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Synergistic of nanoparticles/low salinity water/surfactant: A review on applications, advantages and mechanisms

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1. ABSTRACT

The synergistic technique of nanoparticles, low salinity water and surfactant represents a promising and innovative strategy for enhancing oil recovery and preventing the deposition of asphaltenes. In this study, the applications and advantages of the aforementioned technique are studied. Additionally, the mechanisms of oil displacement, field applications, economic considerations, and future research directions are presented. The findings indicate that the simultaneous use of nanoparticles, low salinity water, and surfactants can significantly reduce costs while enhancing recovery rates by altering wettability to a hydrophilic state, preventing the migration of fine rock particles, and decreasing surfactant adsorption on the rock surface. By employing this technique, the interfacial tension and wettability can be reduced to 0.99 mN/m and 22°, respectively. Furthermore, this technique effectively addresses the challenges related to the asphaltene deposition by dispersing asphaltene molecules within the porous media. Investigations have demonstrated that concentration is a critical factor; therefore, concentrations exceeding 0.2 wt% of nanoparticles are rarely recommended. Future research should focus on exploring the synergy between surfactants/low-salinity water and nanoparticles such as silica, aluminum oxide, and graphene oxide. The results reported in this study can assist researchers in selecting the optimal synergistic combinations for enhanced oil recovery tests, thereby minimizing the detrimental effects of incompatibilities while increasing recovery rates.

Keywords: Nanoparticle, Low Salinity Water, Surfactant, Enhanced Oil Recovery (EOR), Asphaltene Deposition.

2. INTRODUCTION

Fossil fuels are anticipated to remain the predominant energy sources for the coming decades. Complete depletion of hydrocarbon reservoirs is unattainable, with more than 70% of the oil typically remaining unextracted after the initial recovery phase [1]. Consequently, enhanced oil recovery (EOR) techniques are employed to augment the recovery factor [2, 3]. Moreover, numerous oilfields encounter challenges associated with asphaltene deposition. Asphaltene molecules may precipitate and accumulate within the porous media and/or surface facilities [4, 5]. Recently, synergistic technique has been showed promising results in the cource of increasing oil recovery and preventing asphaltene deposition. Therefore, this study examines recent advancements in the utilization of a synergistic approach combining nanoparticles, low salinity water, and surfactant to enhance oil production and mitigate asphaltene-related issues. Specifically, the study explores the advantages, applications, mechanisms, economic implications, and future directions of this technique. The findings presented address some of the limitations associated with the adoption of these method and demonstrate its potential benefits.

3. THE BENEFITS OF NANOPARTICLES/LOW SALINITY WATER/SURFACTANT SYNERGY

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All materials and methods that have been used in the work must be stated clearly and subtitles should be used when Adsorption of the surfactant over the rock surface is a great economical challenge. Here, nanoparticles can be used to solve this problem. In this regard, the adsorption of nanoparticles on the rock surface can reduce the amount of adsorbed surfactant. Moreover, combination of surfactant with nanoparticles and low salinity water can alter wettability toward a hydrophilic state and disperse asphaltene molecules, resulting in increasing oil recovery and postponing the onset point of asphaltene deposition. Also, using nanoparticles along with other EOR methods can hinder the migration of fine rock particles released by chemical interactions.

4. MECHANISM OF OIL DISPLACEMENT USING SYNERGISTIC COMPOUNDS

During the injection of synergistic compounds into the porous media, the interactions between oil/brine water and brine/mineral matter create a negative charge on the rock surface. The thickness of the liquid film is increased by injecting low salinity water, and the injected nanoparticles are adsorbed to the rock surface and interact with the reservoir rock mineral and negatively charged naphthenic acids in the crude oil (Fig. 1). In this regard, the two electric layers of the contact surface are affected by ions and the adsorption of nanoparticles to the stone surface. The presence of surfactant increases the interactions of ions in the liquid film and this approach forms the interphase with crude oil and rock. Surfactant ions will also interact with the nanoparticle ion and the electrolyte present at the interface. The interaction between ions with negative charge of surfactant and nanoparticle is balanced by the repulsion force, which reduces the amount of nanoparticles present in the interface of brine layer. In general, excess surfactant in the system reacts with electrolyte ions and rock minerals to change wettability. Therefore, the synergistic compound changes the wettability to the water-wet state by interacting with more ions at the contact surface.

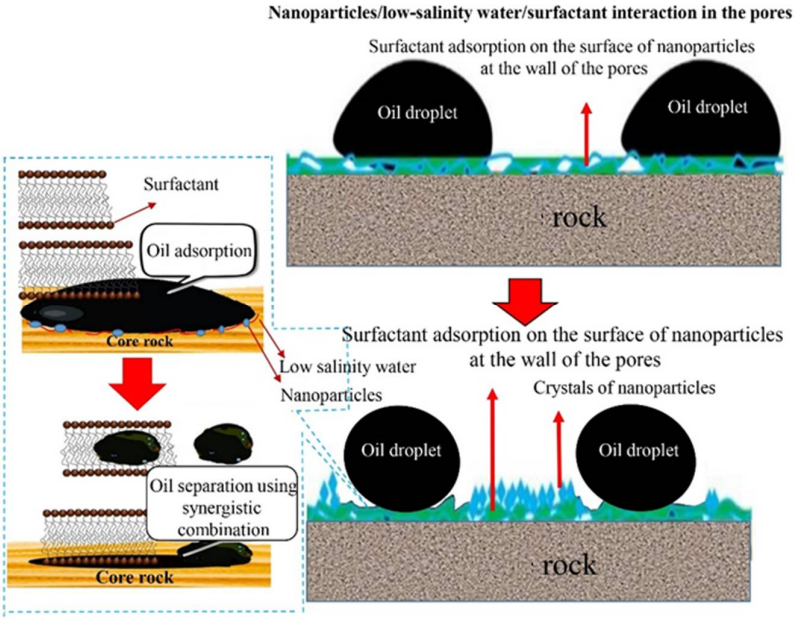

Figure 1. The mechanism of synergistic effect whithin the porous media

5. FIELD APPLICATION

In the field scale, the combined method of nanoparticles, surfactant and low salinity water can be chosen according to the actual condition of the reservoir. This option can effectively overcome the accumulation of nanoparticles and surfactant in the porous media and increase the efficiency of oil sweeping. Moreover, by simultaneously injection of surfactant, nanoparticles and low salinity water into the porous media, the asphaltene aggregation decreases significantly.

6. FUTURE RESEARCH DIRECTIONS

1. Considering the advantages of synergistic compounds, investigating their field application for the Iranian reservoirs (especially carbonate reservoirs) can be one of the main fields of future studies.
2. Metal oxide nanoparticles show great performance against the challenges associated with asphaltene deposition. Investigating the performance of various metal oxides in combination with different surfactants can be considered by researchers as a new field of research.
3. In general, due to the wide variety of nanoparticles and surfactants, creation of new and effective synthetic compounds can provide many research horizons.

7. CONCLUSION

In this study, the synergistic effects of nanoparticles, surfactant and low salinity water were comprehensively investigated. The findings indicate that this synergistic method can significantly reduce costs while enhancing oil recovery rates by altering wettability into a hydrophilic state, preventing the migration of fine rock particles, decreasing surfactant adsorption on the rock surface, and dispersing asphaltene molecules within the porous media. The results reported in this study can assist researchers in selecting the optimal synergistic combinations for enhanced oil recovery tests, thereby minimizing the detrimental effects of incompatibilities while increasing recovery rates.

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