

CRUDE OIL EMULSION TREATMENT THROUGH MICROWAVE HEATING TECHNOLOGY AT DIFFERENT SALINITY LEVELS

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Abstract: Emulsion has been a long-standing challenge in the oil and gas processing in the industry. The water content of the crude oil or gas causes corrosion, sludge and wax formation in the pipeline. These pipeline distribution problems usually lead to the increased cost of processing and distribution. In order to combat this anomaly, different methods have been investigated. Some of which are chemical method, heating, electrical, and microwave technology. Microwave heating has been observed to have had improvement on other methods. However, there are few parameters that affect its performance. These parameters include temperature, dielectric constant, salinity of emulsion, etc. In this study, the microwave technology was investigated in the laboratory to ascertain the impacts of the salt concentration on the separation efficiency of the aforementioned method. The water-in-oil emulsion samples were prepared with the salt concentrations-0ppm, 10000ppm, 15000ppm, 20000ppm, 25000ppm, 30000ppm, 35000ppm and 40000ppm. The time of exposure, average temperatures, pH, volume of water separated were measured while the separation efficiencies at different concentrations were calculated and recorded. The result showed that at zero salt concentration, the separation efficiency was the highest and it began to decrease until zero value for efficiency was obtained, indicating increased concentration salt reduced drastically the separation efficiency of microwave technology. It was also found that there was a rapid increase in the pH from 0ppm to 10ppm, afterwards, slight increase was observed. The microwave technology showed an appreciable distribution of heat within the emulsion samples as the exposure time increased, which was in tandem with previous works. It was found out also that average temperature (From effective heat transfer) varied in accordance with time of exposure of the samples. In conclusion, the study gave a deep insight into effects of salt concentration on the emulsion separation efficiency of microwave technology and pH of the samples being treated.

Index Terms - Emulsion, separation efficiency, microwave technology, concentration, salt concentration, water-in-oil emulsion, temperature.

I. INTRODUCTION

When crude oil is generated, which typically requires water, water-in-oil emulsions are created. A part of this water is often finely dispersed as little droplets throughout the crude oil under production circumstances. Petroleum operators must prevent or disintegrate crude oil emulsions in order to reduce production issues and environmental concerns. Because water and oil are immiscible liquid phases, emulsifying them is typically difficult. Nonetheless, the formation of these emulsions is facilitated by the presence of natural surfactants in the petroleum's composition and the shear mixing that is given to the fluids during production [1][2]. These molecules, which can include thirty or more carbons, are widely thought to represent the most polar and heavy components of petroleum. However, current research indicates that the average molecular weight of asphaltenes recovered using n-heptane is roughly 750 g/mol [3]. Lower amounts (about 400 g/mol) have also been unexpectedly found by researchers [4]. Even though asphaltenes have a specific gravity of almost one and a hydrogen/carbon ratio of 1.15, which is fairly consistent, their makeup in crude oil is still up for debate. Asphaltenes are thought to exist in the oil as a colloidal suspension and to be stabilized by resins adsorbed on their surface [5]. When the resins combine in this way, micelle clusters are formed, which serve as peptizing agents for asphaltenes. These micelles, sometimes referred to as colloids, contain the majority of the polar material present in crude oil and exhibit surface-active characteristics (interfacial active material). They convert sulfur, nitrogen, oxygen, and metal-containing components in asphaltene molecules into polar groups such as amines, amides, carbonyls, carboxylic acids, and aldehydes. These groups are essential to the emulsion's stability. Resins are complex, high molecular weight substances that dissolve in n-heptane but not in ethylacetate. The type of film that forms in crude oil (solid or mobile) appears to be determined by the asphaltene-resin ratio, which is directly related to the emulsion's durability [6]. Emulsions are produced when two immiscible liquids, such as water and oil, are mixed together with the aid of an emulsifying agent. This substance might be a protein, phospholipid, or even a nanoparticle. There are two types of them: oil-in-water (O/W) emulsions, where the continuous phase is water and the dispersed phase is oil, and water-in-oil (W/O) emulsions, where the phases are inverted. The type of emulsion that occurs depends on the emulsifier that is utilized. The hydrophilic-lipophilic balance (HLB) of a surfactant can be used to measure its relative hydrophilicity or lipophilicity. For oil-in-water (O/W) emulsions, emulsifying agents function as hydrophilic, water-soluble surfactants. Conversely, hydrophobic or lipophilic surfactants function as emulsifiers for water-in-oil (W/O) emulsions and are soluble in oil. To maintain the stability of the two phases, emulsions require surface active chemicals. The material's effect on the interface leads to an increase in the kinetic stability of an emulsion. This helps to stabilize the emulsion by maintaining the droplet size over time. Emulsifiers are compounds that typically have a polar or hydrophilic component that dissolves in water and a non-polar or hydrophobic component that is lipophilic or hydrophilic. Emulsifiers dissolve to differing degrees in greasy or watery media.

Bancroft's rule states that emulsifiers and emulsifying particles tend to encourage the dispersion of the phase in which they are less soluble. Oil-in-water emulsions form more readily because proteins are more soluble in water than in oil. This phenomenon is defined by the dispersion of oil droplets throughout a continuous aqueous phase, which is caused by the emulsifying properties of proteins. Oil-in-water emulsions are usually produced by emulsifiers that are more soluble in water, whereas water-in-oil emulsions are usually produced by emulsifiers that are more soluble in oil. Food additives include things like sodium phosphates, sodium stearoyl lactylate, and egg yolk. In the oil and gas sector, emulsion poses a significant problem since it degrades crude quality and raises processing costs either directly or indirectly. When water molecules come into touch with metals, it results in corrosion and other transportation-related problems.

Therefore, the quality of the crude oil produced has a significant impact on processing facilities. One of the biggest problems facing the oil and gas industry is the state of the emulsion in oil well fluid. Emulsion is the term used to describe a dispersion (droplets) of one liquid in another immiscible liquid. The dispersed or interior phase is the one that exists in the form of droplets, whereas the continuous or external phase is the one in which the droplets are suspended. The two liquids that make up produced oilfield emulsions are crude oil and aqueous liquids. The amount of water that emulsifies with crude oil varies greatly from facility to facility. It can be less than 1% at times or more than 80% at others. Emulsions can take many different shapes. These include water in oil emulsions, oil in water emulsions, and a variety of other emulsions. The classification is based on which liquid is the continuous phase. Water is present in the oil emulsion at every stage of the oil production and processing process, including in the reservoir, pipeline, oil wellbore, wellhead, etc. Even though water and oil are incompatible, crude oil emulsion contains incredibly stable water.

II. RESEARCH METHODOLOGY

2.1 Materials

This study employed light crude, heavy crude, Span 80 with HLB of 4.0 and at a concentration of 2.0%, microwave oven model EMO-2305 (900 output power, 23 L capacity), water, salt sample, 500mL glass beaker, aluminum foil, thermocouples, model J-IEC-584-3 (3).

2.2 Method

The method to be adopted for this study is a standard procedure as used by Sweeta, et al, [7].

2.2.1 Preparation of the Emulsion

The water-oil emulsions were created at (20-80) and (40-60) vol.% for both light and heavy crudes, respectively. The emulsions will be formed by dissolving Span 80 in crude oil and shearing violently for 5 minutes. The dispersed phase (water with various salt concentrations: 5g, 10g, 15g, 20g, 25g, 30g, 35g, and 40g) was gradually added to the continuous phase (crude oil) while mixing in a standard three blade propeller and sheared for another 5 minutes at a mixing speed of 2000 rpm at room temperature for each concentration. Then, the test tube method was employed to determine if the emulsion was W/O or O/W. Each emulsion held 300 ml.

2.2 Microwave Heating Demulsification

A domestic microwave oven model EMO-2305 (900 output power, 23 L capacity) will be used for the demulsification process. The freshly prepared W/O emulsion with a volume of 300 mL would be placed in a 500 mL glass beaker. The top and bottom of the beaker would be covered with aluminum foil and placed in the center of the microwave oven. To record the temperature during the microwave heating at three points, three thermocouples, model J-IEC-584-3, will be inserted in the emulsion sample at three different locations; top, middle, and bottom. The thermocouples will be connected to Pico- TC 08, data logger device. The data logger will be connected to a PC with Pico Log software to record the temperature (The microwave heating will be performed using different watts (360-540) W and different microwave processing time (3-5) minutes, with operation frequency at 2450 MHz. and this process will be repeated for the different salt concentration of the dispersed phase (water) to ascertain the effect of salt concentration of the dispersed phase on the separation efficiency (using the change in wavelength due to different salt concentration). The effects of viscosity of the continuous phase (crude oil) will be studied as well. There will be no addition of chemical demulsifier to help discover the performance of microwave heating technology without adding demulsifier.

2.2.3 Separation Efficiency Determination

The separation efficiency was determined using the equation 3.1 in conjunction with the volume of separated water from the experiment conducted.

Separation Efficiency, $E = (\text{Vol of Water Separated (ml)}) / (\text{Total vol at different Salt Conc.}) \times 100\%$

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III. RESULTS AND DISCUSSION

The experiment was carried out following the standard procedure. The results obtained were recorded.

3.1.1 Variation of Average Temperature with Time of Sample Exposure

The change in average temperature of the emulsion samples being microwave-heated as the time of sample exposure increased were shown in Figures 1 – 9

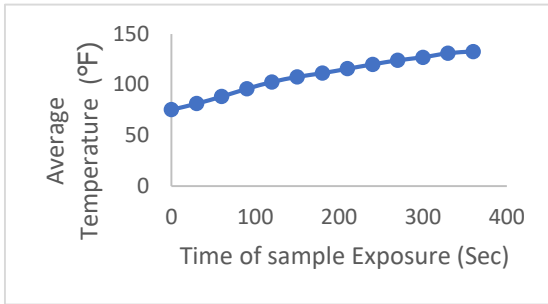


Figure1 Time and Average Temperature for Crude Sample with 0g NaCl

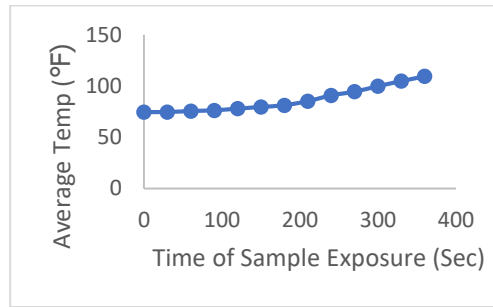


Figure 2Time and Average Temperature for Control Sample Crude Sample with 5g NaCl

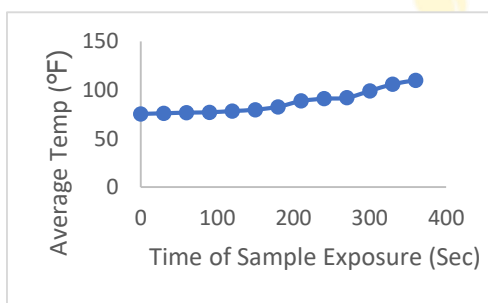


Figure 3 Time and Average Temperature for Crude Sample with 10g NaCl

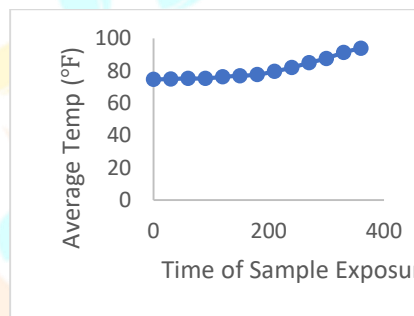


Figure 4 Time and Average Temperature for Crude Sample with 15g

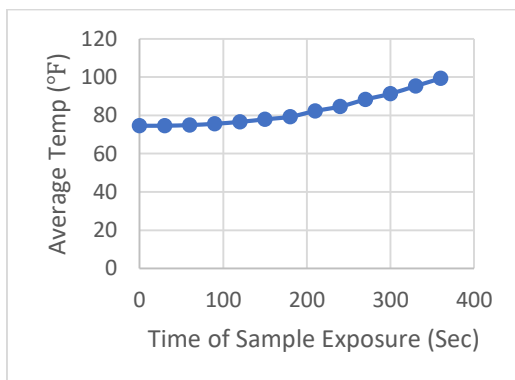


Figure 5 Time and Average Temperature for Crude Sample with 20g NaCl

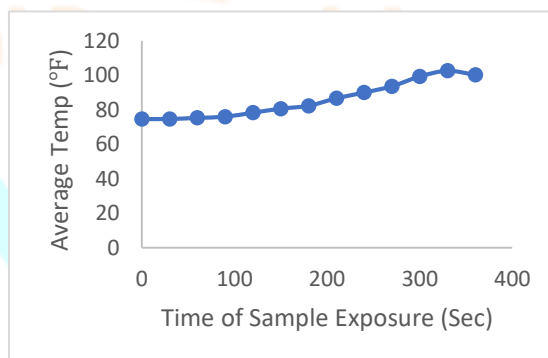


Figure 6 Time and Average Temperature for Crude Sample with 25g NaCl

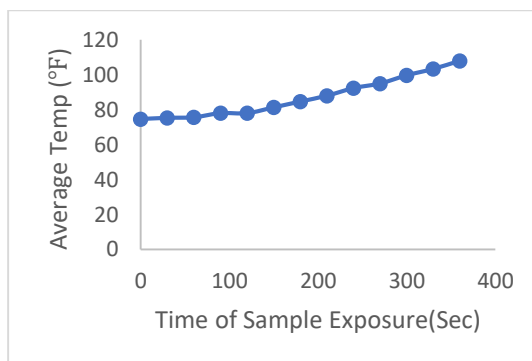
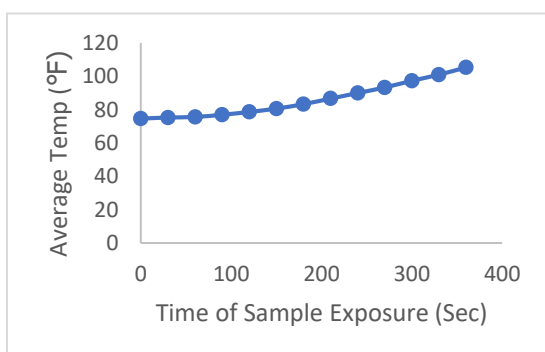


Figure 7 Time and Average Temperature for Crude Sample with 30g

Figure 8 Time and Average Temperature for Crude Sample with 35g NaCl

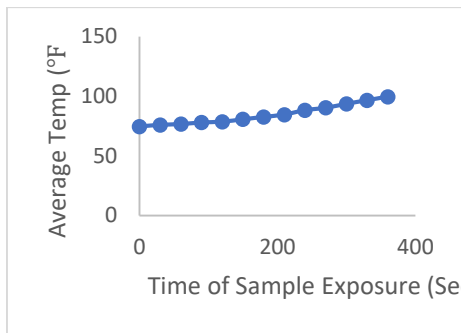


Figure 9 Time and Average Temperature for Crude Sample with 40g

The average temperature is the sum of the temperature values of the sample divided by the total number of temperature point taken. Temperature values taken from different points in the samples being microwaved revealed heat energy distribution in the sample. The result obtained showed there was nearly uniform distribution of heat in the sample. It was observed that there was no much variations in the temperature values obtained from different points in the emulsion sample at any given point in time. This is not the case of the conventional heating where the bottom will have a very high temperature value while the top will have a very low temperature causing pronounced discrepancies in the temperature points of the entire system. The graphical representations of the variation of the temperature with time of sample exposure indicated that there were variations as the time of exposure increased (Figures 1 – 9). For instance, the sample with salinity of zero showed a steady increase in the average temperature of the system as the time of sample exposure increased from 0 to 300 seconds (Figure 2). The change was linear because there was no salt interference in the emulsion sample in question. However, as the salinity level increased, there was a fluctuation in the change in temperature as the exposure time varied. The sample with salinity zero showed steady increase in the average temperature as the time of sample exposure increased from 0 to 300 seconds (Figure 2). However, there was inconsistent increase in the average temperature as the salinity level increased. The sample with salinity of 5g had its average temperature increased slightly from 0 – 150 seconds and began to increase sharply afterward until the time of sample exposure reached 300 seconds (Figure 2). There was also non-consistent change in average temperature from as the salinity increased from 15g to 40g (Figures 4 – 9). The variations could be traced as the influence of salinity of the microwave heating process. The result indicated that salt concentration in emulsion samples has a way altering the separation efficiency. Uniform heating ensuring high separation efficiency. So, if there is no uniformity in the heating of the sample, there will be inefficient separation. The results from this study clearly indicated that microwave method reduced drastically the impact of salinity in the water-in-oil emulsion as there was an observed slight change in the

3.1.2 Variation of pH with Emulsion Salinity

The relation between the change in salinity and pH is shown in the figure 4.10, revealing how change in the salt concentration of the w/o emulsion brought about change in the pH.

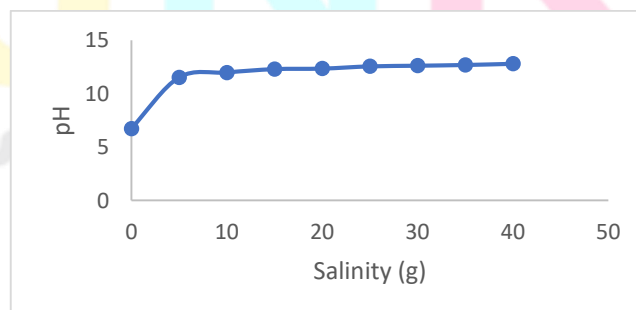


Figure 10 Variation of pH at Different Salinity Levels

The pH of water-in-oil varies depending on the formation from which it is production. It has the potential to affect the separation efficiency. The results obtained from the study (Figure 10) showed that as the salinity increased, the pH increased proportionately to some salinity point (10g/litre of crude sample) and started increasing slightly. It depends on the salt that is present in the emulsion. If it is acidic salt, it will reduce the pH values. The salt present in the emulsion sample used was basic salt that was why the salinity increased as the salinity increased.

Tambe and Sharma [10] investigated the impact of inorganic salts, such as calcium and sodium chlorides, on the stability of emulsions at specific pH levels. It appears that the stability of emulsions is negatively impacted by the presence of salt and decreases with increasing pH. They came to the conclusion that when pH rose, the stability of the oil-in-water emulsion decreased in favour of the comparatively more stable water-in-oil emulsion.

3.2 Relationship Between the Salinity and volume of Water Separated during Microwave Separation of Water/Oil Emulsion.

The volume separated at different concentrations of salt in the emulsion were presented in figure 4.11, showcasing the relationship between the volume separated and the salinity level.

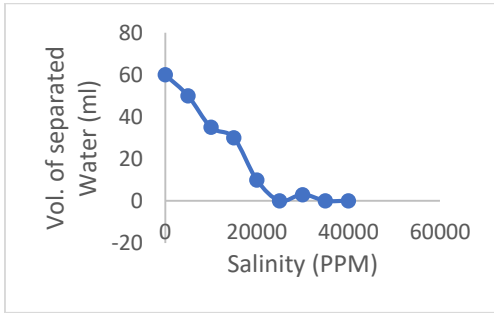


Figure 11 Variation of Vol of Water Separated at Varying Salt Conc

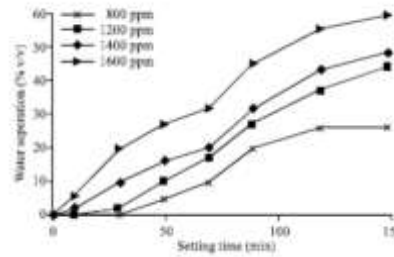


Figure 12 Volume of Water Separated at Different Salinity Levels [8]

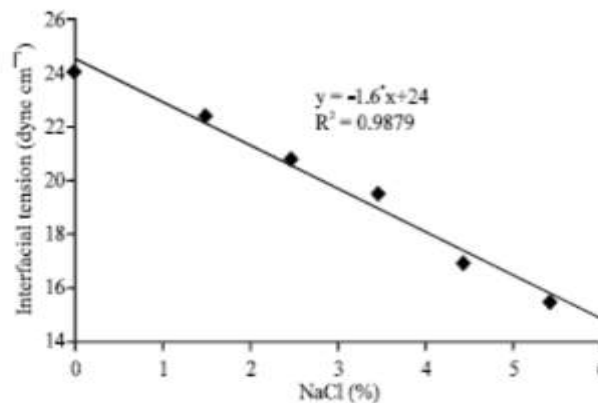


Figure 13 The Interfacial Tension of Crude oil at Different Salinities [8]

The volume of water separated shows the efficiency of the separation. If the volume is little, it could be an indication that some water molecules were left in the crude, indicating that the separation is not good. The result of the study showed that at zero salinity, the separation was very efficient as the volume separated was 60ml (Figure 11). The results obtained by Abdurahman and Rosli [8] in Figure 12 clearly showed that as the salinity increased, the amount of water separated increased. In fact, at 800ppm which was the lowest concentration, the volume of the separated water became the lowest [8]. The was also observed that due to the impact of salinity on the separation, the interfacial tension between the oil and water molecules was weakened making it possible for the water to easily separate within the separation time of 150 minutes (Figure 13). This was to confirm the findings from the study that separation of the water molecules was greatly influenced by the salinity lives. The efficiency of the separation drastically as the water salinity increased from 5000ppm to 45000ppm. In fact, there was no more separation as some salinity points such as 35000ppm – 40000ppm (Figure 11). This was as a result of the effect of salinity on temperature. High salinity usually has an inverse relationship with temperature. And temperature in turn affect the viscosity and the intra and intermolecular forces in the sample. Separation may not be efficient the heat is not uniformly distributed in the sample. The study showed the efficiency of microwave heating method of emulsion separation. The results were in tandem with some finding by previous researchers. For instance, increase in water salinity brings about a decrease in hydrophilicity of a surfactant ie there attraction to water molecules reduces. This is as a result of changing the value of Hydrophilic-lipophilic deviation (HLD) from negative to zero. On the contrary, adding up to the aqueous phase [11], and by so doing enhancing the optimum performance of demulsifier in separating oil from water in oil/water emulsion [12]. The reverse is the case of water/oil emulsion where increasing salinity of the water/oil emulsion help to produce stable emulsion. According to research by [13], w/o droplets shrink in size whereas o/w droplets get larger and solubilize more oil as the salt concentration rises. The monolayer that is forced to lie at the flat interface has a favoured tendency to curve and raise

tension both at low and high salt concentrations. The flat monolayer exhibits little propensity to curve, hence the tension is lowest at intermediate concentrations.

3.3 Separation Efficiency and Salinity

Figure 4.14 showed how the concentration of salinity in the water/oil emulsion affect separation efficiency.

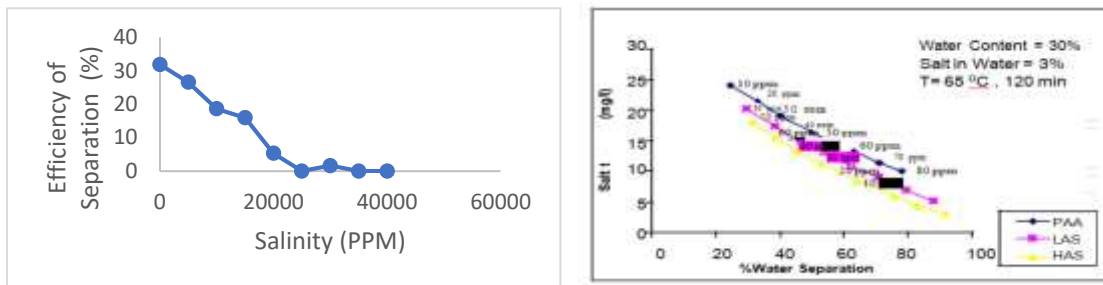


Figure 14 Separation Efficiency and salinity level. Figure 15 Salt Concentration Versus Separation Efficiency of W/O Emulsion [9]

The results obtained on the efficiency of the microwave method should that the increase in the concentration of the salt brought about a decrease in the separation efficiency (Figure 14). The efficiency of separation was observed to reduce as the concentration was increased, which was also seen in the volume of water separated (Figure 11). The efficiency is a function of volume of water separated.

Furthermore, this result was in tandem with findings of some researchers. For instance, it was seen in the work done by Igwilo, et al., [9] using different chemical demulsifiers which included Heavy Alkyl Benzene Sulfonated (HAS), Linear Alkyl Benzene Sulfonated (LAS) and Peroxyacetic acid (PAA) that as the concentration of salt increased, the percentage volume of water separated (Separation Efficiency) decreased drastically with the separation time of 120 minutes (Figure 15). According to Masoud, et al., [14], salts with higher positive charge density, such as $MgCl_2$ and $CaCl_2$ can equally significantly reduce the size of emulsion droplets and increase emulsion stability. Moreover, the presence of divalent anions such as sulfate reduces the amount of asphaltene at the interface between oil and water, thereby reducing the stability of the emulsion. In the order of $MgCl_2 > CaCl_2 > Na_2SO_4 > NaCl$, salts decreased the droplet size and increased the emulsion stability. The viscosity of the emulsion also showed a similar trend, as the average particle size decreases, the viscosity of the emulsion increases. Based on the results, the size of the emulsion droplets decreases up to a certain concentration and then increases. Salt-in and salt-out effects are responsible for the reduction and increase in droplet size [14]. From the above, deductions, it was clear that salt concentration has a pronounced effect on the efficiency of the microwave method of emulsion separation.

IV. Conclusion

From the results of the experimental investigation of the effects of salts on the performance of the microwave method of separating water-in-oil emulsion, conclusions drawn from the discussion of the results were as follows:

- i) Zero salt concentration showed appreciable separation efficiency (31%) of w/o emulsion, indicating that high salinity inhibits water separation from w/o emulsion using microwaving technology.
- ii) The volume of the water separated as the salinity decreased sharply and got to a zero-point ie a point where there was no water separated as a result of high salinity.
- iii) Variation of the salt concentration altered the even distribution of heat in the entire system.
- iv) The increase in the salt concentration brought about a sharp increase in the pH of the emulsion to 10000 ppm and subsequent increase slightly raised the pH.
- v) Microwave method of emulsion treatment was effective because there was some level even distribution going by the temperature results obtained at three different points in the samples.
- vi) It was found out also that average temperature (From effective heat transfer) varied in accordance with time of expose of the samples. Hence, the effective heat transfer brought about the separation of water molecules from oil molecule because the adhesive force was less than the cohesive force as a result of the microwave treatment.

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