CHAPTER

6

SALINITY-RESPONSIVE NANOPARTICLES FOR OIL AND GAS RECOVERY

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6.1 INTRODUCTION

Due to the expansion of industrialisation, there is an increasing demand for natural resources. Most existing oilfields have been found, making discovering new commercially viable resources challenging. Consequently, oil companies focus on enhancing mature oilfields' recovery factor by implementing new enhanced oil recovery (EOR) methods (Ali et al., 2019; Ali et al., 2018).

The extraction of crude oil from a reservoir begins with primary recovery techniques utilising the reservoir's internal energy. Subsequently, secondary recovery methods using water and gas injection are employed when the pressure decreases substantially. Nevertheless, around two-thirds of the original oil reserves in the rock's pores remained uncovered. Therefore, it has been suggested that more efficient enhanced oil recovery methods be utilised, including chemical, miscible gas injection, thermal recovery, and microbial EOR (Yakasai et al., 2021).

Chemical enhanced oil recovery (CEOR) involves injecting various chemicals, including alkaline substances, surfactants, polymers, and combinations. Enhancing oil recovery through CEOR methods involves reducing interfacial tension (IFT), lowering oil viscosity, changing wettability characteristics, and causing oil swelling. Traditionally, surfactant flooding has played a crucial role in improving oil recovery by reducing the interfacial tension between oil and water, altering the wettability of the oil phase to make it water-wet, and creating crude oil emulsions. Nevertheless, its application is restricted by its adsorption into rock formations, elevated expenses, subpar performance in demanding reservoir environments, extraordinarily high salinity, and extreme temperatures (Johannessen & Spildo, 2013). Consequently, new technologies have been developed to address these challenges.

Nanoparticles (NPs) offer significant benefits in EOR applications over traditional CEOR. Their tiny size, ranging from 1 nm to 100 nm, allows them to traverse inaccessible formation pores that more significant substances may struggle to navigate. Their substantial surface energy and reactivity can modify fluid and rock properties to enhance oil displacement, and they can be tailored to encompass multiple features. However, the utilisation of nanoparticles in EOR has drawbacks, including the potential for nanoparticle agglomeration and precipitation in porous media, which can lead to core plugging, reduced permeability, and diminished oil recovery. Consequently, numerous studies on nanoparticle-surfactant combinations have been conducted and have demonstrated superior EOR performance, as the surfactant can stabilise the nanoparticles (Chen et al., 2019; Suleimanov et al., 2011; Zhao et al., 2018).

6.2 CHALLENGES IN UTILISING NANOPARTICLES FOR ENHANCED OIL RECOVERY

Broadly, the application of nanoparticles in EOR can be categorised into three main groups, as outlined by Liu et al. (2022). The first is the concept of nanocatalysts, where nanoparticles are injected as catalysts while injecting steam into reservoirs containing heavy oil, as Hashemi et al. (2014) described. Alternatively, nanoemulsions are a variation of conventional emulsions with particle sizes typically ranging from 50 nm to 500 nm. They employ nanoparticles for emulsion stabilisation and address some of the drawbacks associated with regular emulsions, as Mandal et al. (2012) discussed. The third category, nanofluids, consists of suspensions created by blending nanomaterials with various essential fluids, including water, surfactants, glycols, and ethanol. Among these three nanotechnology categories for EOR, nanofluids have garnered the most attention due to their distinctive spreading and operational mechanisms, as highlighted by Sharma et al. (2016). While silica-based nanomaterials have historically been widely employed in EOR, more recently, metal oxide-based nanoparticles, such as zinc oxide (ZnO), have demonstrated favourable effects on reservoir conditions.

The performance of various types of nanoparticles can be influenced by salinity. Sadatshojaei et al. (2019) studied the impact of silica nanofluid electrolytes on wettability and interfacial tension. Al-Anssari et al. (2016) observed that when salinity is less than 10 wt% sodium chloride (NaCl), it enhances wettability modification. Conversely, when salinity exceeds 10 wt% NaCl, it marginally reduces wettability owing to diminished repelling forces between particles, increasing agglomeration rates. Zargar et al. (2020) reported a 33.6% decrease in contact angle with a 1:10 seawater dilution and a 47.5% reduction with a 1:20 seawater dilution. Consequently, similar to particle concentration and surfactant formulations, salinity has an optimal concentration that can enhance nanofluid flooding. Sulaiman et al. (2015) and Zargar et al. (2020) revealed that 0.3 wt% NaCl provided optimal interfacial tension and contact angle reduction. Furthermore, Shuaibu et al. (2022) researched the synergistic effect of zinc oxide nanoparticles (ZnO NPs), ionic surfactants, and specific salinity concentrations on surface and IFT.

However, the impact of different salinity levels on ZnO NPs combined with sodium dodecyl sulphate (SDS) remains unclear. Therefore, this study has examined how salt content can influence IFT, wettability, and oil recovery. Firstly, the research investigates the effects of salinity on ZnO NPs combined with sodium dodecyl sulphate (SDS) in terms of IFT and wettability. Secondly, it compares oil recovery by displacing sand packs using water, SDS, ZnO NPs with SDS, and a mixture of SDS, ZnO NPs, and NaCl. Particle size analysis (PSA) and