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Biotechnology in Petroleum Geoscience

Sunjay, *Ph. D. Research Scholar*

Introduction:

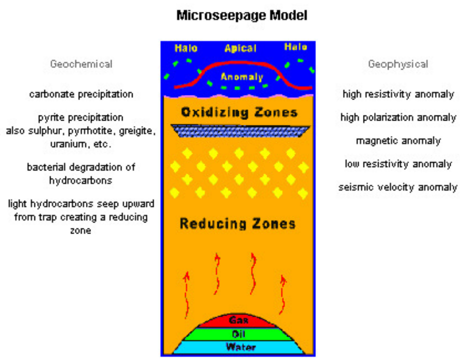
Fuel Biotechnology plays a pivotal role in exploration and production of hydrocarbon for energy security of the world.By healthy observation,upstream sector has to make fashionable the potential of Nanobiotechnology /Nanoscience & technology to enhance R/P ratio of nations . Reservoir surveillance of sweet spot by 4D /time lapse seismic,petrophysical imaging & Computational fluid dynamics is the integral part of enhanced oil & gas recovery from reservoir. Microbial Prospecting for Oil and Gas (MPOG) method , Geo-microbial prospecting for hydrocarbons is an exploration method based on the seepage of light gaseous hydrocarbons from oil/gas reservoirs towards the surface and their utilization by hydrocarbon-oxidizing bacteria. The detection of anomalous populations of methane, ethane and propane-oxidizing bacteria in the surface soils or sediments, helps to evaluate the prospects for hydrocarbon exploration. These light hydrocarbons are utilized by the phylogenetically diverse group of bacteria belonging to genera Brevibacterium, Corynebacterium, Flavobacterium, Mycobacterium, Nocardia, Pseudomonas and Rhodococcus. Microbial Enhanced Oil Recovery (MEOR) is a multidisciplinary embraces in its fold geoscience ,biochemistry,microbiology, fluids mechanics computational fluid dynamics, reservoir engineering. MEOR is used in the third phase of oil recovery from a well, known as tertiary oil recovery. Changes made by Microorganisms on Oil :Reduction of oil viscosity,Production of carbon dioxide gas,Production of biomass , Selective plugging, and Production of bio-surfactants. Other applications of biotechnology in MEOR include genetic engineering techniques and recombinant DNA technology,which are used to develop strains of bacteria with improved oil recovery traits. Microbially enhanced coalbed methane (MECoM) involves the introduction of anaerobic bacterial consortia, which consists of hydrolyzers, acetogens and methanogens, and/or nutrients into coalbed methane wells. Coalbed methane productions may increase through generation of additional methane, removal of pore-plugging coal waxes, and permeability enhancement as cleat-aperture size increases during biogasification. Low Emission Microbial Upgrading and Recovery (LEMUR) technology ,The basic recovery process proposed involves the acceleration of the natural methanogenic biodegradation of hydrocarbons. Because degradation rates slow for increasingly large (less volatile) hydrocarbon components, this process will be more efficient and operate on production time scales for heavy oils and stranded conventional oils. Heavy oil and bitumen production process is mediated by a consortium of syntrophic bacteria and methanogenic archaea and operates over geological timescales in oil-water transition zones. The Bacillus subtilis bacterium that is indigenous to gas hydrate mounds.

Microbial Prospecting for Oil and Gas (MPOG) method:

Microbial Prospection for Oil and Gas is a surface exploration technology based on detection of anomalies in microbial distribution in soil samples. Geo-microbial prospecting for hydrocarbons is an exploration method based on the seepage of light gaseous hydrocarbons from oil/gas reservoirs towards the surface and their utilization by hydrocarbon-oxidizing bacteria. The detection of anomalous populations of methane, ethane and propane-oxidizing bacteria in the surface soils or sediments, helps to evaluate the prospects for hydrocarbon exploration.The methane-oxidizing bacteria are usually predominant over gas fields as the gas reservoirs are commonly dominated by methane. Thermogenic processes produce methane and substantial amounts of other saturated hydrocarbons by irreversible reaction of residual organic matter or kerogen. Ethane, propane and butane are assumed to be originated

Exploration Geophysics, BHU, Varanasi-221005, INDIA
Sunjay_sunjay@rediffmail.com/yahoo.com/hotmail.com

from the migration of thermogenically produced petroleum from depth and are usually not associated with generation in shallow soils. A microbial prospecting method involves isolation and enumeration of various groups of methane, ethane, propane and butane-oxidizing bacteria in sub-soil strata for the delineations of hydrocarbon prospect in an area. The abundance of these hydrocarbon-oxidizing bacteria in the soils yields hydrocarbon signature on the surface and hence they are considered as indicator microbes. The geochemical anomaly at the surface represents the end of a petroleum migration pathway, a pathway that can range from short or long distance vertical migration to long distance lateral migration. Understanding geology, and hence petroleum dynamics, is the key to using seepage data in exploration.



Fig(1): MPOG Microbial Prospection for Oil and Gas.

The surface geochemical expression of petroleum seepage can take many forms : anomalous hydrocarbon concentrations in sediment, soil, water, and even atmosphere , microbiological anomalies and the formation of "paraffin dirt", anomalous non-hydrocarbon gases such as helium and radon , mineralogical changes such as the formation of calcite, pyrite, uranium, elemental sulfur, and certain magnetic iron oxides and sulfides, clay mineral alterations, radiation anomalies, geothermal and hydrologic anomalies, bleaching of redbeds, geobotanical anomalies , altered acoustical, electrical, and magnetic properties of soils and sediments. Bacteria and other microbes play a profound role in the oxidation of migrating hydrocarbons, and their activities are directly or indirectly responsible for many of the diverse surface manifestations of petroleum seepage. These activities, coupled with long-term migration of hydrocarbons, lead to the development of near-surface oxidation-reduction zones that favor the formation of this variety of hydrocarbon-induced chemical and mineralogical changes. The basis of MPOG is that oil or gas fields emit a continuous stream of light hydrocarbon gases at the earth's surface. Generally it is not questioned anymore whether thermogenic hydrocarbons generated and trapped at deep lying structures escape to the surface model macro- and microseepages. Specialized microorganisms, the Hydrocarbon Oxidizing Bacteria, depend on light hydrocarbon gases as their only energy source. Such microorganisms are able to utilize extremely low concentrations of hydrocarbons wherever there is a continuous gas flow, and are only found enriched under the surface above hydrocarbon bearing structures.

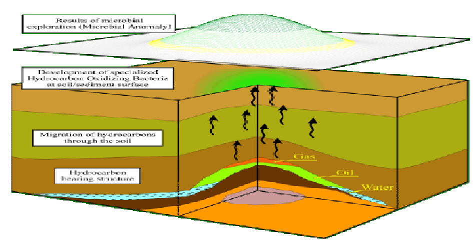


Fig.(2):MPOG has both a physico-chemical and a microbiological basis.

Microbial Prospection for hydrocarbon deposits offers the following advantages:
Sample taking is simple and environmentally friendly, The technique is unaffected by external disturbance factors, Areas of application include both existing onshore (permanently frozen, continental and desert soil) and offshore sites, Establishing a clear distinction between oil reservoirs, gas reservoirs and oil bearing structures with a gas cap is generally fully feasible, The technique is not influenced by fractures, overlying salt or other geological structures, There are no halo effects - unlike other surface prospection processes e.g. ground/air measurements, isotope geochemistry, Reliable results are obtained even for structures having a complex geological formation, Wherever microbial evidence establishes the presence of hydrocarbon anomalies a high yield rate is achieved

Role of Biotechnology in Oil & Gas Production :

Microbial Enhanced Oil Recovery / Microbial Increased Oil Recovery : The microbial processes proceeding in MEOR 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, MEOR is a system integrated by the reservoir, microbes, nutrients and protocol of well injection.

The terms EOR and IOR have been used loosely and interchangeably at times. IOR, or improved oil recovery, is a general term which implies improving oil recovery by any means. For example, operational strategies, such as infill drilling and horizontal wells, improve vertical and areal sweep, leading to an increase in oil recovery. Enhanced oil recovery, or EOR, is more specific in concept, and it can be considered as a subset of IOR. EOR implies a reduction in oil saturation below the residual oil saturation (Sor). Recovery of oils retained due to capillary forces (after a waterflood in light oil reservoirs), and oils that are immobile or nearly immobile due to high viscosity (heavy oils and tar sands) can be achieved only by lowering the oil saturation below Sor. Miscible processes, chemical floods and steambased methods are effective in reducing residual oil saturation, and are hence EOR methods.

Microbial Enhanced Oil Recovery (MEOR) :

Microbial Enhanced Oil Recovery (MEOR) is the use of microorganisms to retrieve additional oil from existing wells, thereby enhancing the petroleum production of an oil reservoir. In this technique, selected natural microorganisms are introduced into oil wells to produce harmless by-products, such as slippery natural substances or gases, all of which help propel oil out of the well. Because these processes help to mobilize the oil and facilitate oil flow, they allow a greater amount to be recovered from the well. MEOR is used in the third phase of oil recovery from a well, known as tertiary oil recovery. Recovering oil usually requires two to three stages, which are briefly described as follows:

Stage 1: Primary Recovery 12% to 15% of the oil in the well is recovered without the need to introduce other substances into the well.

Stage 2: Secondary Recovery The oil well is flooded with water or other substances to drive out an additional 15% to 20% more oil from the well. **Stage 3: Tertiary Recovery** This stage may be accomplished through several different methods, including MEOR, to additionally recover up to 11% more oil from the well.

Oil Recovery Mechanism in MEOR:

MEOR offers a multiple mechanism simultaneously to work inside the reservoir and recover additional oil from depleted reservoir. We could also state that MEOR encompasses a multiplicity of methods ranging from those requiring the injection of microbes into the formation to those depending upon the stimulation of the in-situ micro flora, and from single well treatment to field wise treatments. The bacteria proliferate on the nutrients injected in the reservoir and produce useful metabolic products (metabolites) for enhancement of oil recovery . Works on either aerobic or anaerobic microbes (those not requiring oxygen to survive). The process induces the microbes to become oleophilic (to seek and attach themselves to oil droplets) and induces the microbes to perform an activity and "do" something within the oil reservoir as opposed to "excreting" something (bio-gas, bio-surfactant or bio-polymers).

Types of Microbial Processes for Oil Recovery

Process	**Production Problem**	**Types of Activity or Product Needed**
Well bore cleanup(improve oil drainage into well bore)	Paraffin and scale deposits	Emulsifiers, biosurfactants, solvents, acids, hydrocarbon degradation
Well stimulation (stimulate release of oil entrapped by capillaries and brine)	Formation damage, pore damage, High water production	Gas, acids, solvents, biosurfactants , Biomass and polymer production
Enhanced waterflooding, (reduce permeability variation and block water channels)	Poor displacement efficiency , Poor sweep efficiency, Scouring,Coning	Biosurfactants, solvents, polymers, Biomass and polymer production , Nitrate reduction

The various mechanisms involves in MEOR process are as follows: **Reduction of oil viscosity** – Oil is a thick fluid that is quite viscous, meaning that it does not flow easily. Microorganisms help break down the molecular structure of crude oil, making it more fluid and easier to recover from the well. **Production of biosurfactants that** reduce oil/water interfacial tension (IFT) ,i.e, decrease surface tension and interfacial tensions – Microorganisms produce slippery substances called surfactants as they breakdown oil. Because they are naturally produced by biological microorganisms, they are referred to as biosurfactants. Biosurfactants act like slippery detergents, helping the oil move more freely away from rocks and crevices so that it may travel more easily out of the well. Some biosurfactants can reduce the viscosity of heavy oil by as much as 95%. Bacillus licheniformis also produces a surfactant under anaerobic conditions and has been investigated for in-situ use.

Production of gases:

Most Microbes produce *gases* (CO_2, N_2, H_2, and CH_4) that could improve oil recovery by increasing reservoir pressure and by reducing the viscosity and swelling of individual trapped droplets of crude oil caused by solubilization of gas. CO_2 is usually the primary gaseous product of microbes under oilfield condition . Production of carbon dioxide gas – As a by-product of metabolism, microorganisms produce carbon dioxide gas. Over time, this gas accumulates and displaces the oil in the well, driving it up and out of the ground.

Production of biomass:

When microorganisms metabolize the nutrients they need for survival, they produce organic biomass as a by-product. This biomass accumulates between the oil and the rock surface of the well, physically displacing the oil and making it easier to recover from the well.

Selective plug in :

Some microorganisms secrete slimy substances called exopolysaccharides to protect themselves from drying out or falling prey to other organisms. This substance helps bacteria plug the pores found in the rocks of the well so that oil may move past rock surfaces more easily. Blocking rock pores to facilitate the movement of oil is known as selective plugging.

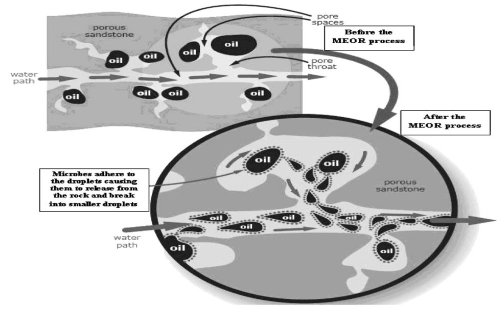


Fig.(3) : Before MEOR process: oil is trapped in porous sandstone. Water flows without dislodging oil droplets from tiny pore spaces in the rock. After MEOR process: microbes surround the oil droplets, causing them to dislodge from the microscopic pore spaces between the tiny sandstone and carbonate rock particles in the reservoir for enhanced recovery .

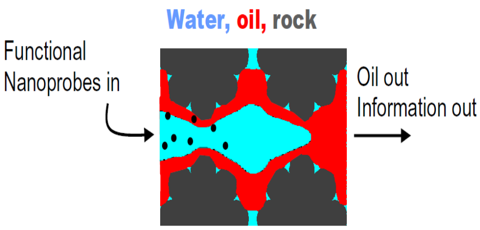


Fig.(4) : Rock properties/Petrophysics

Migration microbial enhanced oil recovery (MMEOR) is a technology that can enhance production and recoveries by treatment programs of existing producing wells. The microbial process thins or reduces oil viscosity in situ increasing production and recoveries.

Microbial Enhanced Gas Coalbed methane

Microbially enhanced coalbed methane (MECoM) imitates and enhances the natural process of secondary biogenic gas generation in coal beds that occurs in coal basins worldwide. MECoM involves the introduction of anaerobic bacterial consortia, which consists of hydrolyzers, acetogens and methanogens, and/or nutrients into coalbed methane wells. Coalbed methane productions may increase through generation of additional methane, removal of pore-plugging coal waxes, and permeability enhancement as cleat-aperture size increases during biogasification. The amount of coal gas potentially generated by MECoM is large .

Microbial Enhanced Recovery Gas Hydrate :

The *Bacillus subtilis* bacterium that is indigenous to gas hydrate mounds . The experimental study indicate that seafloor-biosurfactants can be produced rapidly in-situ to achieve threshold concentrations whereby hydrates are promoted. The biosurfactants accumulate and promote hydrate formation on specific mineral surfaces such as sodium montmorillonite .

Fourth & Fifth Generation Seismic for Oil & Gas Industry:

Time-lapse" or "4D" are names used to describe geophysical data sets that are acquired over the same area at different epochs in time (3D + the dimension of time = 4D). The general purpose is to analyse differences between data sets from different epochs, the underlying assumption being that such differences are due only to production or injection from subsurface reservoirs (subsurface saturation-change maps shown right). Differences between data sets due to other sources such as variations in acquisition/processing parameters, tides, and background noise, must be removed or equalised prior to differencing. Just as 4-D seismic revolutionized the ability to manage reservoir production, real-time completion monitoring has the potential to revolutionize the ability to manage deepwater wells by understanding evolution of flow, drawdown, and impairment in real time.Fifth generation seismic phases of progress in the seismic technology business as the drillers do their offshore rigs.

Geo-Bio reactors for in-situ generation of Methane in deeper coal seams and oil reservoirs:

Microbial characterization. The microorganisms involved in the degradation of oil and its subsequent bioconversion to methane are part of a complex microbial community known as a consortium. Microorganisms- Clostridia and Thermotoga have been studied in the context of fouling, souring, and degradation of oil reservoirs. Clostridia form a broad genus known for its diverse metabolic pathways. Clostridia frequently thrive in anaerobic environments and many species are known for their thermotolerance. Thermotoga micro-organisms are known to play a role in the anaerobic oxidation of hydrocarbons to alcohols, organic acids (e.g., acetic acid), and carbon dioxide . In addition, Thermotoga also thrive in high temperature environments, such as those found in sub-surface oil wells.Because oil is a liquid, it is likely to be an easier substrate for the microbial consortia to contact,biodegrade, and convert to methane compared to solid-phase substrates such as coal and the kerogen in shale. Biodegradation is carried out by the consortia, and it has been shown that a mixed group of microorganisms is more effective at biodegrading organic compounds than any of the component strains acting alone . These microorganisms utilize the hydrocarbons as both a carbon and energy source, and the process most likely takes place at the oil/water interface . The enzymatic diversity within these microorganisms required to carry out the myriad of metabolic steps involved in methanogenesis is extensive. The ability to influence and control these microbial reactions in situ has major economic implications.

Low Emission Microbial Upgrading and Recovery (LEMUR) technology

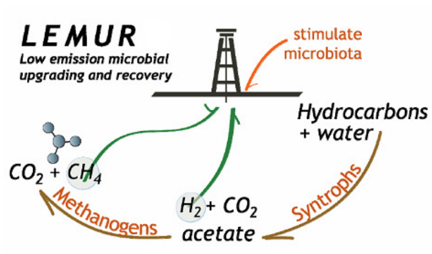


Fig.(5) LEMUR process schematic.

The progress of the industry towards demonstration of low carbon emission commercial methane or hydrogen gas production from oilfields using Low Emission Microbial Upgrading and Recovery (LEMUR) technology. Biodegradation Theory : Recent advances in understanding the origin of heavy oil and tar sand bitumen (HOTS) have shown that the process is anaerobic in the subsurface involving predominantly methanogenic biodegradation of oils in reservoirs as the main process producing heavy oil and bitumen . This involves crude oil hydrocarbons reacting with water to produce methane via intermediate hydrogen and carbon dioxide as well as residual heavy oil or bitumen. This process is mediated by a consortium of syntrophic bacteria and methanogenic archaea and operates over geological timescales in oil-water transition zones.

A microbiological study of an underground gas storage in the process of gas extraction :

The numbers of microorganisms belonging to ecologically significant groups and the rates of terminal microbial processes of sulfate reduction and methanogenesis are determined in the liquid phase of an underground gas storage (UGS) in the period of gas extraction. Aerobic organotrophs (including hydrocarbon-and oil-oxidizing ones) and various anaerobic microorganisms (fermenting bacteria, methanogens, acetogens, sulfate-, nitrate-, and iron-reducing bacteria) are constituent parts of the community.

Conclusions & Discussions :

With a view to fuel security of the world , geoscientists & petroleum technologists have to play a pivotal role to enhance R/P ratio of nations. That's why enhanced oil & gas recovery is pertinent tasks before oil & gas industry . We have to pay too much attention on microbial enhanced oil & gas recovery. Nano science & technology has to revolutionise oil & gas industry as NEOR for improved oil & gas recovery between 80-90 % of the original oil in place (OOIP).

Advantages of MEOR :

Advantages of MEOR over other tertiary recovery processes are specificity, absence of side reactions, and avoidance of capital investment. It is economically attractive for marginal oilproducing fields, with typical surface equipment for water flooding. The cost of the injection of microbes along with nutrients is relatively low, and their activity can be stopped by discontinuing injection of nutrients. Moreover, it can be applied to both heavy and light crude oil. Enhanced oil recovery (EOR) processes rely upon the use of chemical or thermal energy to recover crude oil that is trapped in pores of reservoir rock after primary and secondary (water flood) crude oil production has ceased. The residual crude oil in reservoirs makes up about 67% of the total petroleum reserves, indicating the relative inefficiency of primary and secondary production.. The many applications include oil well work-over, the stimulation of reservoirs and oil wells replacing more expensive conventional methods, and earth surface application for oil spills and petroleum hazardous site clean up. The microbial well treatment processes fall into three basic applications: wellbore clean up, improved water flooding (bypass treatment increases sweep efficiency), and well stimulation. The well stimulation process normally involves injecting both microbes and nutrients together into wells to have the microbes circulate in the reservoir and release the oil from the rock-oil-water structure.

Limitation of MEOR :

Bacteria have numerous limitations, especially when applied in situ. Limitations include substrate availability, substrate toxicity and clogging. Also, once the oil is recovered, it is important to remove the substances produced by the bacteria, as well as the bacteria themselves, to prevent further modification. Bacterial enzymes are mostly intracellular, so the oil would have to be absorbed through the relatively impermeable cell membrane. The cell membrane is especially impermeable to large or charged molecules. This greatly reduces the range of hydrocarbons on which the bacteria can act. Also, because of their size and their tendency to clump together, it has been reported that in-situ microbial growth drastically reduced permeability and, consequently, oil-production. The MEOR process may modify the immediate reservoir environment in ways that could also damage the production hardware or the formation itself. Certain sulfate reducers can produce H2S, which can corrode pipeline and other components of the recovery equipment. This has commonly been observed when injecting water, rich in sulfates, for waterflooding. The addition of nitrate and nitrite nutrients to an indigenous denitrifying bacteria population has been shown to reverse this effect . Despite numerous MEOR tests, considerable uncertainty remains regarding process performance. The chances for success are increased if a specific objective is targeted. Well bore stimulation treatments are technologically simpler and consequently have a higher chance of success. Using microbes to generate and deliver specific EOR agents deep within the reservoir is much more complex. The ability to manipulate environmental conditions to promote growth and/or product formation by the participating microorganisms is critical. Exerting such control over the microbial system in the subsurface is a serious challenge. In addition, reservoir conditions vary, which calls for reservoir-specific customization of the MEOR process. Teleology of fuel-biotechnology is highly prospective & fashionable for upstream industry.

A third generation wavelet:

Theory and techniques for the extraction of morphological structures from micro/nano scalar surfaces. Application of the **wavelet** image analysis technique to monitor cell concentration in bioprocesses,Nucleotide Genomic Sequences.

One of the image processing is the detection of the budding cells. The idea is to find with a lot of precision the Holder Coefficient corresponding to the curvature changing. The Holder Coefficient is carry out by Wavelet Transform coupled to Genetic Algorithms.

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