a certain target reservoir. These microbial systems regulate a variety of processes, such as wet ability modification, oil viscosity reduction, selective plugging, scale and corrosion management, and others [12].

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3.2 MEOR Technologies' Benefits and Drawbacks:

As outlined below and summarized by Lazar *et al.* (2007) [20], MEOR offers a number of advantages:

- The bacteria, nutrients, and/or other natural products that are injected can be made from low-cost, widely available basic ingredients or even waste, and they are unaffected by crude oil prices.

- It is a cost-effective solution for usage in mature oil fields before they are shut down.

- The approach is less expensive and easier to implement than other EOR strategies because it does not require major modification of existing field infrastructure and equipment. Thermal EOR techniques consume more energy than microbial procedures.

- Because alternative EOR technologies would not deliver the appropriate results in these settings, the approach is best suited for carbonate oil reserves.

- The benefits of bacterial activity within the reservoir grow over time, whereas alternative EOR methods do not.

- It makes extensive use of totally biodegradable chemicals and additives, making it a more environmentally friendly approach.

- By activating microbial activities in situ inside the reservoir, large on-site or offshore storage facilities can be reduced or eliminated.

3.3. A list of the numerous MEOR process limitations:

- It is a difficult process because the intended bacterial activity is reliant on the physical and chemical features of the reservoir.

- Because the bulk of MEOR field projects are carried out on stripper wells, MEOR is a low incremental oil recovery technology.

- When compared to chemical or thermal EOR, it is a slower process that takes many days or months to notice any gains.

- MEOR is challenging to control after it is deployed in the field due to the tremendous heterogeneity of reservoirs.

4. Technical and Economic Feasibility

MEOR is a method that has been successfully used to improve oil regeneration from oil wells with high water cuts and to supplement it in older oil wells; however, significant laboratory studies are required before MEOR technologies can be widely recognized and successful in the

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field. It has been difficult to grow microorganisms in the lab that can thrive and/or produce the oil tankers with significant water cuts, as well as to augment older drilling rigs To verify that the microorganisms used in the field are safe and do not pose a risk to humans or the environment, toxicity testing should be conducted on them, was showed at Figure (4).

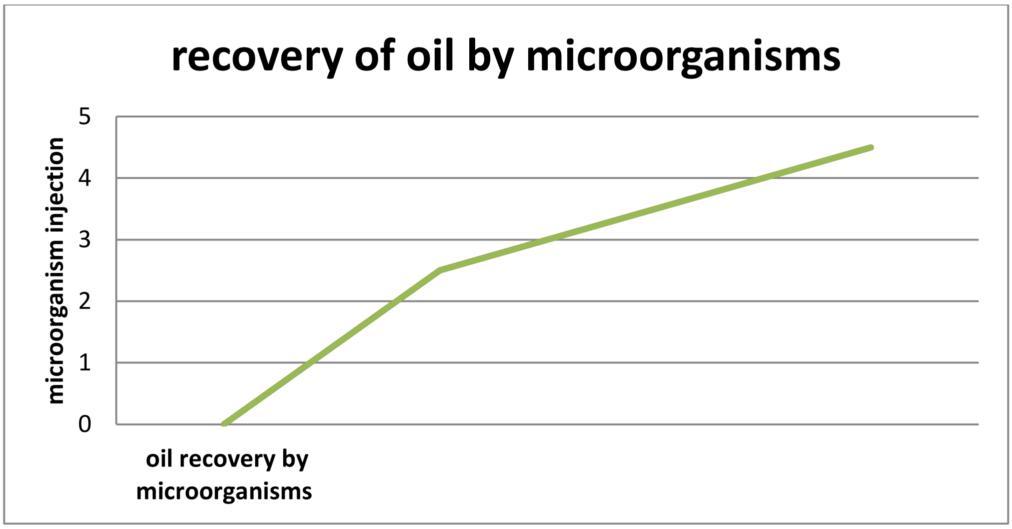

Fig. (4): Increasing oil recovery by microorganisms

5. Conclusions

MEOR is a viable method for improving oil regeneration from oil wells with large water cuts and supplementing it in older oil wells; nevertheless, extensive laboratory research is required before MEOR technologies can be widely recognized and successful in the field. Growing microorganisms in the laboratory that can flourish and create the appropriate metabolic byproducts like biosurfactants when exposed to reservoir conditions has proven difficult. Toxicity testing on microorganisms used in the field should be undertaken to guarantee that they are safe to handle and do not affect humans or the environment. To ensure, toxicity testing on the microorganisms that will be used in the field is recommended.

List of symbols

Rising oil recession (EOR).

Microbial enrichment of oil regeneration (MEOR).

Alternating gas and water (WAG).

Steam-assisted gravity drainage (SAGD).

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