Unlock More Oil with Fewer Chemicals
Dow Additives for Chemical Enhanced Oil Recovery
With a significant amount of oil remaining in a reservoir after primary and secondary recovery, operators continue to hunt for cost-effective ways to increase recovery in existing assets without the need for drilling new wells. Since most fields already use water flooding, chemical methods involving water are a natural evolution in the production of a well. Chemical enhanced oil recovery (CEOR) techniques such as wettability alteration, polymer flooding, surfactant flooding or combinations of each are all options to boost production in mature reservoirs.

Many reservoirs, such as mixed wet sandstone and oil wet carbonates, trap a significant amount of oil at the large rock surface area. This oil is bound tightly and is difficult to remove by traditional water flooding methods. Creating more water wet conditions on the rock releases significant amounts of oil. Wettability can be changed through both chemical (surfactants) and geochemical (water ionic strength) methods.

The most effective improvement to water flooding is achieved through individual design of a CEOR method. After evaluating a reservoir, a combination of alkalis (A), surfactants (S) and polymers (P) can be used to increase oil recovery. While there are many different combinations (ASP, SP, P, AP), one of the most difficult tasks is to find a stable surfactant formulation for a given oil and brine mixture.

With an extensive background and experience in polymer chemistry and surfactants for use in oil production, Dow is at the forefront of the CEOR evolution. We offer a broad portfolio of solvents, surfactants, chelants, biocides and water treatment products, along with the expertise to fine-tune these solutions to individual field conditions to help producers get the most out of their assets.

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**Achieve More with Less**

**Dow's Broad CEOR Portfolio**

- **ELEVATE™ Co-Surfactants** – A broad range of anionic and non-ionic surfactants that can increase oil recovery by lowering surface tension between oil and the reservoir rock. They offer excellent wetting, emulsifying and dispersing properties in a range of oilfield chemicals.

- **ELEVATE™ Wettability Alteration Additives** – Non-ionic surfactants that can increase oil recovery by lowering surface tension between oil and the reservoir rock.

- **ELEVATE™ Co-Surfactants** – Anionic and non-ionic surfactants that work in synergy with the primary surfactant to offer ultralow interfacial tension (ULIFT).

- **DOWANOL™, CELLOSOLV™ and CARBITOL™ Co-Solvents** – Effective glycol ether and alcohol co-solvents for formulating a variety of complex surfactant/co-surfactant/co-solvent mixtures that are suitable for a system’s specific needs.

- **VERSENE™ and VERSENEX™ Chelants** – Chelants used to manage water quality, particularly divalent ions, to allow easier formulation of surfactant brine solutions.

- **AQUCAR™ Microbiocides** – Effective solutions for control of microorganisms for produced water reinjection, as well as for preservation of water-based solutions that are susceptible to microbial attack.

- **FILMTEC™ Reverse Osmosis and Nanofiltration Membranes** – A portfolio of nanofiltration and reverse osmosis membranes is able to provide tailored water for most water-based EOR process such as simple sulphate removing water flooding, chemical EOR or low-salinity water flooding. With extensive experience in seawater injection projects, Dow’s experts can support oil and gas operators in optimizing their water treatment processes to maximize oil recovery.

In addition, Dow has a significant co-solvent portfolio with solvents that are very hydrophilic to very hydrophobic. Given the variability in reservoir conditions that AP and ASP floods can be applied to, their tunability can provide a competitive advantage in terms of formulation optimization.
Common CEOR Methods
After water flooding is no longer recovering oil economically, chemical techniques are often used to improve performance. One of the most cost-effective techniques is wettability alteration. Reservoir rock that has some oil wetting can be changed to a water wet state, allowing more oil to be recovered. In carbonate reservoirs, where porosities are low, a traditional ASP flood may be difficult. Getting the polymer to flow through the rock is made easier through the use of chemical (surfactant) and geochemical (injection water composition) methods.

Surfactant-induced wettability alteration significantly increases water injectivity and recovery rates in carbonate systems. Easy to implement in the field, these tuned surfactant systems are injected directly into the water flooding system, and imbibe deep into the matrix, releasing oil and improving flow pathways. Dow’s experts can tailor an effective wettability solution for your reservoir using state-of-the-art core floods.

Low salinity water flooding is gaining acceptance as laboratory and field tests show increased oil recovery in sandstone reservoirs is possible by reducing the salinity of the injection water. Water flooding salinity plays an important role in the wettability characteristics of the reservoir rock, with desired total dissolved salinity (TDS) between 1,000 and 5,000 ppm. Divalent cations are also important in order to maintain the reservoir clay stability.

Dow, with its portfolio of nanofiltration and reverse osmosis membranes, is able to provide tailored water solutions for most water-based EOR processes, such as simple sulphate-removing water flooding, EOR or low-salinity water flooding.

Alkaline-Surfactant-Polymer Flooding
While wettability alteration is a cost-effective approach, much higher recovery rates are afforded by other CEOR methods. The most effective CEOR operations involve flooding a reservoir with either an alkaline-surfactant-polymer (ASP) combination or an alkaline-polymer-only (AP) injection. These chemical injections interact with water remaining from the secondary recovery stage, freeing the trapped oil and making it recoverable.

A properly formulated ASP flood combines the best of three chemical methods to optimize recovery:
- **Alkali**: Reduces surfactant adsorption on reservoir rock and helps reduce oil-water interfacial tension by interacting with the crude oil to form natural soaps.
- **Surfactant**: Reduces interfacial tension between oil and water to extremely low levels (ULIFT), which makes it easier to displace the oil and drive it to the production well.
- **Polymer**: Increases the drive water viscosity, which improves sweep efficiency and mobility control.

Often, using only a single surfactant in the ASP can lead to the formation of undesired viscous emulsions, necessitating the addition of a second co-surfactant or co-solvent to generate the desired ULIFT. Dow’s ELEVATE co-solvents and co-surfactants enable ULIFT formulations by providing:
- Improved phase stability
- Lower injection slug viscosity compared to viscous emulsions that have high surfactant retention and high-pressure gradients
- Increased residual oil recovery rate compared to viscous emulsions, which tend to stagnate in the reservoir

For CEOR applications, salinity has a significant impact on the viscosity of polymer solutions. This reduces polymer concentrations required, and increases cost-efficiency.
Let Dow Help You Select the Optimal Approach
CEOR design and implementation is a very sophisticated process. Selecting the components for the full formulation depends on many factors, including reservoir temperature, pressure, depth, permeability and, especially, salinity. Each oilfield is different and has to be characterized before the most effective solution can be modeled and produced.

Dow’s team of experts possesses a thorough understanding of the dynamic relationship between oil and brine, as well as the intricacies of geology and the mechanics of oil extraction. That expertise allows us to help evaluate the feasibility of a CEOR plan using various surfactants and co-solvents. We will fully formulate and flood-test a surfactant-oil-brine system for your well that matches both reservoir brine salinity and temperature, one of the most critical factors of a successful CEOR operation.

In addition, Dow can help implement novel solutions for wettability alteration through additives and design of water for injection, further increasing efficiency. This collaboration allows us to customize and fine-tune solutions of high purity and specificity at relatively low cost to optimize operations.

Testing Capabilities Minimize Risk, Maximize Yield
Dow has developed laboratory evaluation and reservoir simulation capabilities to support field implementation to help customers get more out of previously inaccessible reserves. Dow’s EOR lab features extensive capabilities to test multiple core flood set-ups (formation response testers) using PVT cells, phase behavior equipment and interfacial tension measurement equipment. All of our testing is done under actual reservoir conditions to determine the best option for your operation and to allow fine-tuning to meet the precise reservoir pressure, temperature and brine concentrations.

Optimizing Formulations with Winsor Phase Experiments
Winsor phase experiments are widely used in screening and optimizing formulations whose salinity matches the reservoir brine salinity and temperature. Aqueous surfactant solutions and oil are mixed and allowed to coalesce with time, and the phase progression from Winsor Type I (oil-in-water microemulsion) to Winsor Type III (middle phase microemulsion) to Winsor Type II (water-in-oil microemulsion) is observed. This progression occurs by varying formulation components (e.g., hydrophobe length or co-solvent/co-surfactant concentration) or experimental conditions (e.g., salinity, temperature, oil type and pressure).

For CEOR applications, it is typically the salinity that is varied in these experiments, and the salinity at which the lowest IFT is obtained is termed the optimal salinity. The optimal salinity corresponds to where an equal amount of water and oil are solubilized in the Type III middle phase microemulsion.
More Solutions from Dow
In addition to its portfolio of products for CEOR operations, Dow has products to improve other current EOR methods. For example, the ELEVATE™ miscible CO₂ conformance control solution can be customized for each field. EOR techniques often lead to water treatment issues, including mineral scaling, unresolved emulsions and water cleanup. Dow can work with you to find the optimal solution to address water treatment needs for your EOR operation.

Dow’s Commitment to Sustainability
Dow’s commitment to sustainability is infused into the very DNA of our Company. In 2006, we launched our 2015 Sustainability Goals, which focused not only on the Company’s footprint in our own operations but also our handprint through the positive impact of Dow products and their role in global sustainable development. Now we have introduced our 2025 Sustainability Goals. With these Goals, Dow seeks to advance the wellbeing of humanity by helping lead the transition to a sustainable planet and society. The seven commitments that comprise the 2025 Sustainability Goals represent the next step in our long-term strategic journey. For more information on how sustainability is integrated into all aspects of our business and operations, please visit www.dow.com/sustainability.

Product Stewardship and Safety
Dow has a fundamental concern for all who make, distribute, and use its products, and for the environment in which we live. This concern is the basis for our product stewardship philosophy by which we assess the safety, health, and environmental information on our products and then take appropriate steps to protect employee and public health and our environment. The success of our product stewardship program rests with each and every individual involved with Dow products – from the initial concept and research, to manufacture, use, sale, disposal, and recycle of each product.

Dow strongly encourages its customers to review both their manufacturing processes and their applications of Dow products from the standpoint of human health and environmental quality to ensure that Dow products are not used in ways for which they are not intended or tested. Dow personnel are available to answer your questions and to provide reasonable technical support. Dow product literature, including safety data sheets, should be consulted prior to use of Dow products. Current safety data sheets are available from Dow.
This guide is designed as a general product overview. Please contact your local Dow representative for up-to-date, detailed technical information, including registrations and use limitations, and to discuss individual applications or requirements.

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