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Original Research Article

Demulsification of Escravos Crude Oil using Locally Sourced Natural Coagulants

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ABSTRACT

Crude oil prior to refining is always associated with water-in-oil emulsion (w/o) and based on stringent specifications (technical, operation, environmental, etc.,), a demulsifier is necessary to break and remove it to a tolerable limit. This research was carried out to investigate the use of natural coagulants (Moringa oleifera and Bentonite Clay) for demulsifying Escravos crude oil. A sample of the virgin crude was obtained from Kaduna Refining and Petrochemical company Ltd (KRPC), Kaduna, Nigeria. It was subjected to salt in crude oil analysis for its initial salt content which was found to be 3.7 pounds per thousand barrels (PTB). Using some standard procedures for demulsification, the sample was diluted with fresh water in ratio 4:1 and divided into five equal portions (500 ml). Moringa oleifera seed powder obtained from Rafin Yashi Village, Zaria, Kaduna State was added (0.002 g/ml to 0.01 g/ml) to the portions and heated to 50 ^oC, 70 ^oC, 90 ^oC and 120 ^oC. The solutions were stirred at 120 rpm for 90 minutes, allowed to settle for 10 minutes and then decanted for final salt content analysis. The same experimental procedure was repeated for Bentonite Clay obtained from Maiduwa, Yobe State, Nigeria. The results obtained showed that the highest percentage salt removal was found to be 83.78% and 62.78 % corresponding to 0.01 g/ml demulsifier concentration at 120 ^oC for the Moringa oleifera and Bentonite Clay respectively. Therefore, the two coagulants are employable as demulsifier in petroleum refining industries.

1. INTRODUCTION

Crude oil contains water and inorganic compounds such as salts, metals and other sediments. These substances can cause fouling, corrosion, and increase transportation/energy costs and catalyst deactivation during refining (Issaka *et al*., 2015). Petroleum processing actually commences shortly after the production of fluids from the reservoir, when pretreatment operations are applied to the crude oil prior to transportation. Any crude oil to be shipped by pipeline, or by any other form of transportation, must meet strict regulations with regards to water and salt content (Balsamo *et al*., 2017).

This necessitates the idea of desalting/dehydration system which is the process of removing water-soluble salts from an oil stream initially at the production field and thereafter at the refinery site for additional crude oil cleanup, where the salt and water content specifications are even more rigid because of the aforementioned negative effects in the downstream processes (Ekott and Akpabio, 2010). Preliminary emulsion treatment involves adding fresh and/or recycled water at high temperature and pressure where the incoming crude oil is passed through a series of heat exchangers until its temperature reaches between 115 and 150 °C (Al -Otaibi *et al*., 2003). With the increasing regulations on effluent water and the ever-increasing cost of producing a barrel of oil, the use of emulsion-treatment plants has become an important practice in crude oil processing (Hajivand and Vaziri, 2015). Treatment of emulsions has always ranged from simple methods such as gravity settlement to highly sophisticated methods such as tri-volted scale within heat-exchange equipment (Alfa, 2000).

Desalting/dehydration involves mixing heated crude oil with washing water, using a mixing valve or static mixers to ensure a proper contact between the crude oil and the water, and then passing it to a separating vessel, where a proper separation between the aqueous and organic phases is achieved. The operation cycles involved is as shown in Figure 1.

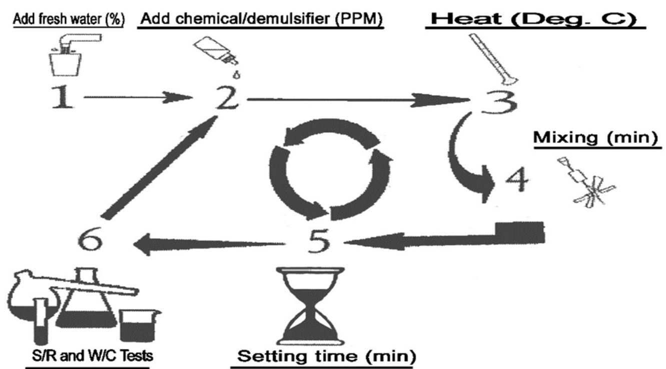

Figure 1: Simplified experimental procedure for crude oil desalting process (Al-Otaibi *et al*., 2003)

Since emulsions can be formed in this process, there is a risk of water carryover in the organic phase. In order to overcome this problem chemical demulsifiers are added to promote the emulsion breaking. When this operation is performed at a refinery, an electric field across the settling vessel is applied to coalesce the polar salty water droplets, and, therefore, a decrease in water and salt content is achieved (Abdurahman *et al*., 2007).

The main objective of a desalting plant is to break the films surrounding the small water droplets, coalescing. The most important variables affecting desalting performance that have been identified and studied include settling time, types and amount of chemical demulsifier injection, heat, adding freshwater, mixing (emulsion, chemical, and the freshwater) and electricity (Hajivand and Vaziri, 2015). Noticing that these are the variables that affect the desalting process, and especially the amount of chemical demulsifiers used, it is therefore important to investigate alternative sources in order to reduce the cost and as well the environmental impact that mineral demulsifier can cause (Falode and Aduroja, 2015). In some similar context *Moringa oleifera* has been reported as organic material that can be used to purify water (Jesse and Sidney, 1984)

Therefore, the aim of this research is to study the demulsifying of Escravos crude by employing some natural coagulants like *Moringa oleifera* and bentonite clay.

2. MATERIALS AND METHODS

2.1. Materials

Materials and instruments that were used during the work are Escravos crude oil, *Moringa oleifera*, bentonite clay, reagents of analytical grades like methanol and xylene as well as distilled water. The major sets of instruments that were employed included measuring cylinder (0 -200 ml), beakers (0 – 500 ml), Water bath (SetA kv-8) for the temperature control of the samples and the controls, Viscometer (84000-0 P) for the viscosities measurement, Jar test machine (Stanhope-SETA UK, 90000–3) for stirring the emulsified samples and Salt-in-crude analyzer oil (Normalab NSB210) for establishing the initial and final salt contents of the crude oil.

2.2. Methods

2.2.1. Salt-in-crude oil analysis

Virgin Escravos crude oil was obtained from the Fuels Laboratory Unit of Kaduna Refining and Petrochemical Company Ltd, (KRPC), Kaduna, Nigeria. Using KRPC Manual (1986) procedure, 10 ml of liquid paraffin was poured into a measuring cylinder, followed by 40 ml of xylene to make 50 ml solution and the mixture was shaken thoroughly for one minute. A quantity of methanol (50 ml) was added to make 100 ml solution and then shaken for thirty seconds. The mixture was allowed to settle for five minutes and the salt-in-crude analyzer was put on and set at 1.00 mA and 125 V. The solution was poured into a beaker, placed on the machine and firmly covered with the cap attached. The nob was pressed to display the readings which was recorded as the blank test reading. The same procedural steps were employed for the sample. The blank reading was subtracted from the sample reading and the difference was multiplied by ten to obtain the correct reading in pounds per thousand barrels (PTB).

2.2.2. Desalting procedure

The Al-Otaibi *et al.* (2003) procedure was employed in the desalting process. As shown in the Figure 1, 100 ml of crude oil sample was mixed with 400 ml of fresh water of which 10 separate portions of 500 ml were prepared. *Moringa oleifera* seed powder (0.002 g/ml to 0.01 g/ml) was added to the 5 portions respectively, then mixed thoroughly and heated up to 50 ºC using water bath. The samples were placed on jar testing machine inside beakers and then the stirrers were lowered into the beakers. The machine was operated at 120 rpm for 90 minutes. It was put off immediately and the stirrers were removed allowing the samples to settle for 10 minutes. The crude oil samples were decanted leaving behind the water and the powder at the bottom of the beakers. Same procedure was carried out on the other four portions using 0.002 g/ml, 0.004 g/ml, 0.006 g/ml, 0.008 g/ml and 0.01 g/ml of bentonite clay. All the 10 samples were taken to the Fuels Laboratory Unit of KRPC, Kaduna, Nigeria to analyse their final salt contents. The results obtained were recorded and tabulated in pounds per thousand barrels (PTB). All the above procedures were repeated at 70 ºC, 90 ºC and 120 ºC keeping all the other parameters constant.

3. RESULTS AND DISCUSSION

Table 1 highlights the properties of the Escravos crude oil that was employed in this work. From Table 1, it can be seen that actually the initial salt content of the crude oil which is of paramount interest to us is 3.7 PTB. This concentration is too high for equipment handling in any process line and usually the recommended specification is 0.5 to 1.0 PTB (Abdurahman et al., 2007). This clearly depict that there is the need to demulsify Escravos crude oil before its processing. Of importance too is the specific gravity and viscosity of the crude which is considered to be medium. It is highly recommended that polymeric materials like plant extracts could effectively demulsify the crude (Falode and Aduroja, 2015).

Table 1: Properties of the crude oil sample

Properties	Description
Name of the crude oil	Escravos, Warri, Nigeria
Initial salt content, PTB (ppm)	3.70 (10.57)
API gravity @ 15/15 ºC	34.2
Specific gravity @ 20 ºC (g/cm^3)	0.86
Viscosity @ 40 ºC (cSt)	4.19
Viscosity @ 50 ºC (cSt)	3.92
Sulphur content (wt %)	0.17 (sweet crude)
Pour point (ºC)	-3
Characterisation factor (K)	11.74
Asphalthene content (wt %)	0.03

Figures 2 and 3 are the profiles of the final salt concentrations using the two demulsifiers. From Figure 2, it is clearly seen that by keeping the temperature constant, the concentration of the demulsifier had played a significant role in the trend of arrival at the final salt content. In any case, the higher the concentration of the demulsifier, the lower the final salt content of the crude and this is quite in agreement with the work of Yasakov *et al*. (2010) who used commercial demulsifier coded RS-N and a developed one. This is because higher concentrations of demulsifier increase the rate of coalescence of droplets due to interfacial film thinning (Al-Otaibi *et al.*, 2003; Hajivand and Vaziri, 2015). Relating this to industrial practice, a user can choose a demulsifier dosage that places emphasis on higher cost of demulsifier but lower equipment capacity or lower cost of demulsifier, but higher investment in the capacity of the equipment. Equally of importance is that there is virtually no difference between demulsifying carried out at 90 ºC and that of 120 ºC. The implication is that in the refinery, demulsifying operation is usually carried out at about 120 - 150 ºC (KRPC Manual, 1986), but in this case the use of *Moringa oleifera* as demulsifier makes it possible at 90 ºC thereby saving energy cost in the process.

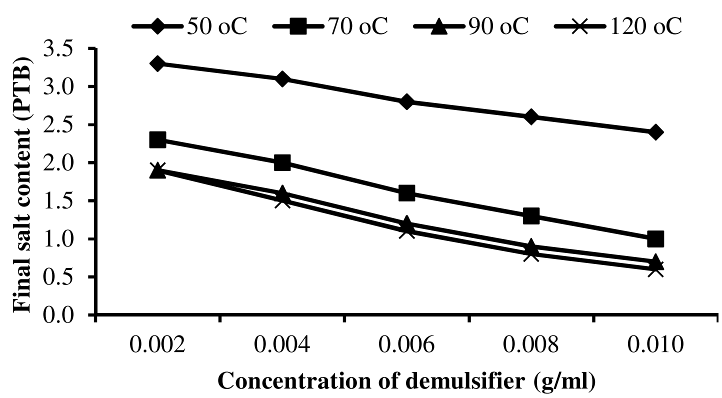

Figure 2: Effect of concentration of *Moringa oleifera* demulsifier on the salt content of the crude at various temperatures

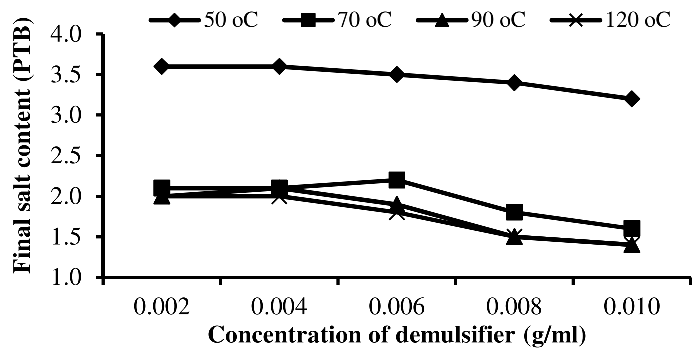

Figure 3: Effect of concentration of bentonite clay demulsifier on the salt content of the crude at various temperatures

It must also be stressed that by specification, the recommended final salt content in crude before atmospheric distillation process should not be more than 1.0 PTB and in this case, this has been achieved at almost 90 °C and of course at 120 °C. It was equally unofficially reported that costly demulsifiers like demtrol, proxamine, dissolvan, proxallite and hydroxylethylated fatty acids are the conventional demulsifiers that are usually employed in the treatment of w/o emulsion in the KRPC, Kaduna, Nigeria and in this case, easily available and cheap *Moringa oleifera* seed powder can be used as replacement.

In Figure 3, the trend of demulsification carried out using *Moringa oleifera* is not that different from that of bentonite clay except that the slope is lower, and hence, the final salt content under the same condition are higher compared with that of the *Moringa oleifera* seed powder. Nevertheless, the higher the concentration of the bentonite clay demulsifier, the lower the final salt content. However, the use of naturally occurring mineral in demulsification is well stressed by Roostaie *et al.* (2017). It is highly hopeful that if a modifier was employed as enhancer in the process, the efficiency would have been probably higher, more so it is non-toxic, non-corrosive, non-hazardous, etc (Roostaie *et al.*, 2017). It is equally of necessity to state that the bentonite had acted as adsorbent because it contained sodium salt (ionic) in its pore hence, had adsorbed the aqueous solution of the salt of w/o emulsion (Amagloh and Benang, 2009).

Still by comparison with Figure 2, especially at the higher concentrations of the demulsifier, the efficiency of the demulsification carried out at 120 °C is not significantly different from that of 90 °C.

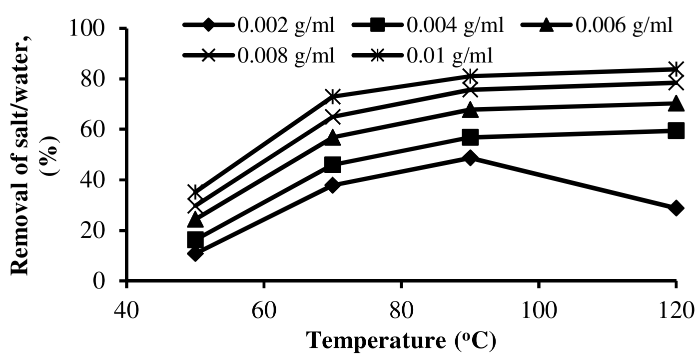

Figure 4: Effect of temperature on the demulsifying of the crude oil at different concentrations of *Moringa oleifera*

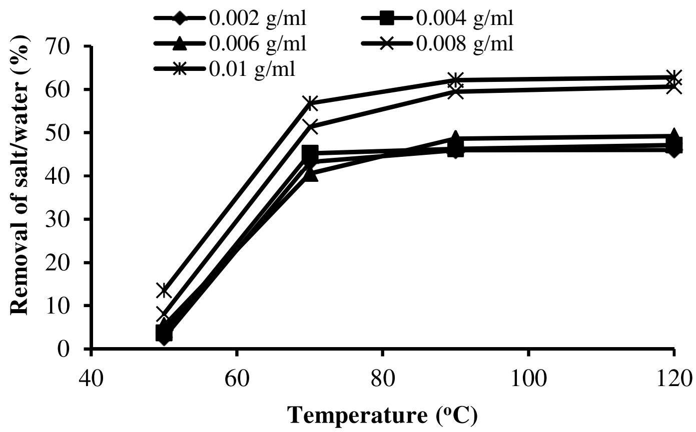

Figure 5: Effect of temperature on the demulsifying of the crude oil at different concentrations of bentonite clay

Figure 4 displays clearly, the effect of temperature on the percentage salt removal. According to the figure the higher the temperature the higher the percentage removal and up to a certain level when plateau rate is maintained. The optimum temperature at which the expected salt removal occurred is between 50-120 °C and this is in conformity with real life refining application and in agreement with Amir and Reza, (2013). This is because desalting practice is majorly carried out at about 120 °C (KRPC Manual, 1986). According to Hajivand and Vaziri (2015), higher temperatures promote destabilisation effects usually caused by Brownian motion and mass transfer across the interface, which is mainly due to the fact that the interfacial viscosity of the internal phase decreases as the temperature increases; as a result, the momentum between the two droplets increases, coalesces, and the two phases of immiscible liquids separate due to their different densities and polarities. It should be noted that excessive heating has a great tendency of rendering the percentage removal independent of temperature and the consequence is the plateau (optimum) and declination (0.002 g/ml of *Moringa oleifera*) rate that sets in after some higher temperatures in the Figure 4 (Al-Otaibi *et al.*, 2003).

The pattern of change of final salt concentrations in Figure 5 is almost of the same profile like that of Figure 4 except that the *Moringa oleifera* has higher efficiency. This is possibly because while clay demulsifies due to action of adsorption capacity, that of *Moringa oleifera* does by action of electrostatic coalescence of the salt solution and water molecules. The use of *Moringa oleifera* in water treatments for removal of salt has been well documented (Amagloh and Benang, 2009), and in this case, it must have acted in the same manner (Jahn, 1988; Abdelaal *et al.*, 2003)

4. CONCLUSION

The salt content of the Escravos crude oil was 3.7 PTB which is too high for refining, hence the need for desalting purpose. It was equally established in the work that the highest percentage of salt removal was found to be 83.78% and 62.78 % corresponding to 0.01 g/ml demulsifier concentration at 120 °C for the *Moringa oleifera* and bentonite clay respectively. *Moringa oleifera* seed powder is more effective than bentonite clay powder in crude oil demulsification. The use of natural coagulant (*Moringa oleifera* seed powder or Bentonite clay powder) in place of chemical demulsifier will save a lot in crude oil demulsification process.

5. ACKNOWLEDGMENT

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6. CONFLICT OF INTEREST

There is no conflict of interest associated with this work.

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