Microbially Enhanced Oil Recovery (MEOR)

Microbial Role in Carbon Storage and Capture

Introduction

Enhanced Oil Recovery (EOR) improves oil extraction from reservoirs beyond primary and secondary methods.

Microbially Enhanced Oil Recovery (MEOR) leverages microorganisms and their metabolic products to increase oil mobilization and recovery.

Microbes also play a role in carbon sequestration and converting carbon sources into useful biopolymers for industrial applications.

Microbial Processes in Oil Reservoirs

Microbes can influence oil recovery via multiple mechanisms:

First \\ Biosurfactant Production

1- Microbial surfactants reduce oil-water interfacial tension.
2- Facilitate oil mobilization and reduce residual oil saturation.
3- Common microbes: Bacillus, Pseudomonas, Rhodococcus.

Second \\ Biogas Generation

1- Microbes produce CO_2, CH_4, and H_2, increasing reservoir pressure.
2- Enhances oil displacement and drives oil towards production wells.

3- Methanogens and fermentative bacteria are key players.

Third \\ Biopolymer Production

1- Microbial exopolysaccharides (EPS) increase oil sweep efficiency.
2- Forms gels in high-permeability zones to redirect water flow.
3- Examples: xanthan, gellan, levan.

Microbial Role in Carbon Capture and Storage

Microbes contribute to sequestration of carbon in subsurface reservoirs.

Carbon Storage Mechanisms:

1- Biomineralization: Formation of stable carbonates ($CaCO_3$, $MgCO_3$).
2- Biofixation: Conversion of CO_2 into biomass.
3- Bio-immobilization: Conversion of carbon into polymers or microbial aggregates.

Microbial transformation of CO_2 and organic carbon into useful compounds reduces greenhouse gas emissions and can produce economically valuable products.

Mechanisms for Carbon Conversion

Biopolymer Formation

1- EPS and other microbial polymers are stable carbon sinks.
2- Can be harvested for industrial applications: adhesives, thickeners, bioplastics.

Methanogenesis

1- Converts CO_2 and H_2 into methane (CH_4).
2- Reduces CO_2 levels in reservoirs and provides alternative energy source.

Carbonate Precipitation

1- Microbes induce calcite or dolomite formation.
2- Traps carbon in mineral form for long-term storage.

Microbial Candidates for MEOR and Carbon Sequestration

A- Bacteria: Bacillus, Pseudomonas, Clostridium, Rhodococcus
B- Archaea: Methanogens for CO_2 conversion to methane
C- Fungi: Some fungi produce biopolymers and surfactants for oil mobilization

Environmental and Industrial Benefits

A- Oil Recovery: Increase extraction efficiency and reduce dependence on chemicals.
B- Carbon Sequestration: Mitigates greenhouse gas emissions.
C- Biopolymer Production: Generates value-added products (xanthan, gellan, levan).
D- Sustainability: Integrates energy recovery with environmental protection.

Challenges and Considerations

A- Reservoir conditions (temperature, pressure, salinity, pH) affect microbial activity.

B- Nutrient supply and oxygen availability must be optimized.

C- Microbial growth control to avoid biofouling and reservoir plugging.

D- Regulatory and economic considerations for scaling up MEOR operations.

Emerging Approaches

- Synthetic biology: Engineer microbes for higher biosurfactant or polymer yields.
- Microbial consortia: Mixed communities improve robustness and efficiency.
- Monitoring and modeling: Real-time reservoir monitoring using molecular techniques to optimize microbial activity.