



Treatment of Oil and Gas Produced Water for Waterflood using Banana (*Musa sapientum*) Stem

Akinade, Akinwumi E.

Department of Petroleum Engineering, College of Technology, University of Petroleum Resources, Effurun, Delta State, Nigeria

Abstract Produced water has proven to be useful in the oil and gas industry for various purposes such as re-injection into the reservoir (waterflooding) to improve oil recovery and maintain reservoir pressure. The quality of produced water which is produced from the field is not usually up to re-injection standard due to the presence of some physico-chemical properties which need be improved in a cost effective manner. This research project is centered upon the cost effective treatment of produced water to re-injection standard during waterflooding by using *Musa Sapientum* stem which is a locally found material and many times consider as waste. The methodology involved the use of the musa stem fibre as an adsorbent to treat produced water sample obtained from Awoba field, Niger Delta basin, Nigeria. The fibre was defatted with n-hexane for 72 hours and then heated with sodium hydroxide (NaOH) with a temperature of 100 °C for 1 hour, it was rinsed with deionized water and dried at room temperature. Using direct filtration method, the produced water was passed through the treated fibre. Physico-chemical properties of the produced water were tested both before and after treatment with the *Musa Sapientum* fibre. The result obtained from the treatment of 250mL of produced water with 1.34gram of treated *Musa Sapientum* stem fibre shows that the total hydrocarbon percentage removal was 99.85%, COD was 45.71%, total dissolved solid 3.19%, conductivity 3.19%, alkalinity 5.80%, sodium 43.22% and some heavy metals such as zinc and sulphate having removal percentage of 75% and 99.9% respectively. Therefore, it can be concluded that banana. *Musa Sapientum* stem is an excellent adsorbent for crude oil removal in produced water and the treatment of injection water. A cost effective, environmentally friendly and very sustainable method of treating water to injection standard using a local material has just been developed.

Keywords Produced Water, Heavy Metals, injection Water, Deionized Water

Introduction

Waterflooding can be defined as the process of injecting water into pressure depleted reservoir (due to primary depletion) usually to boost the reservoir pressure and sweep (push) the reservoir fluid (oil) towards the production well and thereby increase oil production rate and the ultimate oil recovery. Waterflooding as a secondary oil recovery method has been of interest in Nigeria in recent years due to the fact that most oil reservoirs are maturing and primary production from many of these reservoirs are declining significantly. There is a need to carry out secondary oil recovery by injecting water into these reservoirs. Many different types of water have been used for injection into wells. Some of them include seawater, produced water, freshwater, sewage effluent and waste water. [7]

Produced water is the oil and gas industry term for any water that is present in the reservoir with the hydrocarbon resources and is produced to the surface with crude oil or gas (Veil, 2004). The formation which is a body of permeable and porous rocks that are naturally occurring, which are permeated with fluid such as water, Natural gas, Crude oil or combination of these fluids. Sources of the water in the formation includes flow from above the hydrocarbon zone, flow from below the hydrocarbon zone, flow from within the hydrocarbon zone or flow



from injected fluids and additives. This water is usually refers to as formation water and produced water when it is produced to the surface along with hydrocarbon fluid. Produced water consist of solids (dissolved and suspended), heavy metals (including concentrations of Barium, Beryllium, Cadmium, Chromium, Copper, Iron, Lead, Nickel, Silver and Zinc), organic compounds, bacteria, naturally occur ring radioactive materials and scales.

The physical and chemical properties of produced water vary considerably depending on the geographic location of the field, the geo-logic formation, and the type of hydrocarbon product being produced [14]. Because the water has been in contact with hydrocarbon-bearing formations, it contains some of the chemical that are used for production operations. Jacob et al (1992) presented a result of the study conducted on produced water from Oil and Gas fields operated by Shell in the North Sea. It was observed that the produced water associated with Gas and Condensate fields was more toxic that the produced water associated with Oil fields. Due to the toxicity of produced water as well as a high Chemical Oxygen Demand (COD) and Biological Oxygen Demand (BOD) which are generated from compound of fatty acids, it is harmful to the environment (aquatic and terrestrial). All these contaminants must either be removed totally or reduced to a particular injection standard before the produced water can be reinjected into the reservoir for pressure maintenance. Numerous treatment processes with varying level of effectiveness are available. They include, evaporation, Coagulation, Foam floatation, Filtration, Cyclonic separation, Flotation, Aerobic and Anaerobic treatment, Advanced oxidation, Solvent extraction, Adsorption, Electrolysis, Microbial reduction and Activated Sludge. Most of these methods are robust, expensive, inefficient for fine oil particle removal and require a high energy and retention time and most times liable to breakdown in the field. This research work is aimed at developing a new adsorbent that is cost effective, requires no energy, effective for bulk and fine oil suspended solid removal and resistant to breakdown in the field using banana (*Musa sapientum*) stem which is a locally found material and many times consider as waste.

Material and Methodology

Materials

The *musa* stem was gotten from Federal University of Petroleum Resources field located at Effurun in Delta state, Nigeria. The produced water was gotten from Awoba flow station (Niger-Delta province) in River State, Nigeria. The adsorbent and produced water treatment and analysis were carried out at Federal University of Petroleum Resources Central Laboratory, Effurun, Delta State, Nigeria using Spectrophotometer, pH meter, Conductivity meter, AAS (atomic absorption spectrophotometric) machine, BOD trak II bottle, BOD apparatus, mortar and pestle, oven, dryer, filtration column, and weighing balance and other reagent like Nutrient buffer pillow, Potassium hydroxide pellets, N-hexane, sodium hydroxide, beaker, deionized water.

Methods

Musa Sapientum Adsorbent Preparation

The *musa* stem was chopped into small pieces (length fully depends on the size of the mortal and the length of fibre you desire). The fibre was defatted for 72 hours and then heated to a temperature of 100 °C for 1 hour, it was rinsed with deionized water and dried at room temperature. The dried fibre was then weighed. The fibre was then rinsed until its pH got to neutral (pH 7) with deionized water. Dry the fibre in the oven all night at a temperature of about 25 °C. The produced water was properly shaken and filtration commenced. Over 20 parameters were tested in order to determine the adsorption process of the *musa* trunk. The result before and after adsorption treatment were reported in Fig. 4.10 and 4.11 respectively.

Determination of pH

The pH meter was switched on. The reading of the pH 7.0 standard was taken before calibration and the readings were noted. Using the buffer 7.0, the pH meter was calibrated. The deionized water and the pH 7 buffer were transferred into a clean glass beaker each. The electrode was first rinsed with deionized water, and then with pH 7 buffer. After the electrode was placed in the buffer 7, and calibration knob on the instrument was pressed. The sample was transferred into a clean glass beaker. The probe was rinsed with some portions of the



sample and it was immersed into the sample. When the display was stable, the reading was noted. The result has no unit.

Determination of Electrical Conductivity

The conductivity meter was switched on. The prepared conductivity standard was transferred into a clean glass beaker. The conductivity meter was calibrated using the 100 μ S/cm, conductivity standard. The mode key on the conductivity meter is pressed until part of per million (ppm) is displayed. The probe was rinsed with some portions of the sample, it was transferred into the glass beaker and immersed into the sample. When the display was stable, the reading was noted.

Determination of Total Hydrocarbon Content

The spectrophotometer was switched on to warm the HACH program 410nm was pressed and the START button was switched on. The separating funnel was clamped on a retort stand. 100ml of well mixed sample and 50ml of xylene were poured into clean separating funnel. A lid cover was put on the separating funnel and the mixture shake vigorously for 10 minutes allowing vent at intervals to avoid pressure build-up. The mixture in the funnel was allowed to stand for some minutes to separate. After which when the liquid has separated into layers, the funnel tap was open into a measuring cylinder to discharge the dense liquid which is water. The volume was noted. The less dense liquid i.e. oil was collected into a beaker over a filter paper and some portion was transferred into a 25ml cell sample bottle to the 25ml mark. A blank of xylene was alongside prepared. The blank was used to zero the spectrophotometer and the absorbance value was read off in the spectrophotometer.

$$\text{THC (mg/l)} = 4934.109 \times \text{volume of Xylene} \times \text{absorbance} / \text{volume of sample used.}$$

Determination of Biochemical Oxygen Demand (BOD)

With the aid of a measuring cylinder, 100ml of the sample is measured. 1ml of nutrient buffer pillow was added to the sample in the cylinder, it was shaken together and transferred into the BOD trak II bottle. The BOD trak II stirrer bar was put into the bottle. Using a spatula, 2 potassium hydroxide pellets was added to the mixture in the BOD bottle through the scale cup. The bottle was placed on the BOD trak II chassis. The applicable tube was connected to the sample bottle as the cap was tightened. The temperature was regulated to 20 °C. the BOD apparatus was plugged and it was allowed to stay for 5 days before taking the reading. Daily check was done to affirm if the apparatus was working fine. The conductivity meter was switched on. The prepared conductivity standard was transferred into a clean glass beaker. The conductivity meter was calibrated using 100 μ S/cm, conductivity standard. The mode key on the conductivity meter is pressed until mg/l is displayed. The probe was rinsed with some portion of the sample. It was transferred into the glass beaker and immersed into the sample/ when the display was stable, the reading was noted.

Determination of Salinity (Chloride/salt test)

A titration setup of silver nitrate in a dark amber bottle was made ready, 100ml of sample was measured in a measuring cylinder and turn into a conical flask. 1ml of $\text{K}_2\text{Cr}_2\text{O}_7$ (indicator) was added and it was titrated with AgNO_3 . A slight colour change to orange was watched out for. The titration value was noted and the salinity of the sample was calculate as shown below.

$$\text{Salinity} = \frac{\text{Titre value} \times \text{Normality of titrant}}{\text{volume of sample}} \times 33450$$

Where; Normality of titrant -0.0135, 33450- Conversion factor

Determination of Total Suspended Solids

The oven was heated at 110 °C for one hour. A clean Millipore paper (0.45 μ m) was placed in a lean foil plate and put in the heated Oven and allowed to dry to a constant weight at 110 °C in the oven for two hours. The Millipore paper was removed from the oven and place in a desiccator to cool to room temperature. After, using a weighing balance, the weight of the Millipore paper (w) was noted. Gooch funnel (about the diameter of the glass fibre) was prepared with rubber adapter and fix to a filtering flask, the glass fibre into the gooch funnel carefully with the aid of a pair of tongues. The produced water sample was thoroughly mixed and a 100ml was



measured using measuring cylinder. The 100ml was filtered quickly using the filtering setup. Vacuum pump was used to suction the filtering process to make solvent pass through the filters in the presence of solutes. Using a pair of tongues, the wetted Millipore was removed from the glass fibre carefully from the gooch funnel and put in the foil plate and then dry to constant weight at 110°C in the oven for one hour. At the elapse of one hour, the Millipore paper after removal from the desiccators was weighed and the readings was note (W). The difference in the weights of the Millipore pare was calculated in order to obtain the weight of the suspended solids. It calculated as show below

$$\text{TSS (mg/l)} = \frac{W-w}{\text{volume of sample}} \times 10^{-6}$$

Determination of Sulphate

Sulphate is of considerable concern because they are indirectly responsible for two serious problems associated with the handling of waste waters. These are odour and sewers corrosion problems resulting from the reduction of sulphate to hydrogen sulphide under anaerobic conditions. The HACH program 680nm (frequency at which the sulphate can be read in the spectrophotometer) was selected on the spectrophotometer and the START button was pressed. A 25ml clean sample cell bottle was filled with the produced water sample to the 25ml mark. A 25ml clean sample cell bottled was filled with deionized water to the 25ml mark, this is known as the blank. The content of one sulfaver reagent powder each was added into the cell bottles above and shakes to mix. The timer was selected, 5minutes reaction time. Once the timer beeps, place the blank into the cell holder and zero. Place the cell bottle with prepared sample into cell holder and READ. Results are in mg/ml.

Determination of Chemical Oxygen Demand (COD)

COD is a measure of the amount of oxygen required for complete oxidation to carbon (IV) oxide and water of organic matter present in a sample of water, waste water or effluent water. The COD reactor was switched on. Two tubes containing digestion solution for COD is put on the rack. 2ml of sample was pipette into the tube containing digestion solution for COD and 2ml of deionized water was pipette into another tube containing digestion solution for COD i.e. the BLANK. It was ensured that the tubes are covered with their lids tightly fitted. Then the tubes were shaking to mix. When the temperature on the reactor reads 150°C, the tubes were placed onto COD reactor and allowed to stand for 2hours. The sample and blank tubed are removed from COD reactor after 2hours, allowed to cool to room temperature its value was then read off at the spectrophotometer.

Determination of Heavy Metals

This involves analysis of cations, which was carried out by spectrophotometry. The heavy metals that were analysed are Sodium (Na), Chloride (Cl), Lead (Pb), Copper (Cu), Iron (Fe), Barium (Ba), Zinc (Zn), Cadmium (Cd), manganese (Mn), Magnesium (Mg) and Calcium (Ca).AAS (atomic absorption spectrophotometric) machine was switched on. 11 glass beakers were filled with deionized water and each was labelled with each metal to be analysed. Pipettes were washed clean and rinsed with HNO₃, followed by deionized water. 1ml of the sample was pipette into each beaker containing deionized water. On the AAS machine, an outer thin diameter hose is constantly in deionized water. It was ensured that the water do not reduced all through the period of the analysis. Sodium metal was analysed first. Sodium transparent glass was inserted into the glass closure in the machine. The machine was set to read sodium in the water. The tin diameter hole was put into the sodium prepared standard solution and the machine was configured to 0.00 once the standard concentration is confirmed. The glass beaker labelled with sodium (Na) was placed close to the apparatus and the hose was dipped into it. The average value of sodium was read off from the display and the hose was returned back into the deionized water in the glass beaker. The same procedure was done in analysing the remaining metals; Lead, Copper, Iron, barium, Zinc, Sulphate, Cadmium, manganese, magnesium and calcium.



Results

Table 1: Properties of Produced Water and Required Specifications of Water for Reinjection

Parameter	Units	Produced Water	Required Specifications For Reinjection
pH	5~6.8	6.5~7.5
TSS	Mg/L	300	<2
Turbidity	NTU	700	<1
Particle Size	µm	60	<4
TDS	Mg/L	250000	=250000
Oil and Grease	Mg/L	1000	<5
Total Fe	Mg/L	300	<5
DO	Mg/L	2	<0.02
Bacteria	Present	Absent

Table 2 shows the physico-chemical properties of produced water before and after treatment with Musa Stem using standard units of measurement.

Table 2: Comparison and Percentage overall removal of the physio-chemical properties of produced water before and after treatment with *musa* stem fibre

S/N	Parameters	Units	Value Before Treatment	Value After Treatment	Overall Removal (%)
1	pH		9.08	9.17	0.99
2	Temperature	°C	27.6	25.8	6.52
3	Total Dissolved Solid	mg/L	7373	7138	3.19
4	Conductivity	us/cm	14750	14280	3.19
5	Total Hydrocarbon Content	mg/L	6.57	<0.01	99.85
6	Biological Oxygen Demand	mg/L	<0.50	5984	>100
7	Total Suspended Solid	mg/L	28	92	228.57
8	Chemical Oxygen Demand	mg/L	7000	3800	45.71
9	Total Coliform Count	Cfu/100ml	250	NIL	100
10	Alkalinity	mg/L	4140	3900	5.80
11	Carbon oxide		<1	<1	0
12	Sodium	mg/L	5535	3143	43.22
13	Salinity	mg/L	2599	2899	11.54
14	Lead	mg/L	<0.01	<0.01	0
15	Copper	mg/L	<0.01	<0.01	0
16	Iron	mg/L	0.49	0.51	4.08
17	Barium	mg/L	2.0	8.0	300
18	Zinc	mg/L	0.40	0.10	75
19	Sulphate	mg/L	11.0	<0.01	99.9
20	Cadmium	mg/L	<0.01	<0.01	0
21	Manganese	mg/L	<0.01	0.14	1300
22	Magnesium	mg/L	1.78	8.73	390.45
23	Calcium	mg/L	1.94	13.29	585.05



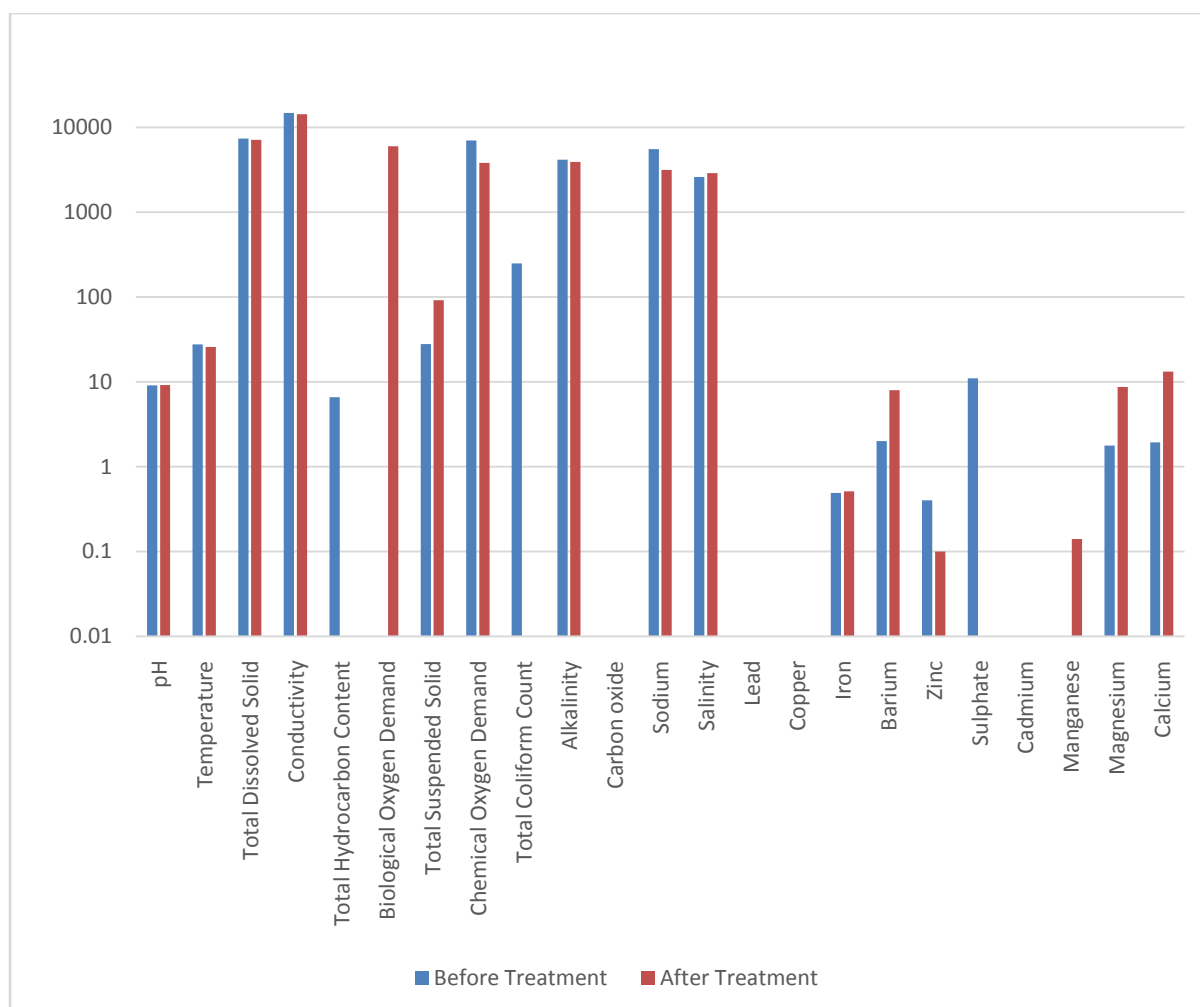


Figure 3: Initial and final physio chemical properties represented in a bar chart

Discussion

Research has shown that *musa* stem fibre has high hemicellulose properties (61.5%) which helps in aiding adsorption process, making it a good adsorbent for the removal of oil, heavy metals, and other water pollutant. Over 20 physio-chemical parameters were study in order to determine the adsorption process of the *musa* stem fibre. The result before and after adsorption treatment are discussed as found in table 1 and 2 respectively.

Total dissolved solid (TDS)

Table 2 shows the value of total dissolved solid before treatment to be 7373mg/L and after treatment to be 7138mg/L. The total dissolved solid decreases by 3.19%. According to table 1 the required TDS specification for re-injection water is < 250000mg/L labelling the treated water fit for reinjection.

Total hydrocarbon content (THC)

After the produced water was treated, the total hydrocarbon content reduced by 99.85%, the before value was 6.57mg/L and after <0.01mg/L. according to table 2, the required specification for total hydrocarbon content in reinjection water is <5 making the treated water suitable for reinjection. The high decrease in the total hydrocarbon content is as a result of high adsorption capability of the *musa* stem fibre.

Chemical Oxygen Demand

COD is a measure of the amount of oxygen required for complete oxidation to carbon (IV) oxide and water of organic matter present in a sample of water, waste water or effluent water. The COD before and after treatment are 7000mg/L and 3800mg/L respectively according to table 2, with removal percentage of 45.71%.



Conductivity

Conductivity is the measure of the water's capability to pass electrical flow. The water conductivity of the sample before and after treatment are 14750 μ S/cm and 14280 μ S/cm respectively, as seen in table 2. The removal percentage is 3.19%. The conductivity decreases as the number of concentration of ions decreases in the sample.

Biological Oxygen Demand

Biological oxygen demand is the measure of the organic waste in the water. According to table 2, the before and after treatment result are <0.50mg/L and 5980mg/L. The increase in the biological oxygen demand is as a result of the biomass used in the treatment of the water sample. Further treatment of biomass can help improve the result of the biological oxygen demand.

Hydrogen ion concentration pH

The pH of the produced water before treatment was 9.08 and increase by 0.99% after treatment to 9.17 and this is as a result of the caustic soda (sodium hydroxide) used in the treatment of the *musa* stem thereby making it more basic. Although from table 1 it can be observed that the required specification for reinjection ranges from 6.5-7.5 which is lower than the pH of the produced water after treatment.

Alkalinity

Water alkalinity is a measure of the water acid to neutralise acids. According to table 2 the alkalinity of the water sample before and after treatment are 4140mg/L and 3900mg/L respectively. The alkalinity reduced with a percentage of 5.8%. The alkalinity of the sample can be further reduced by treating the adsorbent with acid.

Sodium

The sodium of the water sample reduced by 43.22% i.e. from 5535mg/L and 3143mg/L as shown in table 2.

Salinity

Salinity is the measure of all the salts dissolved in the water sample. The salinity of the water sample is found to increase from 2599mg/L to 2899mg/L as seen in table 2. The increase might be as a result of dissolved salt in the adsorbent which was not completely removed during treatment.

Heavy Metals

Heavy metals such as lead, copper, iron, Barium, zinc, sulphate, cadmium, manganese, magnesium and calcium are studied for this research purpose. As seen in table 2, lead, cadmium and copper, before and after concentration was <0.01. Iron increased from 0.49mg/L to 0.51mg/L and this resulted in the reddishness of the water sample. Barium increased from 2.0mg/L to 8.0mg/L. Zinc decreased from 0.4mg/L to 0.10mg/L. Sulphate reduced by 99.9% from 11mg/L to <0.01mg/L. Magnesium increased from 1.78mg/L to 8.73mg/L. Manganese increased from <0.01mg/L to 0.14mg/L. Calcium increased from 1.94mg/L to 13.29mg/L.

Conclusion

From the result gotten from the treatment of produced water using *Musa* stem, it can be concluded that, *musa* stem is a good and effective adsorbent for treating produced water by the reduction of different pollutants (physicochemical properties) found in the produced water sample. The result shows that the total hydrocarbon percentage removal was 99.85%, COD was 45.71%, total dissolved solid 3.19%, conductivity 3.19%, alkalinity 5.80%, sodium 43.22% and some heavy metals such as zinc and sulphate having removal percentage of 75% and 99.9% respectively. It was discovered that *musa* fiber has high affinity to attract oil and repulse water when in contact with oil and water, thus making it an excellent alternative filtration agent for the oil and gas industry and it can also aid the recovery of oil spills from sea water. The use of the banana stem fiber for treating produced water is environmentally friendly and very sustainable. It is a very cheap medium of treating injection water since the stem is considered as waste after harvest in most parts of the world.

References

- [1]. Heins W. and Peterson D. (2005). Use of Evaporation for Heavy Oil. *Journal of Canadian Petroleum Technology*, 26-30.
- [2]. Howard B. B. (1987). *Petroleum Engineering Handbook*. Texas, USA: Society of Petroleum Engineers.
- [3]. King R. (1993). *Maureen Produced Water Injection*. U.K: Society of Petroleum Engineering.



- [4]. Kuraimid K. (2013). *Treatment off produced Water in North Rumela oil field for Reinjection*. Mishref: Society of Petroleum Engineers.
- [5]. Liu s., Shanghai J.and Zhao X. (2005). Treatment of Produced Water For Polymer Flooding Using a New type of Air Sparged Hydrocyclone. *Health, Safety and Environment* (pp. 12-16).
- [6]. M. K., and M, S. (2013). Fiber morphology and Pulping study of Banana Pseudo-stem. *International Journal of Fiber and Textile Research*, 31-32.
- [7]. Michael, D., and P J. S. (2006). *Oilfield Water Technology*. Texas, USA: NAICE Intrernational.
- [8]. Muhammad M., El-Nafaty U., and Abdulsalam A. (2012). *Removal of Oil from Oil Produced Water Using Eggshell*. Minna: Civil and Environmental Research.
- [9]. Muhammad M., El-nafaty U., and Abdulsalam S. (2012). *Oil Removal From Produced Water using Banana Peel*. Bauchi: Proceedings of the Nigerian Institution of Agricultural Enginners.
- [10]. Rangarajan T., Ali H., and Amr H. (2013). State of Art of Treatment of Produced Water. *Water Treatment*, 199-224.
- [11]. Scot N., Randy C. and Angela K. (2006). *Musa species (banana and plantain)*. Hawaii: Permanent Agriculture Resources.
- [12]. Shumeng L., Xigui D., and Xuefeng Z. (2005). *Treatment of ASP Produced Water with Hydrophilic Fibre Ball Filtration*. Seoul, Korea: The International of Offshore and Polar Engineering.
- [13]. Tarek A. (2010). *Reservoir Engineering handbook*. USA: Gulf Professional publishing.
- [14]. Veil J. (2015). US produced water volume and management practices in 2012: A report prepared for Ground water protection council.
- [15]. Jacobs R. P. and Grant W. M. (1992). *The Composition of Produced Water from Shell Operated Oil and Gas Production in the North Sea: produced water Technological /Enviromental issues and solution*, Plenum Press NY, pp 13-22.
- [16]. Wikipedia. (n.d.). Retrieved from Wikipedia: <https://en.wikipedia.org/wiki/Banana>

