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Perspective

Biotechnological Exploitation of Oil Reservoir Microbes for Environmental and Industrial Use

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DESCRIPTION

Oil reservoir microbiology has emerged as a pivotal field bridging petroleum engineering and environmental biotechnology. Subsurface oil reservoirs, once considered sterile due to their extreme temperature, pressure, and salinity, are now recognized as dynamic ecosystems populated by diverse microbial communities. These microorganisms influence hydrocarbon transformation, reservoir geochemistry, and oil production processes. Understanding the ecology and functional roles of reservoir microbes has significant implications for sustainable petroleum recovery, environmental protection, and energy transition strategies.

The microbial ecosystem in oil reservoirs is dominated by bacteria and archaea adapted to harsh conditions. Thermophilic, halophilic, barophilic, and anaerobic species thrive in environments with limited nutrients and fluctuating redox conditions. Among the most studied groups are Sulfate-Reducing Bacteria (SRB), methanogenic archaea, fermentative bacteria, and nitrate-reducing bacteria. These organisms participate in complex metabolic networks that govern the breakdown or synthesis of hydrocarbons. Their metabolic activities not only shape reservoir chemistry but also determine the integrity of metal infrastructure through processes such as microbially influenced corrosion.

Stimulating indigenous microorganisms or introducing selected strains, enhances oil mobilization through the developed and production of biosurfactants, biogases, organic acids, and biopolymers. Biosurfactant-producing microbes reduce interfacial tension between oil and water, improving mobility and displacement efficiency. Gas-generating microbes, including methanogens and fermenters, increase reservoir pressure and promote oil flow. The success of MEOR relies heavily on a molecular-level understanding of microbial community structure, nutrient availability, and reservoir physicochemical properties.

Advances in metagenomics, metatranscriptomics, and metabolomics have revolutionized reservoir microbiology by enabling culture-independent characterization of microbial populations. Traditional cultivation techniques capture only a fraction of the subsurface microbial diversity, whereas high-throughput sequencing reveals abundant uncultured taxa with previously unknown metabolic capabilities. These technologies provide insight into microbial networks, hydrocarbon degradation pathways, and environmental stress responses. Such information supports the development of targeted microbial stimulation strategies and enables predictive modeling of microbial behavior under reservoir conditions.

In addition to oil recovery, reservoir microbiology plays a vital role in environmental sustainability. Microbial biodegradation of hydrocarbons contributes to natural attenuation processes that mitigate environmental pollution. Hydrocarbon-degrading microorganisms such as species within the genera *Pseudomonas*, *Rhodococcus*, *Bacillus*, and *Arthrobacter* are capable of breaking down a wide range of aliphatic and aromatic compounds. Understanding how these organisms function in deep subsurface settings helps improve bioremediation strategies for contaminated soils, groundwater, and marine environments. Furthermore, methane-generating microbial consortia are integral to the formation of biogenic natural gas, a lower-carbon alternative to conventional fossil fuels.

Another emerging area is the study of microbial interactions that lead to biocorrosion. SRB and other anaerobes accelerate pipeline and equipment degradation through the production of hydrogen sulfide and corrosive metabolites. This has costly implications for the petroleum industry. Insights into microbial corrosion mechanisms help develop inhibitors and monitoring systems, reducing operational risks and improving infrastructure longevity.

In conclusion, oil reservoir microbiology provides essential knowledge for advancing petroleum biotechnology and supporting environmental stewardship. As the energy sector

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moves toward sustainability, microbial processes will continue to shape oil recovery technologies, bioremediation strategies, and the development of low-carbon bioenergy systems. This field stands at the forefront of innovation, offering solutions that balance energy needs with environmental protection.