CHAPTER 7

SURFACTANT PERFORMANCE IN ENHANCED OIL RECOVERY

Mohamad Shafiq Raffi, Aizuddin Supee,
Norazana Ibrahim, and Mohd Zamri Mohd Yusop

7.1 INTRODUCTION

The fluctuation in oil prices often relates to factors such as global demand changes, supply disturbance, and precautionary acts (Caladara et al., 2019). Regarding the lower oil price market, the exploration and production of oil from green wells are uneconomical and less effective (Ali et al., 2018). Therefore, most oil producers preferred producing the unrecovered oil from the existing exploited reservoirs. Technically, the oil production method consists of primary, secondary, and tertiary recoveries (Hajiyev et al., 2023). The primary stage involves the natural flow of oil toward the production well, driven by the reservoir's initial energy. Upon reaching the limits of primary recovery, the extraction of remaining oil continued, for instance, by using water flooding as a secondary recovery method. However, both combinations of recovery methods only produced about 30% of the original oil in place (OOIP) for the explored reservoir (Bashir et al., 2022). Vice-versa, the others struggle to pass through and remain trapped in the pore throat of the reservoir (Tabaeh Hayavi et al., 2022). Tertiary enhanced oil recovery (EOR) is then applied to extract as much oil as possible from the leftovers after the primary and secondary methods. The EOR comprises the usage of chemical, gas, thermal, and others (microbial, low salinity, and nanofluids). The different EOR methods involved a variety of mechanisms for improving the microscopic and macroscopic displacement efficiencies through parameter manipulation such as oil viscosity (Zhu et al., 2018), rock wettability (El-hoshoudy et al., 2017), interfacial tension (IFT) (AfzaliTabar et al., 2020), and capillary forces (You et al., 2018) so that the desired mobility ratio of displacing and displaced fluids can be reached (Haruna et al., 2020).

Among those listed EOR, chemical-enhanced oil recovery (CEOR) has been successfully implemented in various types of reservoirs and promises, owning to their better efficiency with justifiable technical and cost-effective (Bashir et al., 2022; Levitt & Pope). A CEOR employs a single (mono-effect) or a combination of polymer, surfactant, and alkaline to obtain a synergistic effect. Their function involved reduction in IFT, modifying reservoir wettability (surfactant and alkaline), and regulating mobility (polymer) (Kamal et al., 2015; Kumar & Mandal, 2020), which then improved oil production remarkably due to improvement in both the sweep (polymer function) and displacement (function of surfactant and alkaline) efficiencies.

A surfactant contained tails (hydrophobic: water unsolvable) and heads (hydrophilic: water-soluble) components and was categorized based on the composition of the hydrophilic portion (Tabaeh Hayavi et al., 2022). The categories of surfactants are anionic, cationic, zwitterionic, and non-ionic, with anionic types (negative charge) widely used in CEOR due to their lower adsorption on negatively surface-charge sandstone and high stability at high-temperature conditions (Kamal et al., 2017; Navaie et al., 2022). Anionic surfactants, specifically the sulfonate, sulfate, and carboxylate types with high molecular weight (MW), effectively reduce the IFT to ultra-low values and are stable in acidic and alkaline solutions (Yang et al., 2010). Cationic surfactants (ionized in an aqueous solution with a positive charge) such as alcohols, phenols, ethers, ester, and amides are suitable to be used for carbonate reservoir (positive surface charge) and capable of removing the oil waxes (Bashir et al., 2022). Meanwhile, the non-ionic surfactants possess a strong affinity to water, do not ionize in the aqueous solution, and the IFT reduction is lower than the ionic (anionic and cationic) surfactants. Besides, the zwitterionic surfactants could exhibit either positive or negative charges depending on the pH of the solution. The anionic and cationic surfactants are often used as primary surfactants, while the non-ionic and zwitterionic surfactants serve as co-surfactants.

Depending on the type of reservoirs, the screening (selection) of surfactant is vital for ensuring the maximum recovery of trapped oil. Much experimental research reported the usage of anionic surfactants in CEOR applications, as summarized in Table 7.1 highlighted that the critical micelle concentration (CMC) of surfactant, type of surfactants, brine-salinity (formation water), wettability, and type of reservoirs are among the factors dictating the amount of oil recovered. Besides, the smaller the size of oils or microemulsion produced, the better displacement efficiency obtained (higher oil recovery due to easy movement of oil). The status quo exhibited that different surfactant formulations resulted in unique characteristics and performance for oil production.

To our knowledge, none of the works in Table 7.1 described the properties and performance of anionic surfactant formulation called C14-16, alpha-olefin sulfonate (AOS), and methyl ester sulfonates (MES) at concentrations ranging from 0.05–0.90 wt.%. Hence, we elaborate on the properties and develop a new database of those surfactant formulations focusing on the density, viscosity CMC and IFT, phase behavior, and performance (oil recovery) obtained in heterogeneous formation. The amount of oil recovered for field implementation owned similar conditions and parameters can be roughly estimated using that developed database.