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Stabilization of Foams and Emulsions by Silica Nanoparticles in the Presence of Surfactants and Crude Oils for Enhanced Oil Recovery

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Foam flooding, one type of chemical enhanced oil recovery (EOR) method, has been used extensively in the management and exploitation of petroleum reservoirs to increase the mobility and recovery of crude oils from geological formations. However, the stabilization of foams by surfactants is deficient in terms of its stability over time, particularly in the physico-chemical conditions (e.g., salinity, pH, temperature) encountered in a petroleum reservoir. Therefore, it is critical to design foams that have the capability to remain stable over long periods of time. Although the synergistic stabilization of foam by nanoparticles and surfactants has been the subject of numerous studies, there are critical gaps in our knowledge on the foam stability resulting from nanoparticles and surfactant dispersions in the presence of crude oil, due to the intricacies of the phase interfaces present in the foam. Furthermore, there is limited information about the used genuine surfactant solutions and the nanoparticles/surfactant dispersion in the presence and absence of crude oil. Additionally, the stabilization mechanisms of the nanoparticles/surfactant dispersion in the presence and absence of a crude oil phase necessitate more study. In this research, the foamability and foam stability of hydrophilically and hydrophobically modified SiO_2 nanoparticles with an anionic surfactant, sodium dodecyl sulfate (SDS), or a cationic surfactant, cationic surfactant cetyltrimethylammonium bromide (CTAB), in the presence and absence of crude oils were assessed. We investigated the relationship between the different substances adsorbed at the interface and the foam properties of the SiO_2 hydrophilic/SDS, SiO_2 hydrophobic/SDS, SiO_2 hydrophilic/CTAB, SiO_2 hydrophobic/CTAB dispersion in the presence and absence of light (West Texas Intermediate), medium (Prudhoe Bay), and heavy (Lloydminster) crude oils. Various concentrations of nanoparticles and surfactants were tested. The foamability and foam stability of the studied foam systems were characterized by their zeta potential, interfacial tension, foam height, drainage half-life, and foam volume. Contact angles of the different foam systems were also analyzed on a glass silica-based slide. The size of the SiO_2 nanoparticles in these different systems was obtained through dynamic light scattering. Percentage of water resolved in the emulsions was also monitored. Based on this comprehensive and systematic study, it appears that the development of nanoparticles-based foams for chemical EOR applications can be optimized for a wide range of crude oils. By comparing the foam properties in the case of the aqueous surfactants solution, a stabilization mechanism of aqueous foam for nanoparticle/surfactant dispersion in the presence of crude oil, was advanced.