INTERFACIAL TENSION OF CRUDE OIL-BRINE SYSTEMS IN THE NIGER DELTA

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ABSTRACT

Interfacial tension in crude oil - brine systems is becoming very important with increasing global efforts for increased oil reserves from enhanced oil recovery projects. Interfacial tension has direct impact on multiphase flow and displacement processes in porous media. It also affects the behaviour of oil field emulsions. Most published two-phase flow and displacement processes carried out under different interfacial tension have been performed for either oil-gas or water-gas two-phase systems. This work investigated the effect of salinity, temperature and oil viscosity on the interfacial tension of oil –brine systems from five different Niger Delta reservoirs. The results show that there is a strong relationship between temperature, salinity, oil viscosity and interfacial tension in heavy crude-brine systems ($R^2 > 0.88$ and $P < 0.05$), between temperature, salinity and interfacial tension in light crude-brine systems ($R^2 = 0.91$ and $P < 0.05$), but no conclusive relationship in medium crudes-brine systems.

Keywords: *Interfacial tension, oil-brine systems, Niger Delta, experimental design, tensiometers*

1. INTRODUCTION

Interfacial tension between two immiscible fluids arises from the dissimilarity of the intermolecular forces between the molecules in the phases. According to Shen et al [1] Interfacial tension affects two-phase flow and displacement processes in porous media. Interfacial films could also contain ionizable groups such as asphaltenes, resins, organic acids and solids which affect the physical properties of emulsions and the solubility of some polar organic compounds at the oil-water interface.

Extensive survey of the literature on the interfacial tension of oil-brine systems suggests that no consistent specific trends have been established in the changes of interfacial tension with temperature, pressure and presence of impurities. Hjelmeland and Larrondo [2], reported this inconsistency in the trend of data on flashed crude oil and formation brines. Similarly, Abhijit [3], noted that the behavior of interfacial tension in oil-water systems with pressure has not yet been well understood. On the other hand, the effect of surface-active impurities on interfacial tension have been widely reported by researchers such as McCaffery [4], Flock, *et al* [5] and Buckley and Tianguang [6]. This current work investigated the relationship between temperature, salinity and oil viscosity with the interfacial tension of brine-oil systems in the Niger Delta.

2. MATERIALS AND METHOD

Crude oil samples obtained from 5 different reservoirs and sample of automotive gas oil (diesel) were used in this study. Viscosity was determined using a Fann rheometer while pH was measured using an analytical pH meter. Brine solutions were prepared using distilled water treated with different concentrations of Sodium Chloride. Interfacial tension of the oil-brine systems were measured at temperatures using the CSC-DuNouy Tensiometer. A heating bath was used to raise sample temperatures as required. Experiments were replicated to enhance accuracy of measurements.

Results were statistically analyzed using the Response Surface Methodology in the **"S Plus"** environment. Predictive models were obtained to describe the established relationship of interfacial tension with temperature (^oC), salt concentration (ppm) and viscosity (cp) respectively. P-Values, diagnostic plots and and coefficient of correlation were also determined.

3. RESULTS AND DISCUSSION

The physical properties of the samples determined routinely at room temperature of 29^0C are presented in Table 1. Figures 1- 6 show the behavior of oil-brine interfacial tension at different temperatures and brine concentrations. The light crude (sample B) was observed to demonstrate increasing interfacial tension with temperature. At 0.0202ppm brine concentration, the interfacial tension increased from 4.2 at 29 ^0C to 8.3 dynes/cm at 80 ^0C. The sample also showed decrease in interfacial tension with increase in brine salinity.

Table 1: Average Properties of Sample Crude oils

OIL SAMPLES	API	DENSITY (g/cm^3)	VISCOSITY (cp)	SPECIFIC GRAVITY	*pH*	Classification
A	21	0.9275	49.0	0.9276	6.5	Heavy
B	39	0.8316	2.5	0.8317	5.2	Light
C	29	0.8796	6.5	0.8798	6.2	Medium
D	34	0.8556	6.0	0.8557	7.5	Medium
E	15	0.9634	50.5	0.9635	7.6	Heavy
F	32	0.8675	4.0	0.8676	7.4	AGO

Samples A, C, D and E gave decreasing interfacial tension with increasing temperature. This is consistent with the work of Taha Oshaka and Al- Shiwaish [7], on the effect of brine salinity on interfacial tension in a Saudi Arabian reservoir. It should be observed however, that the decrease was more pronounced in the heavy crudes A and E. On the other hand, Sample F, which is AGO (diesel), showed an increase in interfacial tension with temperature and an inconsistent decrease in interfacial tension with increasing brine concentration. This agrees with the observation by Princen et al [8], that interfacial tension of modern day engine oils does not follow the same pattern as in natural crude because they often contain additives which could distort their properties.

The generalized model that relates interfacial tension of oil-brine systems with temperature, salinity and oil viscosity is given by equation (1):

$$Y = a + bX_1 + cX_2 + cX_3 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Where,

Y = Interfacial Tension, Dynes/cm
X_1 = Temperature (^oC)
X_2 = Salt concentration (ppm)
X_3 = Viscosity (cp)
a, b, c, and d are empirical constants obtained using response surface methodology and listed in Table 2

Table 2: Empirical Constants

Oil Sample	A	b	C	d
A	3.5040	-0.0170	-14.4896	0.0429
B	3.6626	0.0506	-39.4118	0.0058
C	11.4459	-0.0489	5.9472	0.1585
D	11.1350	-0.0166	-1.1300	0.5800
E	24.2263	-0.0647	-58.6613	0.4100
F (AGO)	20.3605	-83.9374	0.3042	0.0763

The R^2 and P-values obtained are given in Table 3. These values show that in the heavy crudes (samples A and E), all the regressor variables considered were insignificant indicating that they all contributed to the interfacial tension response. It can therefore be strongly concluded that interfacial tension of heavy crudes depend on temperature, salt concentration and viscosity.
For the Medium crudes (samples C and D), there was a greater variability in both correlation coefficients and P-values as shown in Table 3. Temperature did not contribute significantly ($P > 0.05$) to the interfacial tension of Sample D. Also, it can be observed that sample C gave a rather low R^2 (0.38) and significant values ($P > 0.05$) for all variables. It can be concluded that Sample C is either contaminated or its interfacial tension depended on other variables not fully captured in this work. It can therefore be concluded that the contributing factors to interfacial tension response in medium crude systems is yet to be fully determined.

For the light crude system (Sample B), temperature and salinity related significantly ($R^2 = 0.91$ and $P < 0.05$) with interfacial tension. However, viscosity did not contribute to the interfacial tension response.

A close study of equation (1) and the empirical constants given in Table 2 confirms all the above observations. Table 2 shows that in all cases, interfacial tension increases with viscosity, with the minimum effects observed in light crude systems.

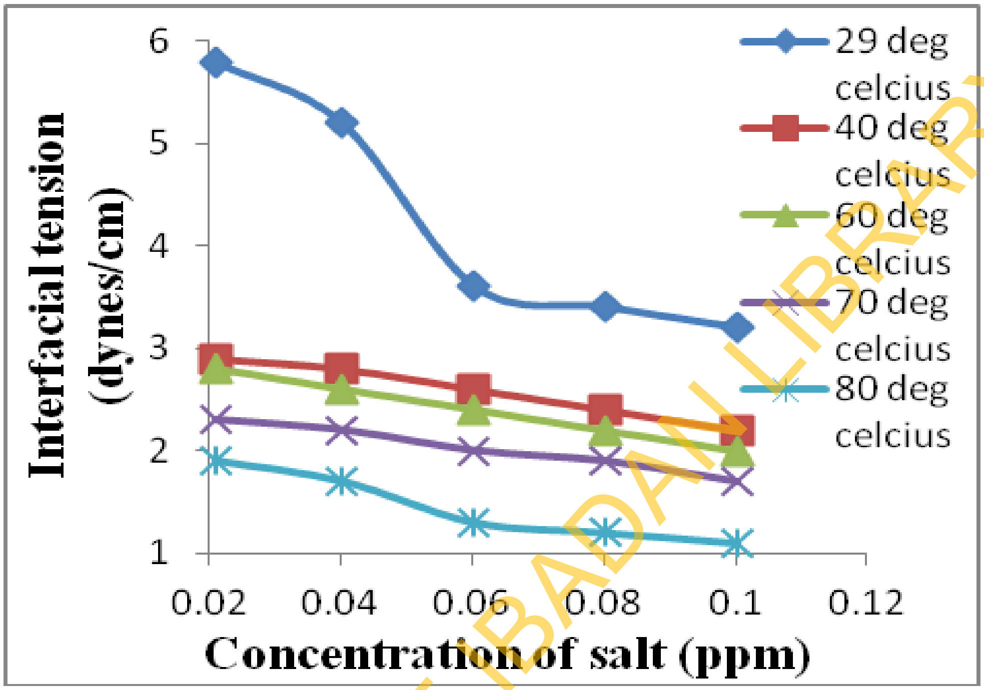

Figure 1: Effect of Temperature and Salinity on Interfacial Tension For Sample A

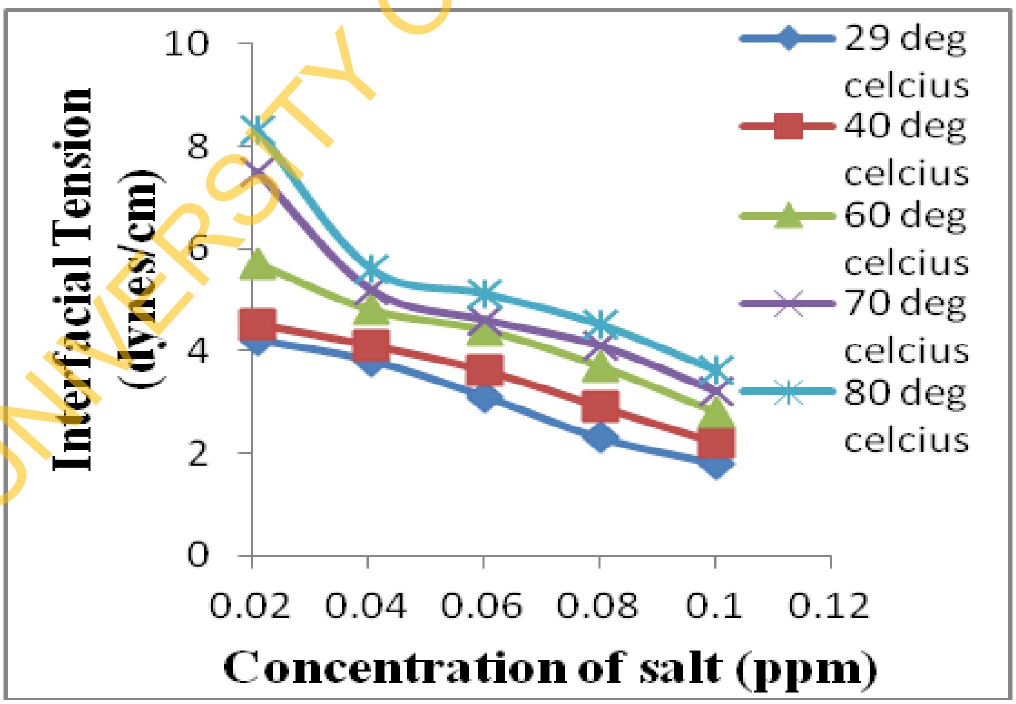

Figure 2: Effect of Temperature and Salinity on Interfacial Tension For Sample B

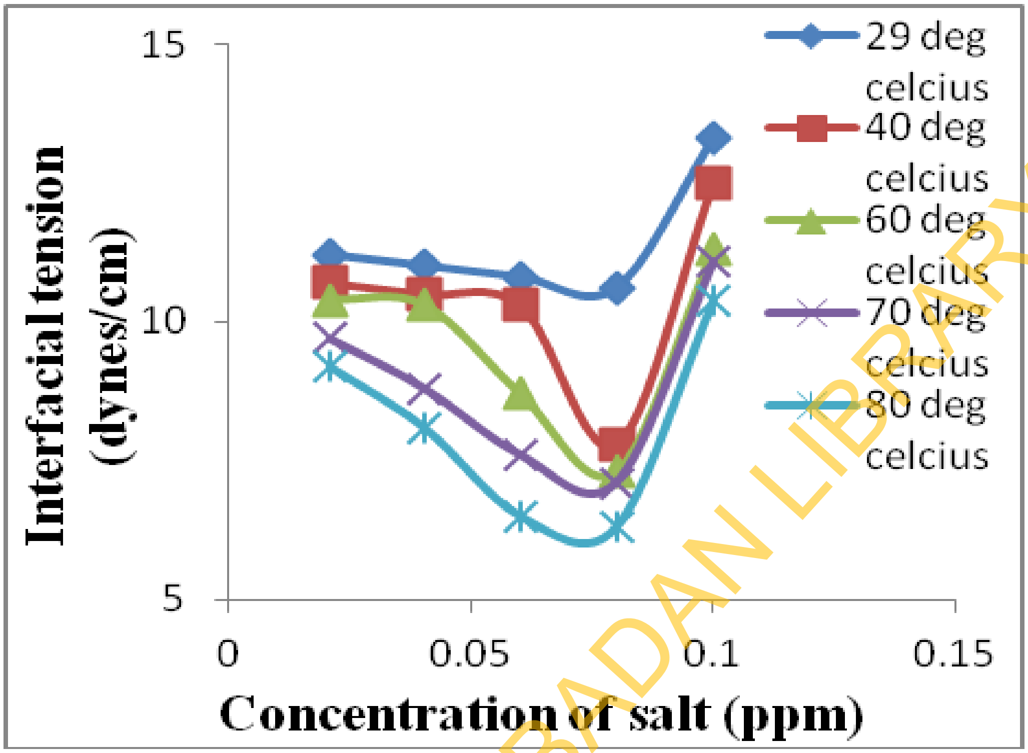

Figure 3: Effect of Temperature and Salinity on Interfacial Tension For Sample C

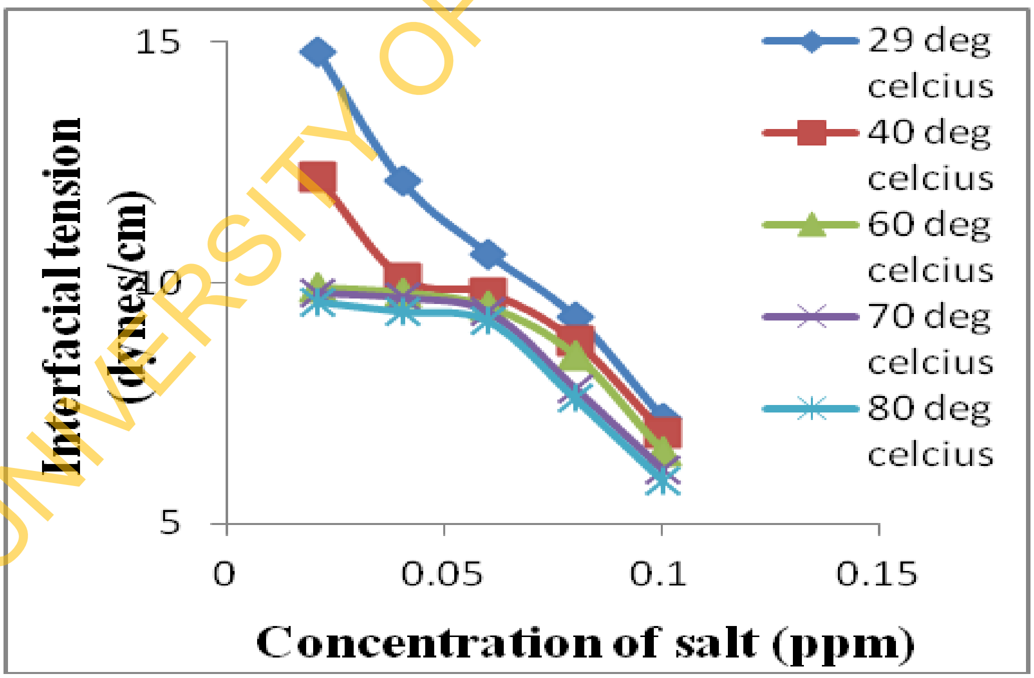

Figure 4: Effect of Temperature and Salinity on Interfacial Tension For Sample D

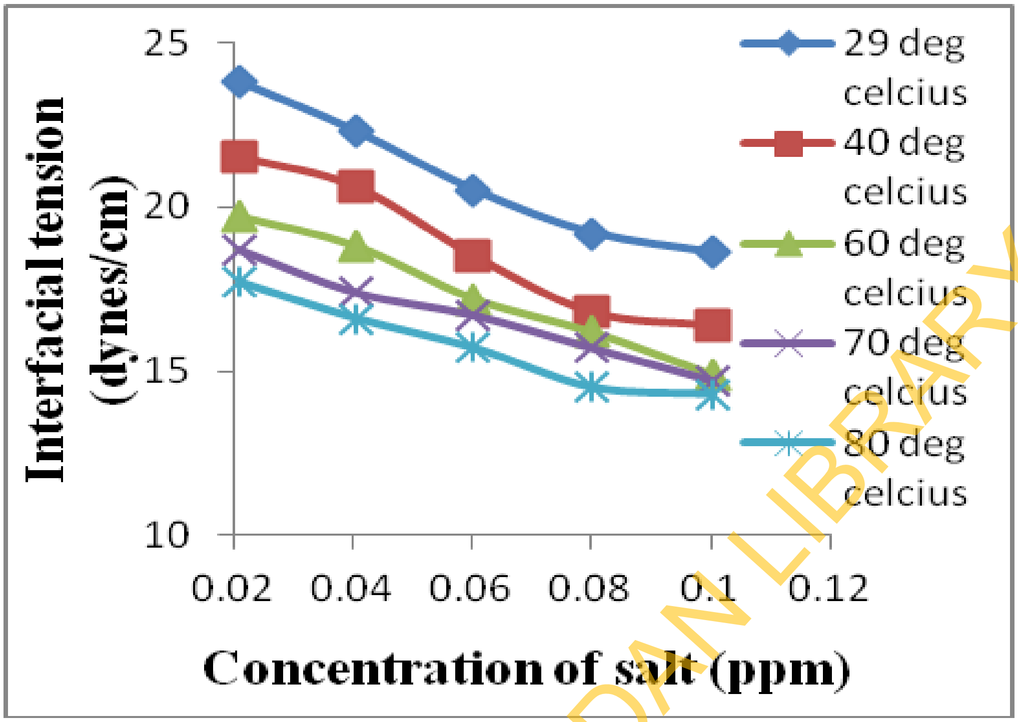

Figure 5: Effect of Temperature and Salinity on Interfacial Tension For Sample E

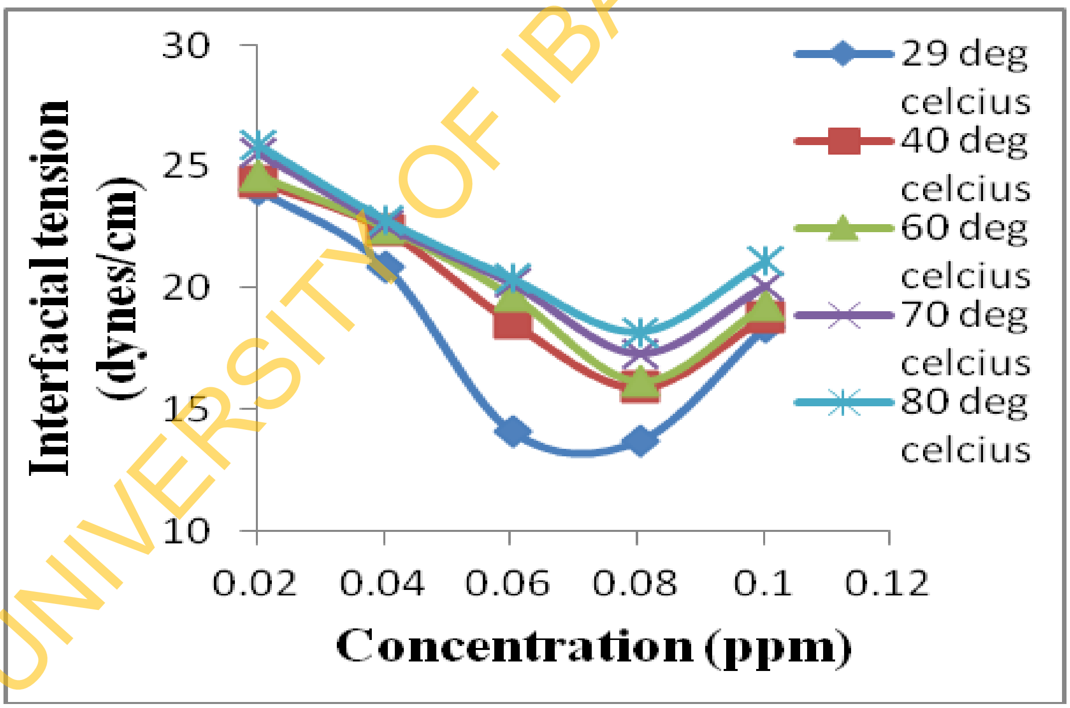

Figure 6: Effect of Temperature and Salinity on Interfacial Tension OF Diesel (Sample F)

Table 3: Correlation coefficient and P-values of Interfacial Tension Predictive models

Sample	Model Parameters	P-Value	Correlation coefficient (R^2)
A	Intercept	0.0000	0.8803
	X1	0.0458	
	X2	0.0001	
	X3	0.0004	
B	Intercept	0.0001	0.9135
	X1	0.0000	
	X2	0.0000	
	X3	0.6306	
C	Intercept	0.0074	0.3849
	X1	0.1582	
	X2	0.5872	
	X3	0.7717	
D	Intercept	0.0000	0.8642
	X1	0.4793	
	X2	0.0000	
	X3	0.1395	
E	Intercept	0.0000	0.972
	X1	0.0000	
	X2	0.0000	
	X3	0.0004	
F	Intercept	0.0808	0.6264
	X1	0.0000	
	X2	0.8795	
	X3	0.4969	

4. CONCLUSION

Based on this study of interfacial tension in oil-brine systems in the Niger Delta, the following conclusion can be reached:

1) Temperature, brine salinity and oil viscosity affect the behaviour of oil-brine systems. The relationship is well defined in heavy oil and light oil systems, but not very conclusive in medium oil-brine systems
2) Interfacial tension increases with increasing temperature in light oil-brine systems but decrease with increasing temperature in heavy crude-brine systems.
3) Interfacial tension is inversely correlated with salinity at specific temperatures for oil-brine systems.
4) Refined products like automotive gas oil may not exhibit the same behaviour pattern of interfacial tension like natural crude because of the presence of additives.

5. REFERENCES

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