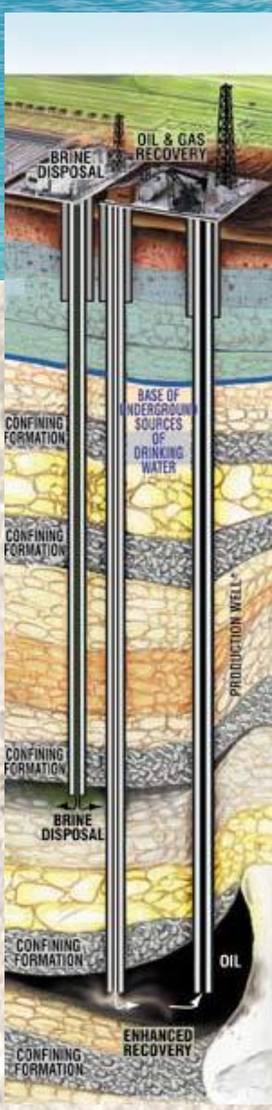
EarthWize LABORATORIES LLC
Oil Field Services Division
835 E. Lamar Blvd. no. 408, Arlington, TX 76011 Phone (817) 291-9122 earthwizelabs.com

Solutions for Water Flood/Injection Production Wells

- *Breaks up Large Molecules Reducing Viscosity*
- *Reduce or Eliminate harmful H_2S (Gas)*
- *Reduce Interfacial Tension*
- *Eliminates chemical bill*
- *Recover more oil*
- *Increase profits*
- *Not a chemical*

EarthWize ECO 9000



Effective in Injection (Water Flood) Well Applications

H2S Production & Corrosion Control with EarthWize ECO 9000

One huge benefit of bioaugmentation of oil production with EARTHWIZE ECO 9000 is that these bacteria do not contain the enzymatic pathways necessary for use of sulfate as the final electron acceptor during anaerobic growth conditions.

The organisms present in the EARTHWIZE ECO 9000 treatment are facultative anaerobes. Many of them are introduced in a resting stage as spores. They can grow anaerobically by using nitrate as the final electron acceptor, aerobically using oxygen as the final electron acceptor, and at any stage in between. Thus, they have a competitive advantage over the SRBs but only if they are added at a higher level than occurs under normal untreated conditions. The continuous addition of the highly concentrated EARTHWIZE ECO 9000 treatment is necessary to counteract the constant inoculation of SRBs naturally occurring subsurface.

EARTHWIZE ECO 9000 facultative bacteria have a faster growth rate than the SRBs mainly because of their ability to use oxygen as the final electron acceptor under aerobic conditions but also because of their flexibility under reduced-oxygen and anoxic conditions. Thus, it can grow under different concentrations of oxygen in a manner that allows it to out-compete SRBs for the available nitrogen and carbonaceous compounds necessary for its proliferation.

The EARTHWIZE ECO 9000 bacteria are accustomed to living in low nutrient conditions. The EARTHWIZE ECO 9000 bacteria is one that, through rapid growth rates, takes over and dominates situations in which resources are temporarily abundant. An additional benefit of the EARTHWIZE ECO 9000 bacterial consortium is that during low nutrient conditions these bacteria can revert to abundant and resistant spores for dispersion and survival. This is a considerable advantage for bacteria in a Microbial Enhanced Oil Recovery system.

In summary, by the continuous addition of the EARTHWIZE ECO 9000 bacterial suspension to a injection/water flood production well, one is able to repopulate the collection system with bacteria that are incapable of producing external H2S or converting H2S to H2SO4, are more flexible in their oxygen requirements, and are better adapted to the injection/water flood production well environment than are SRBs and thrive under anaerobic untreated environments or thrive in aerobic low pH environments in the presence of dissolved H2S. EARTHWIZE ECO 9000 treatment decreases odor by preventing the proliferation of the organisms causing the H2S gas and decreases corrosion by greatly reducing an essential part of the metabolism of thiobacilli. A continuous addition of the EARTHWIZE ECO 9000 treatment allows gradual repopulation of the biofilm that lines the entire global system by nonsulfate- reducing bacteria and prevents the proliferation of H2S oxidizing bacteria.

EarthWize ECO 9000

- More profits
- Reduce Cost
- Reduce Labor
- Improve efficiency
- Environmentally Friendly
- Recover a greater volume of petroleum for market

EarthWize ECO 9000

Environmentally Sensitive Treatment System

A clean environment and Microbial Enhanced Oil Recovery can co-exist and thrive with the application of proper treatment options. No need to add harmful chemicals.

Objective

- Recover marketable hydrocarbons
- Open Capillaries for increased Flow
- Reduce H_2S (Gas) by converting SRBs to NRBs
- Biodegradation of large molecules In order to reduce viscosity
- Natural production of surfactants reducing interfacial tension
- Emitting carbon dioxide provides additional pressure driving force
- Microbial metabolites or the microbes themselves may reduce permeability by activation of secondary flow paths

For more information go to: earthwizelabs.com

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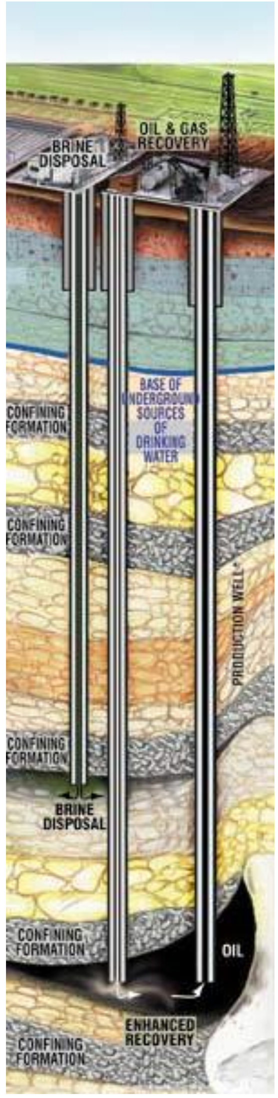
Microbial Enhanced Oil Recovery

Microbial injection is part of **Microbial Enhanced Oil Recovery**. These microbes function either by partially digesting long hydrocarbon molecules, by generating biosurfactants, or by emitting carbon dioxide (which then functions as a Gas injection).

Three approaches have been used to achieve microbial injection.

- In the first and most effective approach, bacterial cultures mixed with nutrients (a food source) are injected into the oil field. After the injected nutrients are consumed, the microbes go into near-shutdown mode, their exteriors become hydrophilic, and they migrate to the oil-water interface area, where they cause oil droplets to form from the larger oil mass, making the droplets more likely to migrate to the wellhead. This approach has been used in oilfields in Arkansas, New Mexico, Texas and Oklahoma.
- In the second approach, used since 1985, nutrients are injected into the ground to nurture existing microbial bodies; these nutrients cause the bacteria to increase production of the natural surfactants they normally use to metabolize crude oil underground.
- The third approach is used to address the problem of paraffin wax components of the crude oil, which tend to precipitate as the crude flows to the surface; since the Earth's surface is considerably cooler than the petroleum deposits (a temperature drop of 9-10-14 °C per thousand feet of depth is usual).



Microbial Enhanced Oil Recovery is a multidisciplinary field incorporating, among others: geology, chemistry, microbiology, fluid mechanics, petroleum engineering, environmental engineering and chemical engineering. The microbial processes proceeding in **Microbial Enhanced Oil Recovery** can be classified according to the oil production problem in the field:

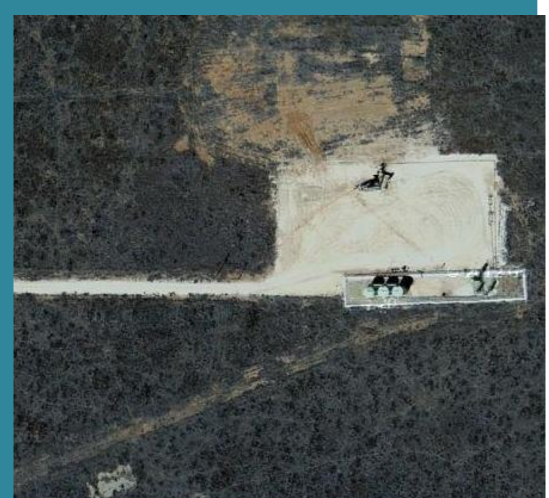
- *Well bore clean up* removes mud and other debris blocking the channels where oil flows through;
- *Well stimulation* improves the flow of oil from the drainage area into the well bore; and
- *Enhanced water floods* increase microbial activity by injecting selected microbes and sometimes nutrients. From the engineering point of view, **Microbial Enhanced Oil Recovery** is a system integrated by the reservoir, microbes, nutrients and protocol of well injection.

Enhanced
Oil Recovery
With

EarthWize ECO 9000

- Improve efficiency
- Reduce Cost
- More profits
- Environmentally Friendly
- Recover a greater volume of petroleum for market

West Texas Location



Microbial enhanced oil recovery

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1. Microbial Enhanced Oil Recovery outcomes

So far, the outcomes of **Microbial Enhanced Oil Recovery** are explained based on two predominant rationales:

Increment in oil production- This is done by modifying the interfacial properties of the system oil-water-minerals, with the aim of facilitating oil movement through porous media. In such a system, microbial activity affects fluidity (viscosity reduction, miscible flooding); displacement efficiency (decrease of interfacial tension, increase of permeability); sweep efficiency (mobility control, selective plugging) and driving force (reservoir pressure).

Upgrading- In this case, microbial activity acts may promote the degradation of heavy oils into lighter ones. Alternatively, it can promote desulphurization [(HDS) is a catalytic chemical process widely used to remove sulfur (S)] due to denitrification as well as the removal of heavy metals.

2. Relevance

Several decades of research and successful applications support the claims of **Microbial Enhanced Oil Recovery** as a mature technology. There is consensus considering **Microbial Enhanced Oil Recovery** one of the cheapest and most efficient existing EOR methods. ***This is probably because Microbial Enhanced Oil Recovery is a complementary technology that may help recover the 377 billion barrels of oil that are unrecoverable by conventional technologies.***

3. History

It was in 1926 when Beckam proposed the utilization of microorganisms as agents for recovering the remnant oil entrapped in porous media. Since that time numerous investigations have been developed, and are extensively reviewed. In 1947, ZoBell and colleagues set the basis of petroleum microbiology applied to oil recovery, whose contribution would be useful for the first **Microbial Enhanced Oil Recovery** patent granted to Updegraff and colleagues in 1957 concerning the in situ production of oil recovery agents such as gases, acids, solvents and biosurfactants from microbial degradation. In 1954, the first field test was carried out in the Lisbon field in Arkansas, USA. During that time, Kuznetsov discovered the microbial gas production from oil. From this year and until the 1970s there was intensive research in USA, USSR, Czechoslovakia, Hungary and Poland. The main type of field experiments developed in those countries consisted in injecting exogenous microbes. In 1958, selective plugging with microbial produced biomass was proposed by Heinningen and colleagues. The oil crisis of 1970 triggered a great interest in active **Microbial Enhanced Oil Recovery** research in more than 15 countries. From 1970 to 2000, basic **Microbial Enhanced Oil Recovery** research focused on microbial ecology and characterization of oil reservoirs. In 1983, Ivanov and colleagues developed the strata microbial activation technology. By 1990, **Microbial Enhanced Oil Recovery** achieved an interdisciplinary technology status. ***In 1995, a survey of Microbial Enhanced Oil Recovery projects (322) in the USA showed that 81% of the projects successfully increased oil production, and there was not a single case of reduced oil production.*** Today, **Microbial Enhanced Oil Recovery** is gaining attention owing to the high prices of oil and the imminent ending of this resource. As a result, several countries are willing to use **Microbial Enhanced Oil Recovery** in one third of their oil recovery programs by 2010.

4. Microbial Enhanced Oil Recovery advantages

There is a plethora of reviewed claims regarding the advantages of **Microbial Enhanced Oil Recovery**.

Advantages can be summarized as follows:

- Easy application.
- Less expensive set up.
- Increases oil production.
- Existing facilities require slight modifications.
- Economically attractive for mature oil fields before abandonment.
- Cellular products are biodegradable and therefore can be considered environmentally friendly.
- Low energy input requirement for microbes to produce **Microbial Enhanced Oil Recovery** agents.
- More efficient than other **Enhanced Oil Recovery** methods when applied to carbonate oil reservoirs.
- Injected microbes and nutrients are efficient, cheap; easy to handle in the field and independent of oil prices.
- Microbial activity increases with microbial growth. This is opposite to the case of other **Enhanced Oil Recovery** additives in time and distance.

5. The environment of an oil reservoir

Oil reservoirs are complex environments containing living (microorganisms) and non living factors (minerals) which interact with each other in a complicated dynamic network of nutrients and energy fluxes. Since the reservoir is heterogeneous, so do the variety of ecosystems containing diverse microbial communities, which in turn are able to affect reservoir behavior and oil mobilization. With the correct nutrients some (microorganisms) sulfate-reducing bacteria (SRBs) will convert to Nitrogen-reducing Bacteria (NRBs) and become beneficial in oil production. Sulfate-reducing bacteria (SRBs) are harmful when found in high concentration. Sulfate-reducing bacteria are those bacteria and Achaea that can obtain energy by oxidizing organic compounds or molecular hydrogen (H_2) while reducing sulfate (SO2−4) to hydrogen sulfide (H_2S). In a sense, these organisms "breathe" sulfate rather than oxygen, in a form of anaerobic respiration.

Microbes are living machines whose metabolites, excretion products and new cells may interact with each other or with the environment, positively or negatively, depending on the global desirable purpose, e.g. the enhancement of oil recovery. All these entities, i.e. enzymes, extracellular polymeric substances (EPS) and the cells themselves, may participate as catalyst or reactants. Such complexity is increased by the interplay with the environment, the later playing a crucial role by affecting cellular function, i.e. genetic expression and protein production.

6. Microbial Enhanced Oil Recovery mechanism

Understanding **Microbial Enhanced Oil Recovery** mechanism is still far from being clear. Although a variety of explanations has been given in isolated experiments, it is unclear if they were carried out trying to mimic oil reservoirs conditions.

The mechanism can be explained from the client-operator viewpoint which considers a series of concomitant positive or negative effects that will result in a global benefit:

- ***Beneficial effects***. Biodegradation of big molecules reduces viscosity; production of surfactants reduces interfacial tension; production of gas provides additional pressure driving force; microbial metabolites or the microbes themselves may reduce permeability by activation of secondary flow paths.

- ***Detrimental effects***. Biologically produced hydrogen sulphide, i.e. souring, causes corrosion of piping and machinery; which can be diminished or eliminated by the introduction of proper nutrients.

7. Microbial Enhanced Oil Recovery strategies

Changing oil reservoir ecophysiology to favor Microbial Enhanced Oil Recovery can be achieved by complementing different strategies. In situ microbial stimulation can be chemically promoted by injecting electron acceptors such as nitrate; vitamins or surfactants. Alternatively, Microbial Enhanced Oil Recovery is promoted by injecting exogenous microbes, which may be adapted to oil reservoir conditions and be capable of producing desired Microbial Enhanced Oil Recovery agents.

a. Biomass and biopolymers

In selective plugging, conditioned cells and extracellular polymeric substances plug high permeability zones, resulting in a change of direction of the water flood to oil-rich channels, consequently increasing the sweep efficiency of oil recovery with water flooding. Biopolymer production and the resulting biofilm formation (less 27% cells, 73-98% EPS and void space) are affected by water chemistry, pH, surface charge, microbial physiology, nutrients and fluid flow.

b. Biosurfactants

Microbial produced surfactants, i.e. biosurfactants reduce the interfacial tension between water and oil, and therefore a lower hydrostatic pressure is required to move the liquid entrapped in the pores to overcome the capillary effect. Secondly, biosurfactants contribute to the formation of micelles providing a physical mechanism to mobilize oil in a moving aqueous phase.

c. Gas and solvents

In this old practice, the production of gas has a positive effect in oil recovery by increasing the differential pressure driving the oil movement. Anaerobically produced methane from oil degradation has a low effect on Microbial Enhanced Oil Recovery due to its high solubility at high pressures. Carbon dioxide is also a good Microbial Enhanced Oil Recovery agent. The miscible CO_2 is condensed into the liquid phase when light hydrocarbons are vaporized into the gas phase. Immiscible CO_2 helps to saturate oil, resulting in swelling and reduction of viscosity of the liquid phase and consequently improving mobilization by extra driving pressure. Concomitantly, other gases and solvents may dissolve carbonate rock, leading to an increase in rock permeability and porosity.

8. Field studies

Worldwide Microbial Enhanced Oil Recovery field applications have been reviewed in detail. Although the exact numbers field trials are unknown, Lazar et al. suggested an order of hundreds. Successful Microbial Enhanced Oil Recovery field trials have been conducted in the U.S., Russia, China, Australia, Argentina, Bulgaria, former Czechoslovakia, former East Germany, Hungary, India, Malaysia, Peru, Poland, and Romania. Lazar et al. suggested China is leading in the area, and also found that the most successful study was carried out in Alton field, Australia ***(40% increase of oil production in 12 months).***

The majority of the field trials were done in sandstone reservoirs and very few in fractured reservoirs and carbonates. The only known offshore field trials were in Norne (Norway) and Bokor (Malaysia).