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Chemical induced enhanced oil recovery: Role of rock mineralogy on surfactant adsorption characteristics

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Highlights

- Interfacial tension reduction behavior with different surfactants.
- Thermal stability evaluation of the desired surfactant by aging.
- Adsorption on potential surfactant with its isotherm and kinetics model investigation.
- Effect of rock minerology on adsorption quantity at different reservoir condition.

1. Introduction

Surfactant flooding has been proven to be effective in recovering large quantity of residual oil which is not possible to be recovered by primary and secondary schemes [1, 2]. Surfactants contribute towards enhanced sweep efficiency that brought forward with higher capillary number and thereby facilitate interfacial tension (IFT) reduction, wettability alteration, emulsion formation and better sweep efficiency to improve oil recovery [2, 3]. Surfactant adsorption characteristics have been extensively studied for various combinations of surfactants (ionic and non-ionic surfactants and natural surfactants) and reservoir core samples (reservoir rocks, sandstone and Berea cores) [4, 5, 6]. Apart from desired characteristics such as minimal adsorption capacity, surfactant stability and thermal aging are relevant parameters to be investigated. The major emphasis of this work is to investigate upon the surfactant adsorption characteristics for Assam reservoir rocks (India) with focus upon mentioned existing research gaps. Seven surfactants were examined and based on preliminary IFT studies with Assam crude oil, Triton X-100 has been chosen as model surfactant to deliberate upon the effect of rock mineralogy, real cores, temperature and saline media on the relevant surfactant adsorption characteristics. In order to determine the adsorption capacity of surfactant on Assam reservoir rock at constant temperature, four different adsorption isothermal models were applied.

2. Methods

Assam reservoir formation water was characterized and prepared in the laboratory for experimental investigation [4, 7]. Reservoir rock samples were mixed with Triton X-100 surfactant solution in the gravimetric ratio of 1:5 with surfactant concentration varying from 100 - 5000 mg/L. The mixture was subjected to rigorous agitation in an orbital shaker at 120 rpm and 30°C for 24 hours. To further evaluate the thermodynamic parameters of adsorption process, the temperature of the system was varied from 30-70°C. After agitation, the sample was centrifuged at 10000 rpm to separate the mixture and was subjected to UV-Visible spectroscopy to obtain equilibrium concentration. X-ray powder diffraction (XRD), Brunauer–Emmett–Teller (BET) and Energy-dispersive X-ray (EDX) characterization was performed to evaluate the minerology composition, surface area, and elemental composition of reservoir rock, respectively.

3. Results and discussion

XRD and EDX analyses confirmed that Assam reservoir rock is anionic in nature. Based on BET analysis, the data shows a specific surface area of 4.97 m^2/g with an average pore radius of 6.99 nm and total pore volume of 0.017 cc/g. Two anionic and five non-ionic surfactants were subjected for the estimation of their IFT values (Table 1). It was observed that Triton X-100 has greater potential in IFT reduction compared to other surfactants, therefore, Triton X-100 was further evaluated for adsorption process. From the Thermogravimetric analysis (TGA) graph, it can be observed that the surfactant is thermally stable up to 305°C. Surfactant was thermally aged by keeping at 90°C in an oven for 10 days and the thermal stability was confirmed by Fouriertransform infrared spectroscopy (FTIR) and Nuclear magnetic resonance (NMR) indicating negligible change in functional group. The IFT values for aged and non-aged samples were similar which further confirms the stability of the surfactant. Langmuir isotherm and pseudo-second order kinetics showed best fitness with maximum regression coefficient R^2 of 0.99 (minimal average relative error of 2.58%) and R^2 of 0.99 (3.64% error) respectively. Figure 1 indicates an adsorption of 10.87 mg/g at 30ºC which reduces to 6.23 mg/g at 70ºC using synthetic formation water as aqueous medium. As the aqueous medium is changed from formation water to millipore water, the adsorption reduces from 10.87 mg/g to 7.53 mg/g at 30ºC. Higher illite content resulted in higher adsorption capacity, showing linearity with R^2 value of 0.95. Similarly, the R^2 value for feldspar, montmorillonite and kaolinite were found to be 0.92, 0.91 and 0.81 respectively.

Table 1. IFT values of various anionic and non-ionic surfactants with Assam crude oil at 0.025 wt% surfactant concentration.

Surfactant (Name)	SDS	Sodium Lignosulphonate	Triton X-100	Span 80	Tween 80	Brij 30	Titriplex III
IFT (mN/m)	0.78	2.14	0.22	0.98	2.82	3.12	No droplet

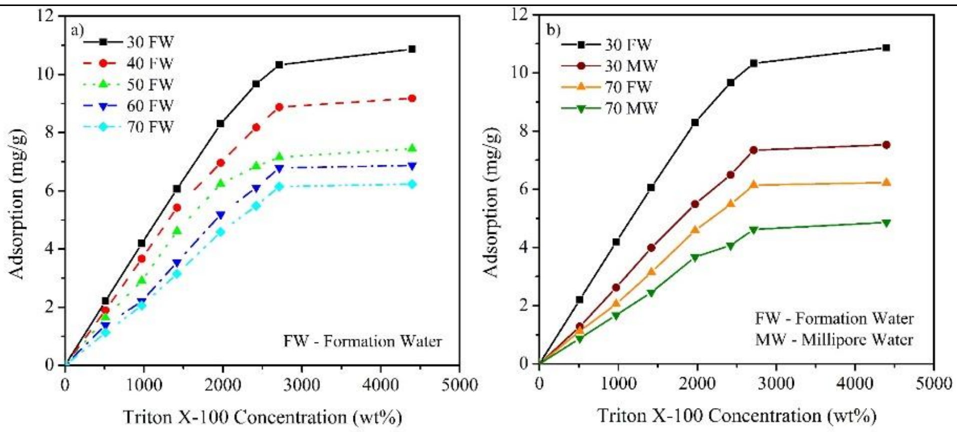

Figure 1. Effect of a) temperature and b) formation water (salinity) on adsorption capacity.

4. Conclusions

TGA, NMR and FTIR studies conveyed that the selected surfactant (Triton X-100) is stable at reservoir conditions with negligible effect of thermal aging. The salinity effect was confirmed during millipore water based IFT studies and conveyed that the IFT was significantly higher (> 1 mN/m) with Millipore water. Among alternate equilibrium isotherm models and kinetic models, the best fit models are Langmuir model and pseudo-second order model. Thermodynamic adsorption parameters specify the feasibility, spontaneity and exothermic nature of the adsorption process. The reduction in adsorption with variation in temperature was observed to be around 42.68%. The adsorption capacity decreased by 30.7 % when the aqueous medium was bereft of salinity condition. The correlation so developed indicated the contribution of each minerals in the order of illite > feldspar > montmorillonite > kaolinite.

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Keywords
Interfacial tension; Surfactant stability; Adsorption, Rock minerology