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Enhancing the Productivity of Oredo Field using Microbes and Combination of Zinc Oxide and Calcium Oxide Nanoparticles.

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ABSTRACT

Microbial enhanced oil recovery (MEOR) is receiving renewed interest worldwide in recent years as a viable method in producing entrapped oil in the reservoirs at the end of primary recovery. Many laboratory works have been done on MEOR which shows success, and field trials also carried out in stripper wells and has showed success. This study describes MEOR experiment, done in the laboratory using zinc oxide (ZnO) and calcium oxide (CaO) and in combination of both nanoparticles to ascertain the extent to which it can increase production of oil in depleted reservoirs. Three litres of crude oil and seven litres of water where mixed together and later 20ml, 40ml and 60ml of bacteria were added with 5g, 10g and 15g of zinc oxide (ZnO) and Calcium oxide (CaO) nanoparticles. The nanoparticles were combined and all pumped at 2bars in an enhanced oil recovery system set up. The result shows that 97% was recovered on 60ml of bacteria using calcium oxide, 93% for zinc oxide and 95% combination of calcium and zinc oxide nanoparticles. The result reveals that 40ml of bacteria oil percentage recovered was 87% for calcium oxide, 83% for zinc oxide and 84% in combination of both calcium oxide and zinc oxide. Also, for 20ml of bacteria, 80% oil was recovered using calcium oxide, 54% zinc oxide and 61% on combination of nanoparticle. The use of nanoparticles, Nano fluids and nanotechnology is a new advances in the Energy industry as a whole, they will rapidly increase the recovery of oil if put into practice in the industry to speed up reaction and subsequently production.

Keywords: MEOR, Nanoparticles, Crude Oil, Enhancing, Zinc/Calcium Oxides and Oredo Field.

1 INTRODUCTION

The demand for energy in recent years is onwardly increasing. In order to make available enough gas and oil for people's consumption and for industries more production is required from conventional and non-conventional resources. These demands can be met by exploring new hydrocarbon fields and drilling wells, also by improving the production of the current producing fields. However, most of the easily accessible reservoirs have been explored and drilled, leaving the heavy oil trapped in the reservoir. Since the oil left in the reservoir is not producing economically, Petroleum Engineers has focus on improving productions from current fields by different EOR methods.

One of the method is water flooding which helps to provide additional flooding capable of producing additional portions of initial oil in place by injecting water into the reservoir and pushing oil towards producing wells. After water breakthrough, this method is not economical

anymore, therefore tertiary methods are used to produce the other portion of trapped oil by changing rock and fluid properties. Scientists and researchers have introduced several new methods for EOR that can improve oil recovery significantly. Currently surfactant and CO_2 flooding are the most common EOR methods which are used in upstream oil industry.

Another EOR method is the Microbial Enhanced Oil Recovery method although still under scrutiny. MEOR is a biological based technology consisting in manipulating function of structure both of microbial environment existing in oil reservoir. According to Diposkan (2018), the ultimate aim of MEOR is to improve the recovery of oil entrapped in porous media while increasing economic profits. MEOR is a tertiary oil extraction technology allowing the partial recovery of the uncommonly residual two thirds of oil, thus extending the life of mature oil reservoirs.

Microbial Enhance Oil Recovery works by modifying the interfacial properties of the system oil - water minerals, with the aim of facilitating oil movement through porous media. In such system microbial activity affects fluidity (viscosity reduction, miscible flooding), displacement efficiency (decrease interfacial tension, increase of permeability), sweep efficiency (mobility control, selective plugging and driving force/ reservoir pressure). More so, MEOR is favoured where layer permeability is greater than 20md, reservoir temperature is inferior to 85°C, salinity is below 100,000ppm and reservoir depth is less than 3500m. The recent cases proved that there is no corrosion during MEOR, based on continuous field monitoring results. In addition, the microbes do not affect crude oil qualities and there is no sign of increasing microbes in the produced liquid. MEOR has several advantages, it is said to be easy to handle in fields and independent of oil price, hence economically attractive, it increases oil production in matured oil fields, with only a slight modification required for compatibility with existing facilities, easy application, it is less expensive set-up, more efficient than other enhanced oil recovery methods in carbonate oil reservoir. This is opposite to the case of other EOR additives in time and distance. In a simple term, MEOR are biodegradable and therefore can be considered environmentally friendly (Said *et al*., 2012).

Nanoparticles on the other hand are tiny particles with less than 100 nanometers dimension (the equivalent of a thousand atoms). Their field application spanning various field such as medicine, electricity, cosmetics or optics, engineering amongst other. Nanoparticles serve various purposes in the hydrocarbon industry amongst which they are utilized to improve the volume of oil and gas produced. In recent time, nanotechnology has attracted much attention for applications in EOR to produce more oil from reservoirs hence it is only pertinent to study the synergistic effect of the simultaneous microbes and nanoparticle effect on the recovery of oil. Numerous studies confirm that both can alter the wettability characteristics of rocks to more water-wet conditions, reduce interfacial tension (IFT), and function effectively in oil recovery. This study aims to utilise the abilities of both product to improve oil recovery either by reducing IFT or decreasing the viscosity of the injected solution. These results are useful in extending the application of nanostructures in MEOR.

1.2 Statement of the Problem

It is a known fact that in practical cases, reservoir pressure as a primary source of reservoir energy for hydrocarbon production would rarely yield a desirable amount of recoverable hydrocarbon during production. At present, primary and secondary oil recovery methods yield production of roughly 15 – 30% of the original oil in place (OOIP), depending on reservoir temperature and pressure, petrophysical properties of the porous media and the type of reservoir fluids. A higher oil recovery of 30 to 60% of OOIP can be obtained through enhanced oil recovery (EOR) processes, (Thomas, 2008), which can be divided into thermal and non-thermal methods (Donaldson *et al.*, 1985; Green and Willhite, 1998; Lake and Venuto, 1990). However, the selection of the most suitable EOR method to adopt for specific field application is challenging. Enhanced oil recovery methods, especially the Microbial Enhanced Oil Recovery (MEOR) application, have gained prominence in recent years and are often applied to depleted reservoirs for enhancing oil and gas production. Recent studies have also indicated key technological advancements in getting the most out of many recovery processes by primarily focusing on the increment of cumulative production and ultimate oil recovery. Nanotechnology has proven to be a useful innovation to industry operators in these technical domains. It is therefore necessary to understand how the application of nanotechnology on a particular field proves useful in hydrocarbon recovery, with the Microbial Enhanced Oil Recovery (MEOR) process as a primary focus. Hence, this laboratory investigation presents a detailed study of the effects of zinc oxide (ZnO), Calcium oxide (CaO), and equal blend of zinc and calcium oxide nanoparticles on the productivity of crude oil from Oredo oilfield during Microbial Enhanced Oil Recovery (MEOR) application.

1.3 Aim of the Study

The aim of this study is to conduct a laboratory investigation to determine the effects of nanoparticles and microbes activities on the productivity of Oredo Oil field.

1.4 Objectives of the Study

The following objectives will be used to achieve the above set aim:

i. To determine the physical properties of crude oil with and without nanoparticles (zinc oxide and calcium oxide).
ii. To compare and analyse the effects of zinc oxide, calcium oxide and an equal combination of zinc and calcium oxide nanoparticles during Microbial Enhanced Oil Recovery (MEOR) application.
iii. To evaluate the percentage of recovery of oil and water when calcium oxide and zinc oxide are added to bacteria.

1.5 Scope of the Study

This is an experimental study where crude oil sample was subjected to different nanoparticles and bacterial concentration to improve production. The results were generated from laboratory test and physical properties of the crude oil such as pour point, viscosity, density and oil volumes were measured.

1.6 Significance of the Study

The significance of the study is as follows:

i. The use of bacteria and nanoparticles in the petroleum industry will be of great help for the recovery of crude oil in the industry only if the idea will be put into consideration and practice.
ii. The use of bacteria and nanoparticles in oil recovery will extend the life of mature wells and also increase profit for the industry.
iii. It will create and increase employment for petroleum engineers.

2 MATERIALS AND METHODS

This Section describes details of the materials used and the experimental procedure followed to investigate the effect of bacteria and nanoparticles (Calcium Oxide and Zinc Oxide) on oil production enhancement. The procedure used to carry out the microbial enhanced oil recovery in the Petroleum Engineering laboratory, Department of Petroleum Engineering involves the procedures to determine the flow property of the crude oil (i.e viscosity, density, API gravity, specific gravity), before and after the application of microbialin addition with nanoparticles (Calcium Oxide and Zinc Oxide) to the crude oil sample, and also include the procedure followed to culture the bacteria for the MEOR process

2.1 Materials

The following materials and equipment were used in this experiment;

i. Crude Oil
ii. Capillary Viscometer
iii. Weighing balance
iv. Thermometer
v. Test jar
vi. Pycnometer
vii. Nanoparticles
viii. Spatula
ix. Separation funnel
x. Clamp
xi. Stirrer
xii. Stop watch
xiii. Ice Bath
xiv. Pressure Cylinder
xv. Enhanced Oil Recovery Laboratory Set Up
xvi. Bacteria

2.2 Methods

2.2.1 Crude Sample Collection and Preparation

The crude oil sample was obtained from Oredo-X Oilfield Edo State

2.2.2 Formulation of Crude oil Sample with Bacteria and Nanoparticle

i. 20ml of Bacteria, 5g, 10g, and 15g and Nanoparticle (ZnO,CaO and ZnO +CaO) was added to Sample A to constitute new crude composition and labeled;
ii. 40ml of Bacteria, 5g, 10g, and 15g and Nanoparticle (ZnO,CaO and ZnO +CaO)was added to Sample A to constitute new crude composition and labeled;
iii. 60ml of Bacteria, 5g, 10g, and 15g and Nanoparticle (ZnO,CaO and ZnO +CaO) was added to Sample A to constitute new crude composition and labelled.

Formulation for 20ml Bacteria

Sample A is crude oil + water (3 litres of crude oil and 7 litres of water)

Sample B is Crude oil (3 litres) + water (7 litres) + Bacteria (0.02 litres)

Sample C is Crude oil (3 litres) + water (7 litres) + Bacteria (0.02 litres) + 5g nanoparticle (Zinc Oxide, Calcium and 2.5g of Zinc Oxide and 2.5g of Calcium Oxide combined)

Sample D is Crude oil (3 litres) + water (7 litres) + Bacteria (0.02 litres) + 10g nanoparticle (Zinc Oxide, Calcium and 5g of Zinc Oxide and 5g of Calcium Oxide combined)

Sample E is Crude oil (3 litres) + water (7 litres) + Bacteria (0.02 litres) + 15g nanoparticle (Zinc Oxide, Calcium and 7.5g of Zinc Oxide and 7.5g of Calcium Oxide combined)

Formulation for 40ml bacteria

Formulation for 40ml Bacteria

Sample A is crude oil + water (3 litres of crude oil and 7 litres of water).

Sample B is Crude oil (3 litres) + water (7 litres) + Bacteria (0.04 litres).

Sample C is Crude oil (3 litres) + water (7 litres) + Bacteria (0.04 litres) + 5g nanoparticle (Zinc Oxide, Calcium and 2.5g of Zinc Oxide and 2.5g of Calcium Oxide combined).

Sample D is Crude oil (3 litres) + water (7 litres) + Bacteria (0.04 litres) + 10g nanoparticle (Zinc Oxide, Calcium and 5g of Zinc Oxide and 5g of Calcium Oxide combined).

Sample E is Crude oil (3 litres) + water (7 litres) + Bacteria (0.04 litres) + 15g nanoparticle (Zinc Oxide, Calcium and 7.5g of Zinc Oxide and 7.5g of Calcium Oxide combined).

Formulation for 60ml Bacteria

Sample A is crude oil + water (3 litres of crude oil and 7 litres of water).

Sample B is Crude oil (3 litres) + water (7 litres) + Bacteria (0.06 litres).

Sample C is Crude oil (3 litres) + water (7 litres) + Bacteria (0.06 litres) + 5g nanoparticle (Zinc Oxide, Calcium and 2.5g of Zinc Oxide and 2.5g of Calcium Oxide combined).

Sample D is Crude oil (3 litres) + water (7 litres) + Bacteria (0.06 litres) + 10g nanoparticle (Zinc Oxide, Calcium and 5g of Zinc Oxide and 5g of Calcium Oxide combined).

Sample E is Crude oil (3 litres) + water (7 litres) + Bacteria (0.06 litres) + 15g nanoparticle (Zinc Oxide, Calcium and 7.5g of Zinc Oxide and 7.5g of Calcium Oxide combined).

2.2.3 Bacteria (Baccilussubtilisspp) Preparation

The bacteria used for this experiment is prepared through the following means:

(a) **Reagents**: The reagents included normal saline for serial dilution process - Ethanol, hydrogen peroxide, Kovacs reagent, crystal violet, phenol red, Tetramethyle-p-phenylendiaminedihydrochloride (TMPD) and biuret reagents, etc.

(b) **Media used for the cultivation of bacillus species**: Nutrient Agar (NA) medium was used to cultivate bacillus on total heterotrophic bacteria (T.H.B) according to manufacturer's specification. The medium is a general purpose media for Bacteria. Two (2) Nutrient broth (NB) for proliferation of bacteria (Bacillus Subtilis).

(c) **Preparation of Bacillus species:** Serial dilution procedure as described by Obire and Wemedo, (1996), Ofunne, (1999), and Csuro, (1999) was employed for the cultivation of known bacteria (Bacillus Subtilis). About 1 gram of soil sample was transferred into 9ml of sterile normal saline, separately to obtain a mixture dilution of 10^1. The mixture was then diluted through a ten-fold serial dilution process to a maximum of 10^{-5}. About 0.1ml of the selected dilution were inoculated separately onto the nutrient Agar plate (NA) in duplicate. The inoculated plates were incubated at 37°C for 24 hours. After incubation period the ensuring colonies suspected to be Bacillus were subculture onto a freshly prepared plates of nutrient Agar to obtain a pure culture. The plate was incubated again at 37°C for 24 hours. The incubated selected colonies of bacteria were later subjected to microscopic examination and biochemical test that proof the real identity of Bacillus species. The test includes catalase test, citrate test, starch hydrolysis, motility test, MRVP test, indole test and sugar fermentation test. The sugars are, glucose, mannitol, lactose, xylose, and maltose. The isolate were further identified based on microscopic morphology and reaction pattern to biochemical and sugar fermentation test.

2.2.4 Proliferation of Bacillus Spp

A code isolate confirmed to be Bacillus species were retrieved from the slant and inoculated in 1 litre of nutrient broth. The inoculated broth were incubated at 37°C for 24 hours within which the broth attained a high level of turbidity.

2.2.5 Procedures for the Determination of Density.

The density of all crude oil samples were measured using the pycnometer method. Firstly the pycnometer was emptied, cleaned and dried properly after which the weight of empty, dry pycnometer was recorded. The pycnometer was then filled with the crude oil and the temperature of the sample was checked. The stopper was placed above the lid and excess liquid on the body of the pycnometer was wiped after which the new weight of the pycnometer containing fluid was recorded.

The density of the liquid was calculated using theequation:

$$Density = \frac{Filled\ \ Pycnometer\ \ - Empty\ \ Pycnometer}{Volume\ \ of\ \ Pycnometer} \quad (2.1)$$

Figure 2.1: Weighing Balance and Pycnometer

2.2.6 Measurement of Viscosity

The viscosity of all formulated samples were measured using a Cannon Fenske Capillary viscometer. First the viscometer was properly cleaned and dried using the drying agent then the viscometer was filled with sample A, the viscometer containing the sample was then clamped and placed in a constant temperature bath. A suction tube was connected to one part of the viscometer so that at the application of pressure, the liquid was raised in the tube to the upper etched line. The time to the liquid to flow freely from the upper etched line to the lower etched line was recorded in seconds. This is the efflux time. Kinematic viscosity was calculated by multiplying the efflux time by the viscometer constant and the dynamic viscosity by multiplying kinematic viscosity by density. That is Oil viscosity can be calculated using the equation below

$$Viscosity = (Ct)\rho \quad (2.2)$$

where:

C = 0.015 t = Time of flow,ρ = Density

These steps were repeated for all the various Samples.

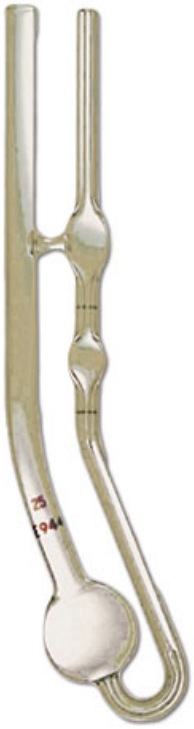


Figure 2.2: Cannon Fenske Capillary Viscometer

2.2.7 Procedures for the Determination of Cloud Point and Pour Point

In determining the cloud point and pour point, an Ice bath was employed. The test jars were labeled properly then filled to the level mark. A closed cork carrying the thermometer was placed over the tube's mouth and the jar was placed in the bath of crushed ice. After a few minutes, the test jar was removed from the jacket quickly without disturbing the specimen to check for cloud point. The jacket was replaced. The process was repeated until the cloud point appeared observation the temperature at that point was recorded as the cloud point temperature. The sample was allowed to remain in bath until it was observed that the oil surface stayed in the vertical position for a period of 5 seconds without sagging. At this point the thermometer was inserted to cool for 10 seconds and the temperature of the oil was taken as the pour point. This procedure was repeated for all remaining samples.

Figure 2.3: Ice Ba

2.2.8 Procedure for the Determination of Flash Point

The method used for the determination of flash point in this work is the Pensky-Martens Closed Cup test which is used for the determination of the flash point of flammable liquids. Before beginning the experiment, the brass test cup was clean and dried. The brass cup was then filled to the marked specified dimension with the sample and the device was assembled properly. The device was connected to electric source to heat and stir the liquid in the cup was put on and at regular interval, direct ignition source was placed in front of the ignition point to check if it will flash, if it does not, the sample was again heated, stirred and checked till it ignites. The lowest temperature at which the crude oil ignited was recorded as the flashpoint of the sample in ^{o}C. The sample was discarded and the brass test cup was cleaned and allowed to dry. The same procedure was used to find the flashpoint of the remaining samples.

Figure 2.4: Pensky-Martens Flash Point Tester

2.2.9 Experimental Procedures for Specific Gravity.

The Specific Gravity of the samples was measured directly from a hydrometer. Using this method, the cylinder was filled with the crude oil and the temperature of the liquid was measured by the thermometer and recorded. The hydrometer was dropped into the sample slowly and carefully away from the wall of the cylinder until a steady floatation in center of the cylinder was observed. After stabilization of the hydrometer, the point was noted where the surface of the liquid touches the stem. This point is the specific gravity of that fluid.

$$\text{API gravity} = \frac{141.5}{S.G} - 131.5 \qquad (2.3)$$

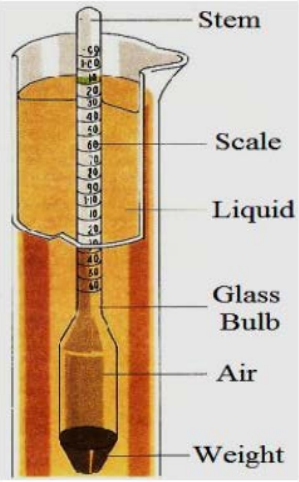


Figure 2.5: Hydrometer

2.2.10 Microbial Enhanced Oil Recovery (MEOR)

The set up used for this is a laboratory set up for enhanced oil recovery (refer to Figure 2.6), the setup is made up of a series of equipment that represents the setup of a well head, the set up makes use of a carbon dioxide cylinder (CO_2) that acts as the reservoir pressure, this cylinder is connected to a 12liter metal tank which stands are the reservoir, a pipe is connected to this tank which along its line comprises of a tap handles (stands at the well head valve) and a pressure gauge used to read the tank outlet pressure (reservoir outlet pressure), a condenser to condense any gas if present then a second tap handle which stands as a valve which leads to the collection container (temporary storage tank).

After checking the properties of the crude oil to be used, 3liters of crude oil and 7liters of water (carrier fluid) was measured and mixed in a bucket to be poured into the tank. The pressure vessels were tightly closed and the tank and the flow line is free from any liquids or dirt. The tank was then filled with the mixture of crude oil and water and allowed to settle. On the start of the stop watch, the pressure valve was relieved at a constant pressure, the tap handles were also opened. At exactly 10 seconds, the pressure valves and the tap handles was returned to a closed position. The volume of the crude oil and water recovered after 10seconds was taken and recorded. After the mixture had settled, the water cut was determined and the amount of water and crude recovered was also determined. A sample of the recovered crude oil was set aside and tested for the physical properties. The mixture containing crude oil and water was returned into the tank and 0.02liter of bacteria was introduced into the mixture and allowed to react for 24hours.After 24hours, the same procedure used for the recovery of crude and water was again carried out. The tank was now filled with crude oil, water, bacteria and 5g of calcium oxide and the above stated procedure was carried out to determine the oil and water recovered. The experiment was repeated for all constitute and analysed properly.

Figure 2.6: Enhanced Oil Recovery Laboratory Set Up

2.3 Chemistry of the Reaction

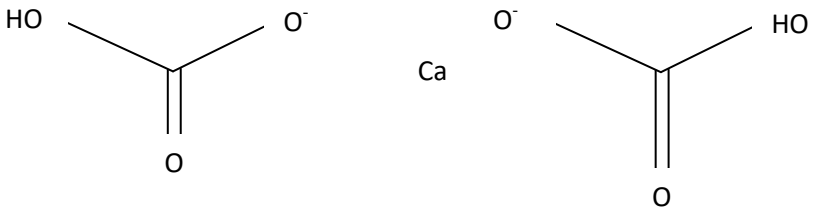
Bacteria + hydrocarbon = Carbon dioxide + Water

Reaction with Nanoparticles

i. Reaction with Calcium Oxide (CaO)

$$2CO_2 + H_2O + CaO \longrightarrow Ca(HCO_3)_2$$

Calcium Hydrogen Carbonate



ii. Reaction with Zinc Oxide (ZnO)

$$ZnO + 4CO_2 + 5H_2O \longrightarrow Zn(C_2H_5)_2 + 7O_2$$

3. RESULTS AND DISCUSSION

The result obtained from the various experiments are presented and analyzed in this Chapter.

3.1 Physical Properties of the Crude Oil

3.1.1 Viscosity

3.1.1.1 Viscosity at 20ml bacteria and Nanoparticle Concentration

The result of the viscosity of the experiment are presented in Table A of the Appendix. From Figure 4.1, point A is the initial viscosity of the crude oil sample, the viscosity was about 2.5cp. At point B (crude oil, water and bacteria), the viscosity of the crude oil increased above that of the crude oil and water. The viscosity further increased at the addition of 5g of Zinc Oxide (sample C) to sample B well above the viscosity of sample A. Then at point D& E, (10g & 15g of Zinc oxide nanoparticle respectively), the viscosity reduced gradually. In calcium oxide, the viscosity decreased on the addition of 5g, and further decreased on the addition of 10g and 15g. In the combination of zinc oxide and calcium oxide nanoparticles, at 5g there was reduction in viscosity and at 10g the viscosity increased and further reduced on the addition of 15g of zinc and calcium oxide nanoparticles.

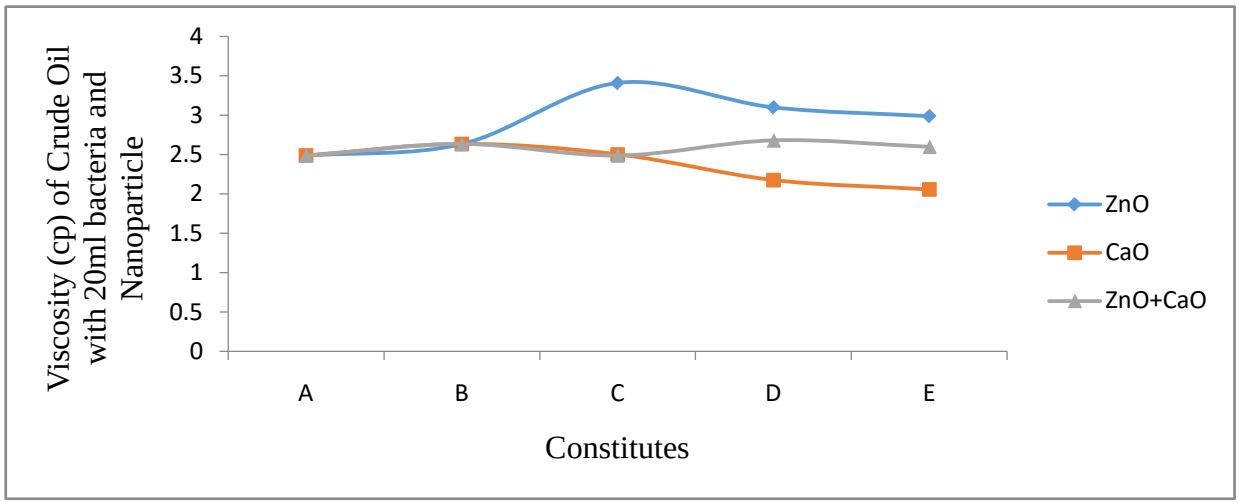


Figure 3.1: **Effect of Nanoparticle Concentration at 20ml bacteria on Oil Viscosity**

3.2 Viscosity at 40ml Bacteria and Nanoparticle concentration

Figure 4.2 illustrates the viscosity behaviour of crude oil at 40ml of Bacteria and varying concentration of the different nanoparticles as plotted from Table 1 of the Appendix. The viscosity at point A was recorded as the initial oil viscosity. It is observed that on the addition of the 40ml of Bacteria, the viscosity increased in all cases as shown in point B. At point C, calcium oxide reduced the viscosity of the crude the most followed by the equal combination of zinc oxide and calcium oxide nanoparticles to the crude oil system. However, Zinc oxide nanoparticles viscosity increased again at point C. At point D and E, all three constitute was observed to maintain a gradually decreasing viscosity. From Figure 3.2, calcium oxide still showed a higher reducing ability followed by the equal combination of zinc oxide and calcium oxide nanoparticles and lastly zinc oxide nanoparticles.

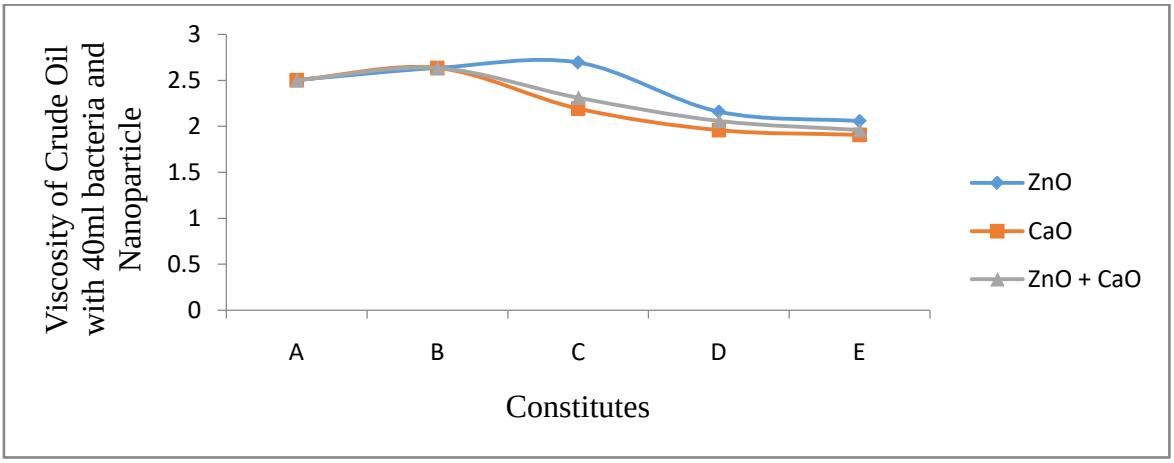


Figure 3.2: **Effect of Nanoparticle Concentration at 40ml Bacteria on Oil Viscosity**

3.1.1.2 Viscosity at 60ml Bacteria and Nanoparticle concentration

From Figure 4.3 it is clear that at point B, the addition of Bacteria to the crude oil resulted in an increase in viscosity of the crude oil above point A. At point C, the viscosity decreased in all constitute and appeared to tie. The viscosity continued to decrease at points D and E respectively with calcium oxide maintaining a high reducing ability. It therefore implies that any increase in the quantity of nanoparticles with bacteria will cause a decrease in the crude oil viscosity.

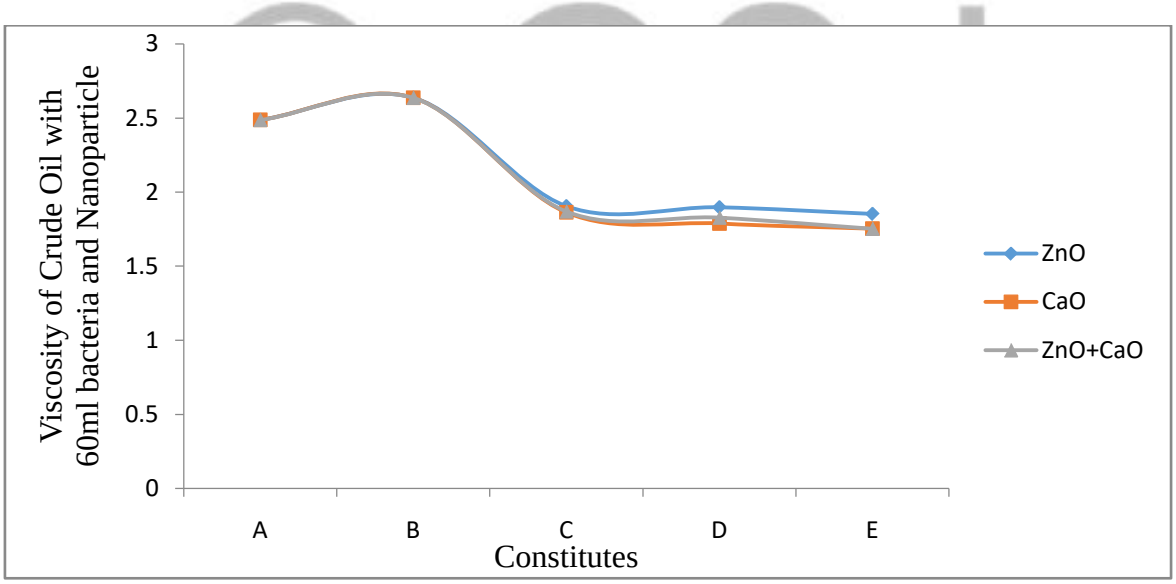


Figure 3.3: **Effect of Nanoparticle Concentration at 60ml Bacteria on Oil Viscosity**

3.1.2 Density

3.1.2.1 Density at 20ml Bacteria and Nanoparticle Concentration

Figure 3.4 illustrate the result obtained from the experiment. The result shows that the density of constitute with Bacteria decreased. On the addition of 5g, 10g and 15g of zinc oxide nanoparticle the density increased. On the addition of 5g of calcium oxide, the density increased and reduced at

10g and 15g. The same was observed on the equal combination of zinc and calcium oxide nanoparticles at 5g, 10g and 15g respectively.

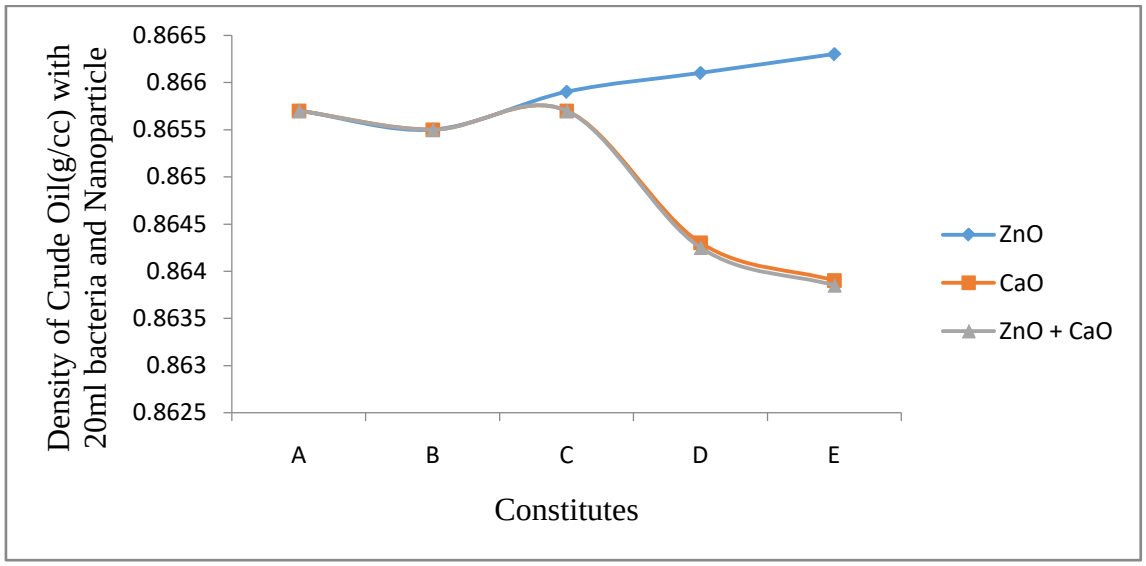


Figure 3.4: **Effect of Nanoparticle Concentration at 20ml Bacteria on Oil Density**

3.2 Oil Produced

3.2.1 Volume of Oil Produced at 20ml Bacteria

From Figure 3.5, 20ml Bacteria shows low oil recovery rate. It was observed for zinc oxide nanoparticle, that the oil production reduced at 5g and increases slightly at 10g and 15g. At equal combination of zinc oxide and calcium oxide nanoparticle, there was an increase in oil production at 5g and sharp increase at 10g and 15g.

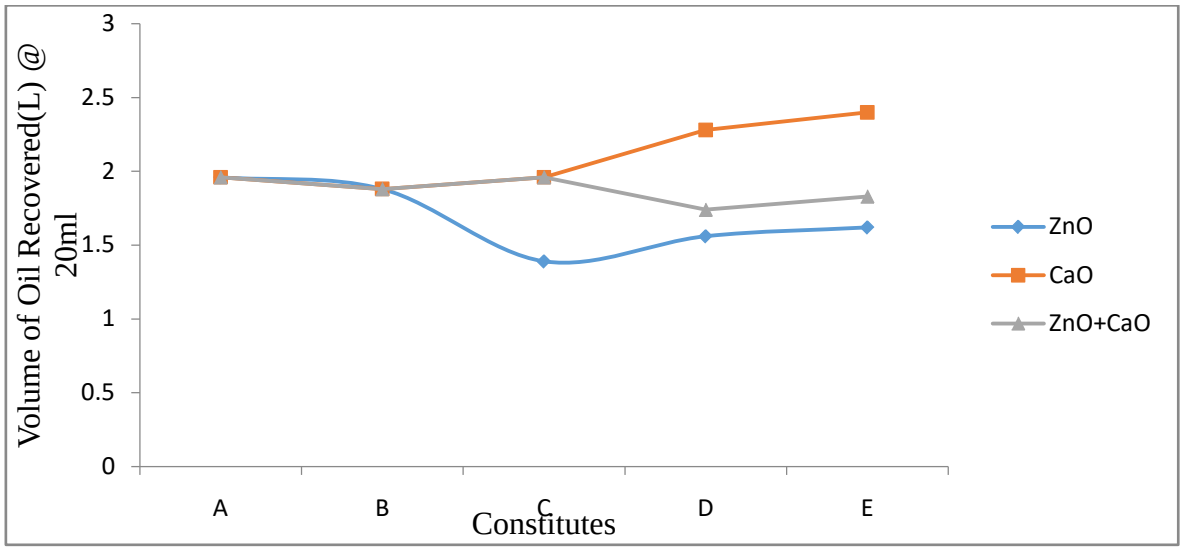


Figure 3.5: Effect of Nanoparticle Concentration at 20ml Bacteria on Volume of Oil recovered

3.4 Volume of Oil Produced at 40ml Bacteria

At 40ml Bacteria, there was a slight decrease in oil production and at 5g, 10g and 15g of Calcium Oxide and equal combination of zinc and calcium oxide, oil recovery continued to increased whereas a slight drop was observed at 5g of zinc oxide nanoparticle while at 10g and 15g, there was an increased in oil production as shown in Figure 3.6.

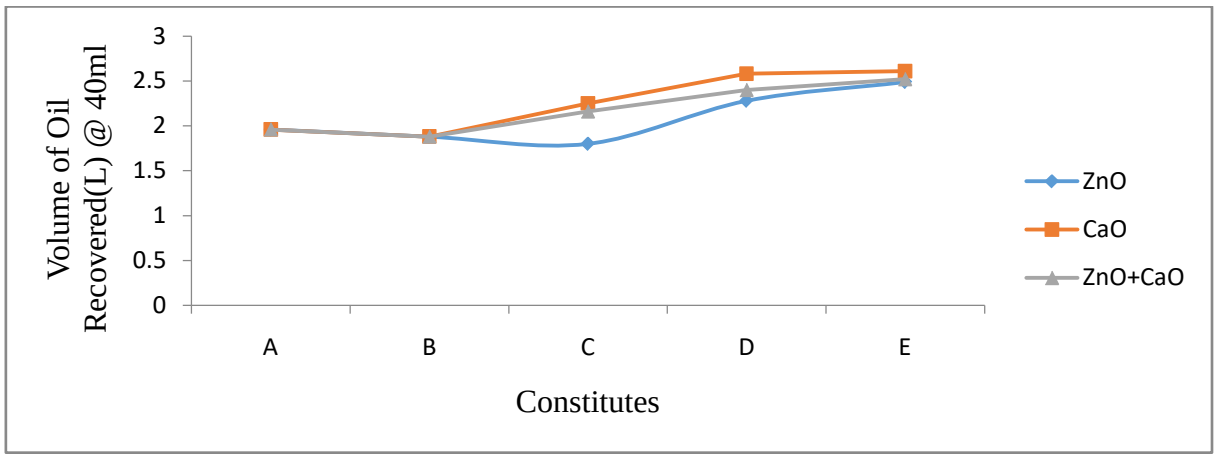


Figure 3.6: Effect of Nanoparticle Concentration at 40ml Bacteria on Volume of Oil recovered

3.5 Volume of Oil Produced at 60ml Bacteria

The Volume of oil recovered at 60ml bacteria decrease produced oil volume. The volume of oil recovered at 60ml of bacteria incorporating various concentrations of different nanoparticles are presented in Figure 3.7. At initial concentration of 5g, the volume of oil recovered by zinc oxide, calcium oxide and equal combination of zinc and calcium oxide nanoparticles increased. The rise continued for zinc oxide, calcium oxide and equal combination of zinc and calcium oxide nanoparticles at 10g and 15g.

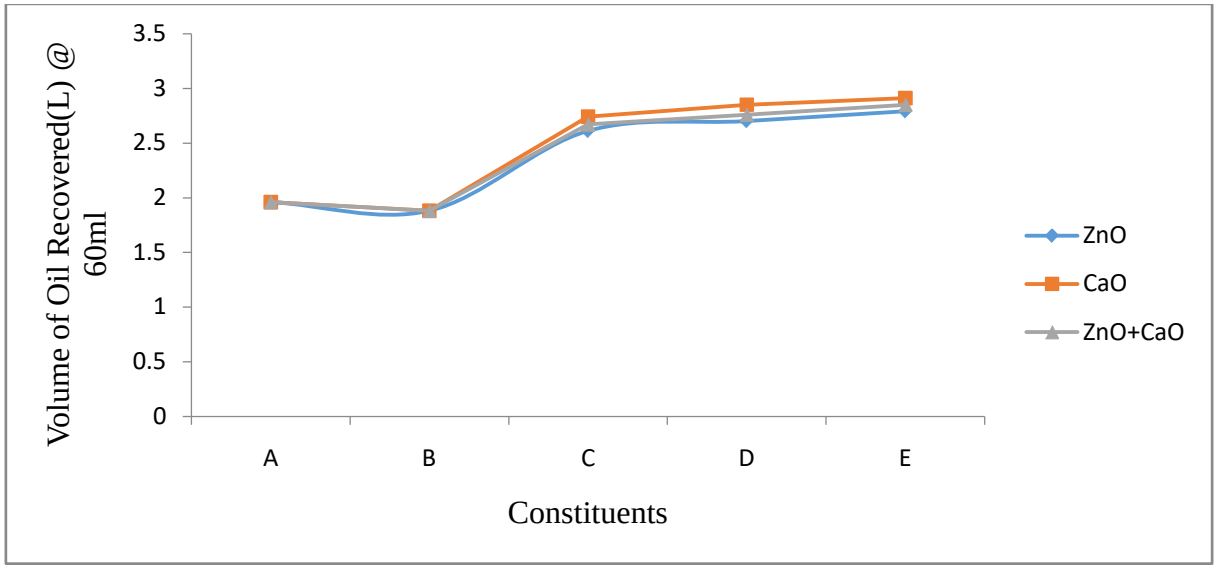


Figure 3.7: Effect of Nanoparticle Concentration at 60ml Bacteria on Volume of Water Produced

3.6 Percentage of Oil Recovered

3.6.1 Percentage of Oil Recovered at 20ml Bacteria

From Figure 3.8, 20ml bacteria shows little reduction in percentage oil recovery rate. It was observed that for zinc oxide nanoparticle, the percentage oil recovery reduced at 5g and increases slightly at 10g and 15g. On equal combination of zinc oxide nanoparticle, there was an increase in oil production at 5g and sharp increase at 10g and 15g. However, calcium oxide saw an increase in percentage oil recovered at 5g, a higher percentage was recorded at 10g and at 15g.

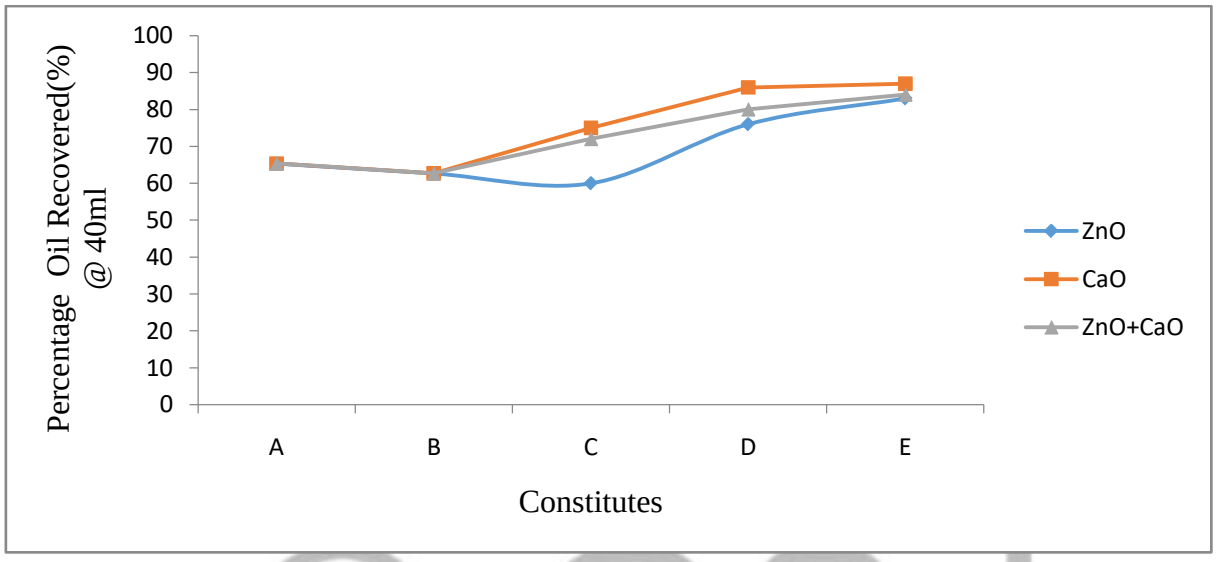


Figure 3.8: Effect of Nanoparticle Concentration at 20ml Bacteria on Percentage Oil Recovered

3.6.2 Percentage Oil Recovered at 40ml Bacteria

On 40ml bacteria, percentage oil recovery dropped a little and at 5g, 10g and 15g of Calcium Oxide and equal combination of zinc and calcium oxide, oil recovery continued to increase whereas a slight drop was observed at 5g of zinc oxide nanoparticle while at 10g and 15g, there was an increase in oil production as shown in Figure 3.9.

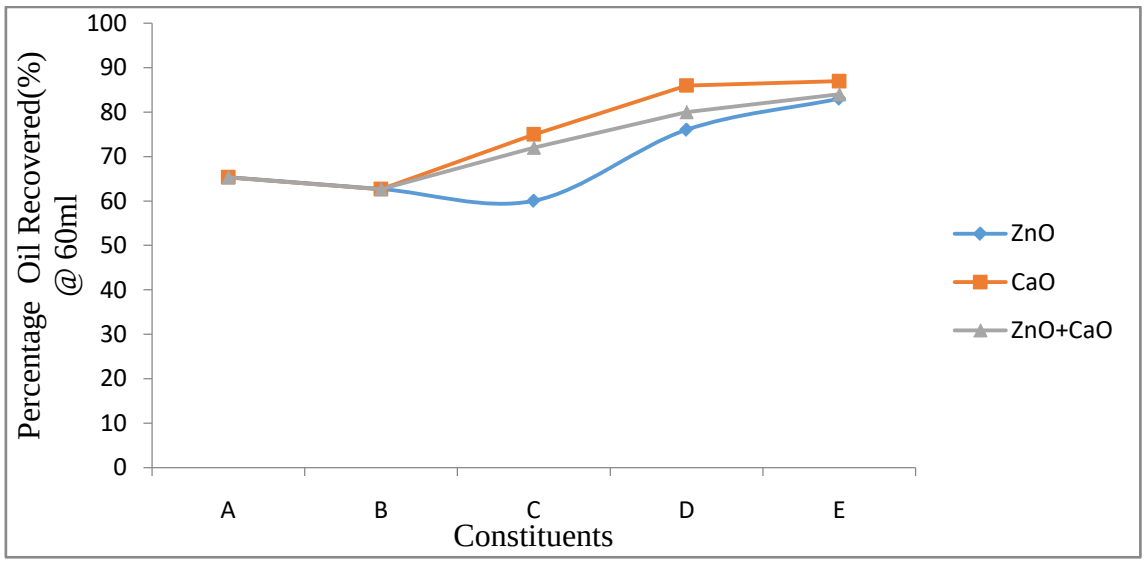


Figure 3.9: Effect of Nanoparticle Concentration at 40ml Bacteria on Percentage Oil Recovered

3.6.3 Percentage of Oil Recovered at 60ml Bacteria

The 60ml bacteria lowered the percentage oil recovered as presented in Figure 3.10. At 5g, the percentage oil recovered by zinc oxide, calcium oxide and equal combination of zinc and calcium oxide nanoparticles increased. The increase continued for zinc oxide, calcium oxide and equal combination of zinc and calcium oxide nanoparticles at 10g and 15g, so that calcium oxide had the highest percentage oil recovered.

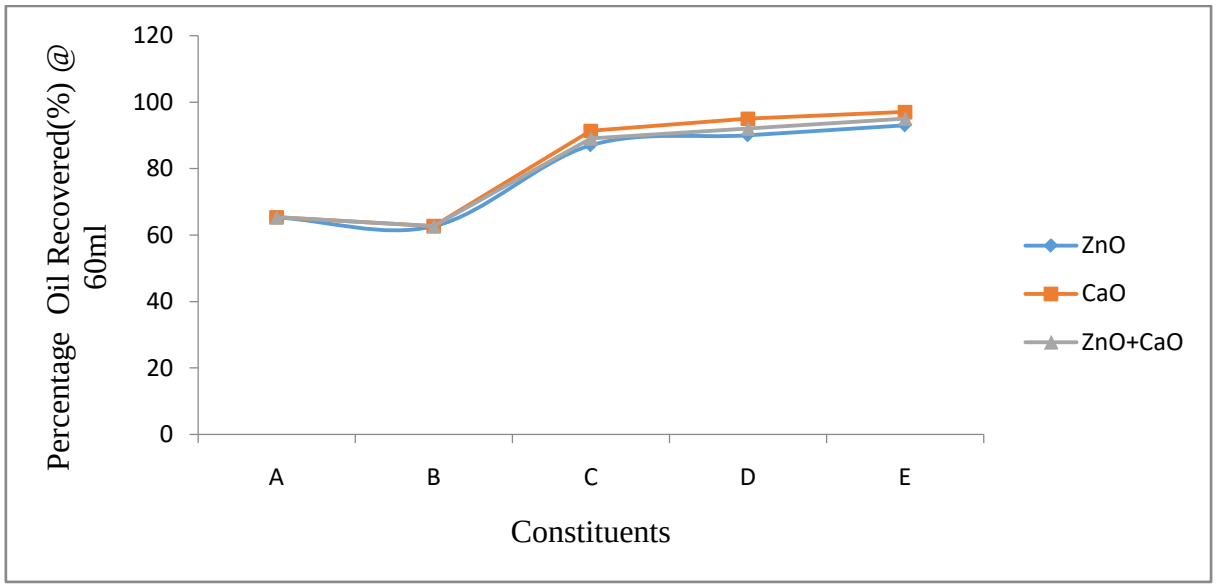


Figure 3.10: Effect of Nanoparticle Concentration at 60ml Bacteria on Percentage Oil Recovered.

4 Conclusion

The experiment on enhancing the productivity of oil from Oredo oil field, using microbes andin combination of zinc oxide (ZnO), calcium oxide (CaO) as well as a blend of zinc oxide and calcium oxide nanoparticles. This experiment seeks to find out the physical properties of crude oil which are very important in the recovery of crude oil and finds out the percentage recovery of oil and water.

i. The findings shows that the physical properties such as density and viscosity are reduced when reacted with bacteria and nanoparticle.
ii. The Calcium oxide nanoparticle increased crude oil production more than zinc oxide nanoparticle.

iii. The experiment shows that combination of bacteria and nanoparticle can increase crude oil production.

Recommendations

The objective of every work is to obtain results which are not only practicable but also helps economically. Therefore the following recommendations can be drawn:

(i) From all the results calcium oxide is a good enhanced oil recovery nanoparticle and can be used to greatly improve oil recovery in combination with Bacteria.

(ii) The morphology and appearance of bacteria reaction on the crude should be investigated in further research.

(iii) Zinc oxide nanoparticle should be preferred to Calcium oxide nanoparticle in terms of water production.

(iv) This work should be upscale to pilot field case to verify the results.

Contribution to Knowledge

Most of the published data on MEOR is based on laboratory tests where MEOR is shown to work. In our research, we discovered that calcium oxide nanoparticles when reacted with Bacteria produces more crude oil and water from the reservoir than zinc oxide nanoparticle, whereas the zinc oxide nanoparticle produces less oil and lesser water under the same condition.

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