



Enhanced Oil Recovery

Vinay Sahni
June 23, 2022



Contributors



- David Hampton (Occidental)
- Kishore Mohanty (The University of Texas at Austin)
- Mike Onyekonwu (University of Port Harcourt)
- Vinay Sahni (Occidental)
- Vlad Sudakov (Kazan Federal University)



Enhanced Oil Recovery (History and Current Status)



- Enhanced oil recovery (EOR) processes improve oil recovery through the injection of substances that are not native to the reservoir
- EOR processes have been applied actively in various forms for more than 50 years in conventional reservoirs
 - Thermal: steam injection, most frequent & successful 1970s to 2000s
 - Chemical: Interest in chemical EOR methods peaked in the 1980s, polymer flooding being the most mature technique and Alkaline-surfactant-polymer flooding is now viewed as the most-promising
 - Solvent: Since 1972, CO₂ successfully applied in Permian Basin carbonate reservoirs and in Mississippi/Wyoming sandstone formations (1980s). Hydrocarbon gas injection projects implemented on the North Slope in Alaska.
 - Only a handful of CO₂ injection projects have been attempted outside the US
 - Recent interest in using CO₂ and hydrocarbon gas or enriched gas for HnP EOR in unconventional reservoirs



Enhanced Oil Recovery (Challenges)



- Despite more than 50 years of active use, EOR accounts for less than 10% of the oil produced daily
- The factors that have resulted in slow adoption include
 - Limited number of EOR processes might be applicable to any individual reservoir
 - High operating costs (injection fluids) and capital costs (facilities)
 - Significant expertise required to manage and surveil EOR projects
 - Long construction lead times and slow oil response (cash-flow impact)
 - Competition with faster-responding projects for capital



Enhanced Oil Recovery (A Look Ahead – Evolving Needs)



- The average primary recovery factor for URs is typically less than 10% (enormous potential for EOR processes)
 - HnP process preferred (due to extensive induced fracturing and very low matrix permeabilities)
 - Laboratory and numerical modeling studies show that optimizing the HnP process variables (cycle number, soak/injection/production times) for Shales can result in a substantial increase in oil recovery at acceptable utilization ratios (Gamadi et al. 2014)
 - Recent field trials show natural-gas injection could help recover 30 to 70% more oil (over primary) from Eagle Ford Shale (Sheng 2017)
- Exponential increase in research joint industry projects and field trials for gas EOR in unconventional plays across North America (Rassenfoss 2017).
- The application of chemicals, such as surfactants, in URs, both as completion additives and cyclic EOR injectants, has also recently gained research attention.
 - Key mechanisms - wettability alteration, IFT reduction, fracture damage removal, re-pressurization (Zhang et al. 2019)
- In offshore reservoirs, EOR implementation is technically and economically challenging (low number of wells, relative inaccessibility of the wells, and limited platform capacity)
 - WAG flooding is commonly accepted EOR practice in the North Sea
 - Chemical EOR might be the easiest to implement.
 - New polymers (synthetic and plant-based) being developed for harsh reservoir conditions.
 - New biopolymers could offer environmentally friendly approaches



Enhanced Oil Recovery Takeaways (know-how preservation/transfer)



- Knowledge of the basic EOR concepts and state-of-the-art EOR methods should be preserved (Lake et al. 2014; Kamal et al. 2017; Green and Willhite 2018)
- Basic EOR concepts include
 - understanding of the forces that help OR hinder recovery
 - viscous forces, capillary forces, applied pressure forces, and gravity
 - The recovery factor (microscopic displacement efficiency + volumetric sweep efficiency)
- Future practitioners must understand both the relationship between essential factors and how they are affected by fluid and rock properties
- Other important EOR concepts that must be understood
 - Phase behavior
 - Rock/fluid interactions during EOR
 - Mechanism/mitigation of Formation damage during EOR

