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8698 DOI: 10.1021/acs.energyfuels.7b01083
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8708 DOI: 10.1021/acs.energyfuels.7b01278
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8733 DOI: 10.1021/acs.energyfuels.7b01312
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8742 DOI: 10.1021/acs.energyfuels.7b01342
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8803 Ⓢ DOI: 10.1021/acs.energyfuels.7b01124
Experimental Study on the Removal of VOCs and PAHs by Zeolites and Surfactant-Modified Zeolites
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8813 DOI: 10.1021/acs.energyfuels.7b01610
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Additions and Corrections

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Correction to Impact of Pre-equilibration on the Assessment Methodology of Interfacial Tension Measured between Aqueous and Heavy Oil Phases
Sharath Chandra Mahavadi,* Jose Zacharia, and Geza Horvath-Szabo

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Correction to Detection and Impact of Carboxylic Acids at the Crude Oil–Water Interface
Simon Ivar Andersen,* Sharath Chandra Mahavadi, John Chen, Ben Y. Zeng, Fenglou Zou, Mmilili Mapolelo, Wael Abdallah, and Johannes Jan Buiting

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Correction to Interfacial Films Adsorbed from Bitumen in Toluene Solution at a Toluene–Water Interface: A Langmuir and Langmuir–Blodgett Film Approach
Sharath Chandra Mahavadi, Zhenghe Xu, and Jacob H. Masliyah*

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Review

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Review on Surfactant Flooding: Phase Behavior, Retention, IFT, and Field Applications

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ABSTRACT: Surfactant flooding is an important technique used in enhanced oil recovery to reduce the amount of oil in pore space of matrix rock. Surfactants are injected to mobilize residual oil by lowering the interfacial tension between oil and water and/or by the wettability alteration from oil-wet to water-wet. A large number of cationic, anionic, non-ionic, and amphoteric surfactants have been investigated on a laboratory scale under different conditions of temperature and salinity. Selection of the appropriate surfactant is a challenging task, and surfactants have to be evaluated by a series of screening techniques. Different types of surfactants along with their limitations are reviewed with particular emphasis on the phase behavior, adsorption, interfacial tension, and structure–property relationship. Factors affecting the phase behavior, interfacial tension, and wettability alteration are also discussed. Field applications of surfactants for chemical enhanced oil recovery in carbonate and sandstone reservoirs are also reviewed. Finally, some recent trends and future challenges in surfactant enhanced oil recovery are outlined. Field studies show that most of the surfactant flooding has been conducted in low-temperature and low-salinity sandstone reservoirs. However, high-temperature and high-salinity carbonate reservoirs are still challenging for implementation of surfactant flooding.

1. INTRODUCTION

Oil has been the most important and significant source of energy so far, and it will contribute significantly in meeting the future energy demand as well.[1] Thus, it is necessary to enhance the current production level in the next few decades, which can be achieved by either discovering new fields or increasing the production from existing oil fields. Only about one-third of the oil present in a reservoir can be recovered using primary and secondary recovery techniques.[2−5] Oil is initially recovered from a reservoir using the inherent pressure of the reservoir (primary recovery). After the dissipation of the initial pressure, oil is recovered by applying external pressure using seawater injection into the reservoir (secondary recovery). Enhanced oil recovery (EOR) or tertiary recovery techniques are used to recover the remaining oil which cannot be recovered using water flooding.[6] Although chemical EOR (cEOR) is one of the most promising methods available to recover residual and remaining oil, it was not very commonly employed in the past due to low oil prices and the high cost of chemicals. However, continuous rise in oil prices and the growing demand for oil have encouraged researchers to determine economical and low-cost cEOR technology to recover the maximum amount of the remaining oil.

In cEOR, a range of chemicals such as surfactants, polymers, and/or alkalis are used to increase the microscopic efficiency (displacement efficiency) and the macroscopic efficiency (volumetric sweep efficiency).[7−16] Macroscopic efficiency is related to the effectiveness of the displacing fluid in sweeping out the reservoir volume both areally and vertically as well as moving the oil toward the production well.[17] Macroscopic efficiency can be increased using mobility control methods. Polymers are used to increase the viscosity of the displacing fluid (water), which improves the oil/water mobility ratio.[18−21] On the other hand, microscopic efficiency is related to the displacement of oil at the pore scale. It is not possible to displace all the oil that comes into contact with water during water flooding, due to trapping of oil by capillary forces. The relationship between the capillary forces and the viscous forces results in a dimensionless capillary number ($\mu v/\gamma \cos \theta$), where μ is the viscosity of the aqueous phase, v is the velocity, γ is the interfacial tension between oil and water, and θ is the contact angle.[22,23] Microscopic efficiency can be improved by decreasing the capillary forces and the oil/water interfacial tension. Capillary number is closely related to oil recovery and residual oil saturation (oil saturation is the volume fraction of oil within the pore volume) and is in the range of 10^{-7} to 10^{-6} for typical brine flooding. Increasing the capillary number to between 10^{-4} and 10^{-3} reduces the oil saturation to 90%,[6] and residual oil saturation approaches zero if the capillary number reaches 10^{-2}.[24] In order to reach this value, the interfacial tension (IFT) should be decreased from an initial value of 20–30 mN/m to values in the range of 10^{-2} to 10^{-3},[25] which is achieved through the use of surfactants during flooding with brine.[26−28] Surfactants also influence the amount of residual oil recovered via other mechanisms, including microemulsification of trapped residual oil, changing the wettability of rock, and improving the interfacial rheological properties.[29−36] Here wettability is defined as "the tendency of one fluid to adhere to a solid surface in the presence of another immiscible fluid".

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