Petroleum Research

Petroleum Research, 2019(December-January), Vol. 29, No. 108, 1-5

DOI: 10.22078/pr.2019.3221.2487

Experimental investigation of the Effect of Salinity and Type of Ion on the Stability of Water in Oil emulsion

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DOI: 10.22078/pr.2019.3221.2487

Received: March/12/2018 Accepted: March/03/2019

INTRODUCTION

Among multiple other EOR methods, low salinity water flooding has been widely studied and performed in order to increase the oil recovery from oil reservoirs in recent years. In this study, a microscopic approach was utilized to investigate the effects of fluid/fluid interactions on the overall performance of smart waterflooding, as it has received less attention compared with the attention received by the rock/fluid interactions in the literature [1,2]. To assess and measure the size distribution of oil/water emulsions, the bottle test method was utilized. In all the experiments, samples with 20 percent crude oil and 80 percent low-salinity water, containing different salts in different salinities, were mixed to acquire oil/water emulsions. Then, samples taken from oil-water interface were used to obtain the size distribution of water droplets dispersed in the oil phase. The results showed a droplet size distribution between 0.02 and 11.65 mm with a maximum relative frequency of 0.73 at its maximum. Furthermore, based on the results obtained in these experiments, the lower the water salinity, the smaller the droplets are.

METHODOLOGY

CRUDE OIL

The crude oil used for the experiments was from one of the southern oil fields of Iran. The properties of the selected crude oil can be seen in Table 1.

Distilled water

Experiments were performed using five times distilled water to make saline solutions and to wash the bottles and apparatus.

SALTS

The used salts are laboratory grade salts and the properties are listed in Table 2.

MICROSCOPIC APPROACH

To observe the water droplets of water-in-oil emulsions used at the water-oil contact surface, an electron microscope (Figure 1) was used. In addition, the microscope can zoom up to 400 times.

Table 1: Properties of crude oil

Density (gr/cm^3 at 90 °C)	Viscosity (cP at 90 °C)	Acid number (mg KOH/gr oil)	Asphaltene (wt.%)
0.84	2.35	0.14	0.6

Table 2: Properties of salts

Salts	Formula	Molecular weight (g/mol)
Sodium Chloride	$NaCl$	58.4
Calcium Chloride	$CaCl_2$	110.98
Magnesium Chloride	$MgCl_2$	203.31
Sodium Sulfate	Na_2SO_4	142.04

Figure 1: Microscope

TEST METHOD

When water is injected into the injection well, the water content is greater than oil around the well; therefore, the experiments were performed with a mixture of 20% of dead crude oil and 80% of saline water in a bottle. Moreover, the method of making samples is as follows:

1- Making brine solutions with the four salts and each salt in four different salinities (6,000 ppm, 10,000 ppm, 20,000 ppm and 40,000 ppm).

2- Mixing water and oil in a 20 cc vial containing 20% oil and 80% saline water for one of the salts with one of the salinities listed.

3- Stirring the sample at 100 as shown in Figure 2.

4- Waiting 24 hours so that the samples stabilize.

5- Performing an emulsion stability test, which will be discussed in the next section.

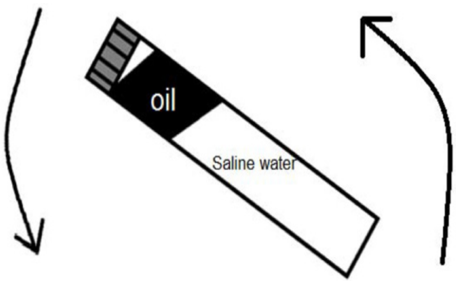

Figure 2: Stirring the sample.

SAMPLING METHOD AND ANALYZING IMAGES

As mentioned, the samples are given a 24-hour deadline for stabilization. Then, using an insulin syringe, the water present in the oil at the contact surface is sampled on a slide and photographed using an electronic microscope (Figure 3). In this study, four salts were used and four salinities were considered for each salt. Each saline (each test tube) was sampled four to five times with a syringe and photographed using the microscope. Furthermore, the data of these photographs are aggregated at each salinity and a relative frequency graph is obtained at that salinity. In addition, the procedure of extracting droplet sizes using Image J software is shown in Figures 3 to 6.

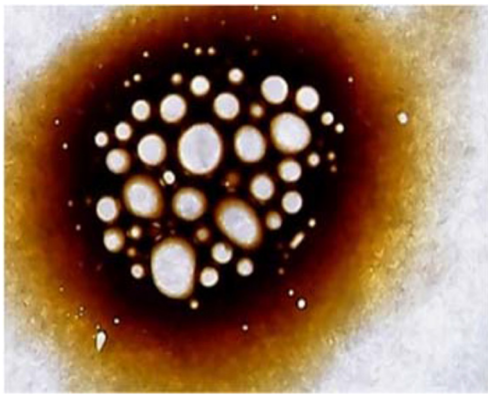

Figure 3: The image taken from the emulsion by the microscope

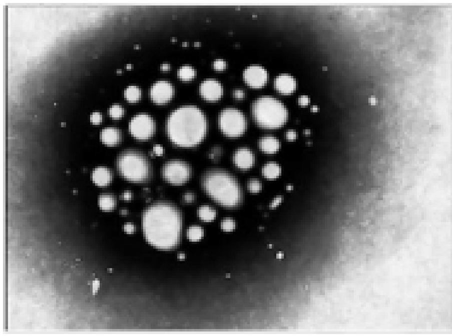

Figure 4: Black and white image (8 bits).

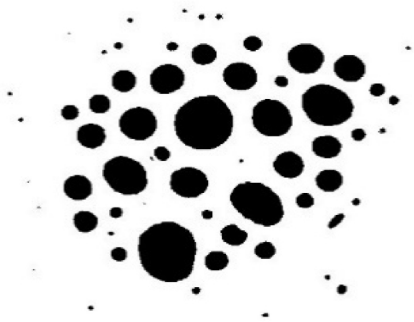

Figure 5: Defining threshold for the droplets.

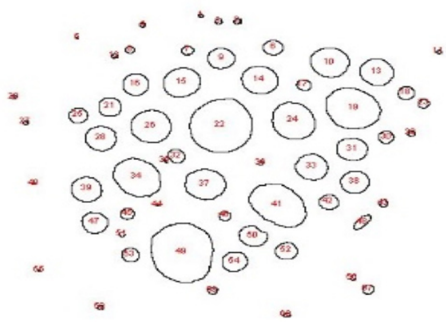

Figure 6: Detection of droplets and their area by Image J software.

RESULTS AND DISCUSSION

Emulsion formation indicates the possibility of migration of surfactants (asphaltenes and resins) to the contact surface of water and oil. Moreover, the amount of asphaltene in the test oil is very low, and it is 0.6% by weight. In the water used in this study, there is no surface-active ingredient and only petroleum contains natural surface-active agents. What makes the connection between two immiscible fluids, one hydrophilic and the other hydrophobic, are the same surface active components in the oil that draw water toward them [3]. Figures 7 to 10 are diagrams of the relative frequency for the categories of emulsion droplets.

THE METHOD OF ANALYZING RELATIVE FREQUENCY GRAPHS

The higher relative frequency of smaller droplet categories indicates that the droplets are generally smaller than other salinities. For example, the higher peak of the curve at 6000 ppm indicates the accumulation of smaller droplets (and thereby, smaller overall droplet size).

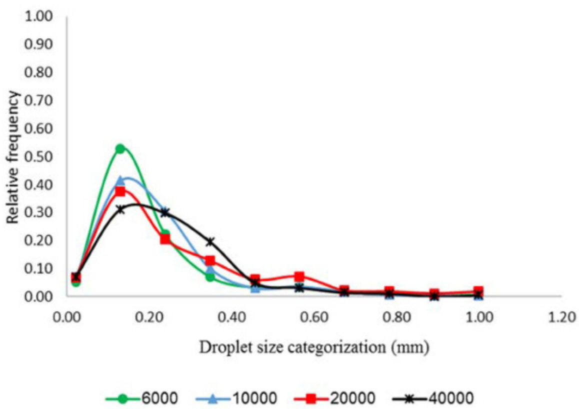

Figure 7: Water in oil emulsion droplet size distribution curve for sodium chloride.

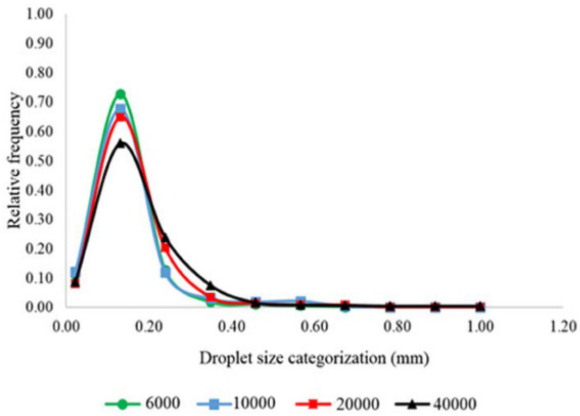

Figure 8: Water in oil emulsion droplet size distribution curve for calcium chloride.

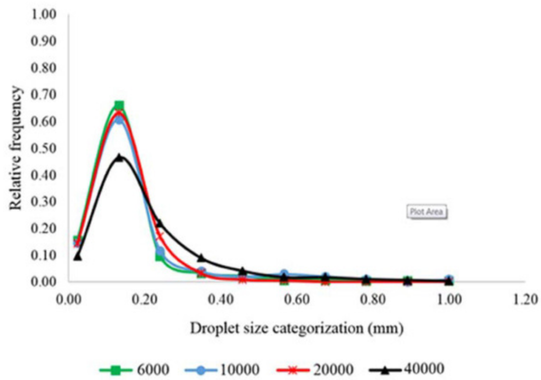

Figure 9: Water in oil emulsion droplet size distribution curve for magnesium chloride.

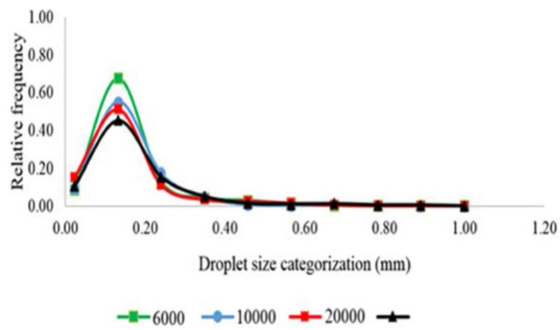

Figure 10: Water in oil emulsion droplet size distribution curve for Sodium sulfate.

CONCLUSIONS

According to the analyzing method and Figures 7 to 10, the overall size of emulsion droplets becomes larger in calcium chloride, magnesium chloride, sodium sulfate, and sodium chloride respectively. It has also been observed that with an increase in salinity in each salt, emulsion droplet size increases. In oil in contact with low-salinity water, the natural surfactants (asphaltene and resin) accumulate on the surface of the water-oil contact area and cause a decrease in oil mass. This shift of asphaltene and resin contents towards the contact surface between water and oil causes some of the non-polar heavy oil molecules such as waxes and paraffins to move to the surface, and thereby, enhancing the stability of the emulsion at the contact surface. Finally, the concentration of asphaltenes and organic acids in the contact surface has a great effect on the visco-elastic properties of the surface and its stability.

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