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Formulation and Environmental Impact Evaluation of Walnut and Soya Bean Oil Based Drilling Fluid

Fadairo Adesina[1*], Adeyemi Gbadegesin[1] and Olafuyi Olalekan[2]

[1]Department of Petroleum Engineering, Covenant University, Nigeria.
[2]Department of Petroleum Engineering, University of Benin, Nigeria.

Authors' contributions

This work was carried out in collaboration between all authors. Author FA designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript and managed literature searches. Authors FA, AG and OO managed the analyses of the study and literature searches. All authors read and approved the final manuscript.

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ABSTRACT

One of the oil and gas hazard that associated with drilling operation is oil based drilling fluid and its associated cutting disposition. It is highly imperative for policy maker to propagate the use of environmental friendly oil based mud for drilling operation. This paper formulated environmentally friendly oil based mud (using walnut and soya bean plant oil) that can carry out the same function as convectional oil based drilling fluid and equally meeting up with the HSE (Health, safety and environment) standard. Mud laboratory tests were carried out at standard condition on plant oil samples so as to ascertain the rheological properties of the drilling fluid formulations. The synthetic oil based was obtained from drilling company in Nigeria and was used as control experiment.

At the end of the experiment, the properties of the walnut and soya beans based mud was compared with industry oil based mud (synthetic oil based mud). All the results were shown to be similar to that of commercial synthetic oil based drilling mud which was gotten from the industry. From the results it can be seen that walnut and soya beans based mud actually gives a less toxic, better rheological properties, requires less waste disposal costs, hence making them more economically and technically viable for oil and gas drilling operation.

**Corresponding author: E-mail: adesinafadairo@gmail.com;*

Keywords: Synthetic drilling mud; Walnut seed; Soya Bean seed; environmentally friendly mud; reological properties; oil based mud.

NOMENCLATURES

WBMs : Water based muds
OBMs : Oil based muds
SBMs : Synthetic based muds
SBFs : Synthetic based fluids
EPA : Environmental protection agency
PAO : Poly Alpha Olefins
ELGs : Effluent legislation guidelines

1. INTRODUCTION

Today's drilling challenges are so unforgiving that usually only the best drilling fluid will do, irrespective of cost, therefore drilling-fluid companies strive to maintain an "economic-ecological" balance when it comes to choosing drilling-fluid systems and additives. Conversely, using a properly managed high-performance synthetic-based fluid (SBF) can shorten the duration of the drilling operation and/or help maintain wellbore stability, thereby reducing opportunities for environmental damage. These and other factors must be weighed in the design of any drilling-fluid system. A lot of studies and analysis have been carried out to proffer solutions to the choice of drilling fluids to be used during drilling operations and activities [1-5]. Efforts to eliminate environmental hazards resulting from unfriendly drilling mud or the negligent in handling of drilling fluids and/or drilled cuttings encompass several contamination issues related to drilling fluids [5-12]. Therefore the development of synthetic oil based drilling fluid (SBFs) stemmed from the need to replace diesel- and mineral-oil-based fluids (OBFs) mostly because of environmental restrictions [2-6]. It has become more necessary to focus on environmental impacts involved in the drilling process, the industry has responded with new and improved drilling mud that is highly environmental friendly and cost saving [12-18]. Drawing a conclusion based on the above, synthetic oil-based mud could be a potential solution to meeting current as well as future technical and environmental challenges in drilling fluid technology [3-14]. Owing to the significance of the down-hole control of drilling fluid properties, it becomes imperative to study and understand the performance of the plants oil based mud at down-hole conditions which differs greatly from ambient conditions. The innovative study increase the number of studied plant oil that could be technically, economically and environmentally viable for drilling fluid technology in oil and gas drilling industry.

The earliest study of mud and other additives used for drilling dates back to about thirteen years after the first oil was drilled by rotary method. Hegen and Polland [6] investigated the use of mud-laden fluids for cable tool drilling in Oklahoma, U.S.A. Their experiment and research with muds for drilling purposes was quite helpful and was one of the pioneering works on drilling muds.

Combs and Whitmire [7] showed that the change in viscosity of the continuous phase is the main factor in controlling the change in the viscosity of the mud with pressure.

Politte [8] carried out investigations on invert diesel oil emulsion mud viscosity and how it is affected by downhole conditions. Results were given from tests on diesel oil, brine, low colloid oil brine emulsions, low colloid muds, ranging in density from 10-18 ppg. It was discovered that invert oil muds generally behave like Bingham plastics. The plastic viscosity can be normalized with the viscosity of the continuous phase and can therefore be predicted as a function of temperature and pressure. The yield value was only weakly affected by pressure. The emulsions and muds exhibited an approximately linear shear rate to shear stress relationship at lower temperatures and higher pressures. At higher temperatures (greater than 76.7ºC), the flow curves deviated from a perfected linear fit. Data analysis showed that the fluids exhibited more of Bingham plastic behaviors than Power law.

Potman et al. [9] looked into the application of oil based muds in drilling responsibly with environmental protection as a first priority. Alternative muds and improved mud cleaning technology was also looked into. Their research work was very environment conscious. The short coming is that no matter how careful one tries to be using diesel oil based muds during drilling with environment protection in mind, pollution and environmental degradation will still occur. This degradation could be made as minimal as possible, with improved safety and precaution.

Yassin et al. [10] carried out tests on palm oil derivatives as the continuous phase for oil based drilling fluids, and the toxicity effect on plant and aquatic life. The oils used in this case include: Methyl esters of Crude Palm Oil, and Methyl esters of Palm Fatty Acid Distilled. Rheological tests were carried out on the drilling muds formulated with these oils. The rheological tests showed that the high plastic viscosities and high gel strengths of the palm oil ester based muds can be effectively treated by adding appropriate concentration of thinners.

Xiaoqing et al. [11] developed environmentally acceptable modified natural macromolecule based drilling fluids, which are mainly composed of shale inhibitor agents, fluids loss control agents, bloomless white asphalt, and dry powders of poly alcohols. After a series of rheological, performance and environment compatibility test, formation damage control ability tests, inhibitive property test, they came up with the following results, its ability to withstand temperatures as high as 140ºC, its strong inhibitive and formation damage control and anti-contamination abilities. The formulation is also suitable for both land and marine drilling activities, and its use did not disturb other field operations such as production, casing, and well logging.

Fadairo et al. [2] developed artificial neural network model for predicting the down hole mud density of diesel, jatropha and canola oil based drilling mud. The results revealed that the back propagation neural network model (BPNN) showed perfect agreement with the experimental results in term of average absolute relative error returned.

Fadairo et al. [3] confirmed jatropha oil based mud to be less harmful to plant life and soil micro organism than diesel based mud via their environmental impact assessment carried out in the mud laboratory in Covenant University. The overall results obtained from laboratory rheological tests indicate that jatropha oil based mud pose great chance of being among the technically and environmentally viable replacements for convectional diesel oil based mud.

Fadairo et al. [4] reported that the cutting carry capacity of jatropha oil based mud and identified that drilling cutting has derimental effect on the rheological properties of the mud. As the drill cuttings are removed, the plastic viscosity decreases that will increase the low shear rate viscosity which will bring larger, more easily removable cuttings to the surface. It also works the other way; failure to bring cuttings to the surface while they are large enough to be removed by the equipment will increase the plastic viscosity. Increase in plastic viscosity will decrease the ability to bring cuttings to the surface and allow them to grind into smaller, more numerous particles. Proper solids control (i.e drill cuttings removal) plan should be a routine practice for successful drilling since it has a direct bearing on drilling efficiency.

2. EXPERIMENTAL PROCEDURE

In this section a brief description is given of the various chemistries used to produce synthetic fluids.

3. SEEDS PREPROCESSING

3.1 Soya Beans

The first step taken was to get half a bucket of raw soya seeds form the open market in Ota Ogun State and blend them into powdery form. The ground sample above is then weighed and wrapped within a porous medium ready for extraction.

3.2 Walnut

The walnut was gotten in bulk from the open market in Oyinbo Ebutte Meta Lagos state. After that the bark was cracked open with a stone to get access to the whitish colored nut. Then it was chopped it to bits with a knife, the nuts were put in an oven for about 20 minutes to dry at a temperature of 70ºC, after that all of it was blended, the nuts were weighed with the weighing balance then taken back to the oven for complete drying, for about 70 minutes until it was completely dry. It was prepared for extraction by weighing 60gramms of the blended nuts and wrapping it carefully in a filter paper.

3.3 Oil Extraction

This is a method of extracting essential oils by the use of a chemical (solvent) which dissolves the plant resins and produces absolutes. After the extraction trace amounts of the solvent still remain in the oil produced. Examples of solvent are n-hexane, toluene, petroleum ethers etc. The apparatus used for the solvent extraction is the SOXHLET APPARATUS and n-Hexane solvent was used for the extraction (Fadairo et al., 2012).

The purpose of using a Soxhlet is the ability to perform a large number of extractions on a liquid or solid sample with minimal effort. Before extraction starts the sample has to be placed in a timble before it is loaded into the main chamber of the apparatus. Then the extractor chamber is fitted into a round bottom conical flask containing the extraction solvent. But the extractor chamber has to be equipped with a condenser to ensure cooling of the solvent vapor when it gets to a certain temperature e.g. n-hexane vaporizes at 70ºC, so that it dips back down into the chamber housing the sample.

The solvent is heated to reflux using a thermo heater. When the Soxhlet chamber is almost full it is automatically emptied by a siphon side arm, with the solvent running down to the round bottom distillation flask. During each cycle, a portion of the non-volatile compound dissolves into the solvent. Hence this cycle may be repeated over hours or days and after many cycles the desired compound is concentrated into the distillation flask. The non-soluble portion of the extracted solid otherwise called the shaft remains in the timble, and it is discarded afterwards. This process is carried out until the entire sample has been exhausted, then the product gotten is either evaporated or distilled.

In this research work the concentrated sample was distilled in order to separate the oil from the sample for the solvent to be recycled for other extractions.

4. OIL EXTRACTION AND YIELD

For 60grams of SOYA beans, the oil yield was 20ml and 17ml for walnut. A total of 450ml of oil was extracted for each, it was performed 23 times to get this volume the total mass of sample blended for soya was 1350g and 1500g for walnut. It took 9weeks to get the volume required.

4.1 Mud Preparation

The muds was prepared using a set configuration of 50% oil, 30% water, 9% barite, 7% clay and 3% salt and 1% emulsifying agent. The following procedures were carried out to prepare the mud sample:

- The mixer was set up and the power cord was connected to the mains but was not turned on;
- The compounds were weighed out for them to conform to the mud density of the industrial sample at room temperature;
- The compounds were poured into the mixing cup and fixed the cup unto the mixer;
- The mixer speed was selected to 3 and turned on; and
- After 2 minutes, the mixer off was switched and disconnected it from the mains

4.2 Mud Property Determination

4.2.1 Rheology tests

The tests conducted under rheology were the viscosity and the gel strength tests respectively.

4.2.2 Viscosity [after Covenant University drilling fluid manual (13)]

The apparent, the plastic viscosity and yield point will be measured using the Rotary Viscometer for the two muds that is the control (industrial synthetic) mud and the experimental (laboratory-formulated biokerosene) mud. The following were the procedures undertaken for the experiment:

- The viscometer was set up and was connected to the power source;
- The test fluids were placed in a sample cup and the rotor sleeve was immersed to the fill line on the sleeve by raising the platform;
- The lock nut was tightened to stabilize the platform;
- The mains and the power switch on the back panel were turned on;
- The knob was turned to STIR setting to agitate the sample for some seconds;
- Then, the knob was rotated to 600 RPM setting and waited for a stabilized dial reading and recorded the value of the 600-RPM reading;
- The procedure step 6 was repeated for 300 RPM, 200 RPM, 100 RPM, 60 RPM and 30 RPM and their respective stabilized dial readings were recorded.
- The steps were again conducted at varied temperature conditions.

4.2.3 Gel Strength [after Covenant University drilling fluid manual (13)],

The gel strength of the control mud and experimental mud will be measured using the Rotary Viscometer. They will be done after 10 seconds of agitation and 10 minutes (600 seconds) after relative calmness also. The following are the procedures of the experiment:

The viscometer was set up and was connected to a power source;

The test fluids were placed in a sample cup and the rotor sleeve was immersed to the fill line on the sleeve by raising the platform;

The lock nut was tightened to stabilize the platform;

The mains and the power switch on the back panel were turned on;

The knob was turned to STIR setting to agitate the sample for some seconds;

Afterward, the knob was rotated to the GEL setting and the power was switched off and the test was started when the rotor stopped rotating and timed for 10 seconds;

The power was turned on while looking at the dial to read and record the maximum deflection after the 10 seconds;

Procedure steps 5 through 8 were repeated but were done so for the 10-minute gel strength;

The steps 1 through 8 were conducted at varied temperatures same as the viscosity measurement.

4.2.4 Density [after Covenant University drilling fluid manual (13)],

The density of the mud was measured by the use of a mud balance supplied by the laboratory. The following procedures were done:

The balance was calibrated by using fresh water;

The mud balance was placed on a flat surface;

The cup was cleaned to dryness and then filled to the brim with the mud samples;

The lid was placed on the cup twisting it on the top to expel the mud through the hole and remove the gases within the mud;

The hole was covered and cleaned the mud from the cup exterior and surrounding and dried the cup exterior and surrounding;

The mud was placed on the knife-edge and the rider was moved along the arm of the balance until equilibrium was obtained;

The mud weight was read off the arm of the balance;

The preceding steps were carried out for the fluids at different temperatures, which are the same as the viscosity and gel strength measurement conditions.

4.2.5 pH test [after Covenant University drilling fluid manual (13)])

The muds, control and experimental will be tested for their acidity or alkalinity using the pH meter. Drilling muds are normally expected to be on the basic side, as acidic muds will corrode the metal fittings in the borehole like the strings and also damage formations in the subsurface. The following procedures obtained for this experiment:

The mud was placed in a cup and dipped the electrode into the sample and the glass electrode while lightly mixing the fluid for uniformity of properties;

This step was carried out for the varied temperatures at which the viscosity, gel strength and density tests were conducted.

4.2.6 Filtration Test [after Covenant University drilling fluid manual (13)]

This test was undertaken to determine the filtration properties of the formulated mud and the industrial mud namely the size of mud cake and the fluid loss. The following procedures obtained for the test undertaken:

The filtration unit was set up with the top cap left open and a filter paper placed at the bottom part of the cell and a graduated cylinder placed under the cell assembly filtrate exit tube;

The mud was poured into the cell and about 10 millimeters of space was left from the top of the cell;

The top cap was closed and the T-screw was used to secure the assembly on the frame;

The T-screw was turned anticlockwise until the screw was free turning and the diaphragm pressure was relieved during which the Safety Bleeder valve on the regulator was in the closed position;

The air hose was connected to the pressure source and then the valve of the pressure source was opened to pressurize the hose.

The regulator was adjusted by turning the T-screw clockwise so that 40 psi was applied to the cell in 35 seconds. After this pressure was achieved the test begun and was stopped after 30 minutes after which the volume of filtrate was measured and the air flow was ceased by turning the regulator in a counterclockwise manner and the pressure source valve was closed while the relief valve was opened carefully.

5. TOXICITY TEST

After the mud has been formulated, it will then be tested on plants using beans seed, to see the effect on h replant growth and the living organisms in the soil. Beans seed was planted an exposed to 1500ml of the four different mud samples, the growth rate was measured, and the number of days of survival.

6. DISCUSSION OF RESULTS

6.1 Mud Density Values

The results as obtained from the density measurements using the mud balance are contained in Table 1, it clearly shows that the densities for walnut and soybeans have approximately similar readings with the base fluid that was gotten from the industry (jatropha), and after mixing the mud it also showed similar readings with the industry mud (jatropha). In all, these muds were compared with diesel based mud. Also the error differences between the calculated and measured densities for muds and base fluids all lie below 0.01, thus the readings obtained using the mud balance have a high accuracy. It also showed that the denser the base oil, the higher the starting density, and thus, the higher the amount of barite needed to build.

Table 1. Calculated and measured mud density values for the mud

Sample	Measured density (kg/m^3)	Calculated density (kg/m^3)
Jatropha	832	832.6
Walnut	833	833
Soyabeans	831	831.2
Diesel	826	826.1

6.2 Viscometer Readings

Viscosity readings obtained from the experiment carried out on the rotary viscometer are contained in Table 2. The Dial reading values (in Ib/100ft^2) are tabulated against the viscometer speeds in RPM, Plastic Viscosity, Apparent Viscosity, Yield Point and Gel Strength values are calculated with equations respectively as presented in Table 3.

Rheology formulae

1. Plastic Viscosity, μ_p (cp)= $\theta_{600} - \theta_{300}$
2. Apparent Viscosity, μ_a (cp)=$\frac{\theta_{600}}{2}$
3. Yield Point, τ_y (lb./100ft)=$\theta_{300} - \mu_p$

Tables 2 and 3 show that Diesel OBM has the highest viscosity followed by Soyabeans, Jathropha then Walnut. This infers that for reduced friction during drilling Walnut gives the best result even more that the control experiment (from the industry) followed by Walnut.

This means that diesel mud offers the greatest resistance to fluid flow. Therefore Walnut and Sayabeans pose better prospects in this area because of their low viscosities which means less resistance to fluid flow. This in turn will lead to reduction in wearing and tearing of the drill string.

7. FILTRATION TEST

The filtration tests were carried out at 350 kPa due to the level of the gas in the cylinder. The mud cakes obtained from the API filter press exhibit a slick, soft texture and spur loss these were calculated for each sample. From Table 4, it is inferred that Diesel OBM has the highest rate of filtration and spurt loss. The result shows that the mud cake from Diesel OBM is the most porous and the thickest. The thickness and filtration volume for Walnut and Soyabeans indicated that they are better in filtration properties than Diesel OBM.

7.1 Hydrogen Ion Potential

The Alkanality of a Drilling mud is determined when the pH value **i**s greater than 7. If the pH of the drilling mud is greater than 7, it will cause more shale problems as it would increase the viscosities and make it bad for the drilling properties to function properly. Therefore the best range of drilling mud is 8.3 to 9.5 this is because it gives the best hole stability and also helps to minimize shale problems (Fadairo et al 2012). The pH values of walnut, soybeans and jatropha shows better results since pH values lies within this range as observed and reported in Table 5.

7.2 The Result of Toxicity Experiment

After the samples of 150 ml of each sample were exposed to beans seed the numbers of days which the crop survived are as indicated in the graphs in Fig. 1. The growth rate was also measured i.e. the new length of the plant was measured at regular time intervals. But apparently it was noticed and indicated on the graph of the diesel base mud growth reduced, it was also observed that the leaves began to turn yellow-brown and the zero static values indicate when the plant died. The toxicity of a drilling fluid and/or of cuttings that are generated with the fluid is determined by the fluid composition and is measured using a variety of testing protocols.

Table 2. Viscometer readings for jatropha, soyabeans, walnut and diesel base fluids

Dial speed (RPM)	Jatropha	Walnut	Soyabeans	Diesel
600	134	128	130	143
300	126	120	125	138
200	115	110	102	132
100	100	100	100	127
60	110	96	94	100
30	97	87	88	96
6	95	80	85	90
3	90	75	80	88

Table 3. Viscosities gel strength, yield point, apparent viscosities

	Diesel	Jatropha	Walnut	Soyabeans
Plastic viscosity	15	6	5	7
Apparent viscosity	74	72.5	71.5	80
Yield point	132	112	113	113
Gel strength after 10 seconds	13	8.2	6	7.3
Gel strength after 10 minutes	18	16	12	12

Table 4. Filtration properties

	Diesel	Jatropha	Walnut	Soyabeans
Totalfluid volume	6.8 ml	6.0 ml	5.72 ml	5.7 ml
Oil voume	2.5 ml	1.0 ml	0.92 ml	0.9 ml
Water volume	5.3 ml	5.0 ml	4.8 ml	4.8 ml
Cake thickness	1.0 ml	0.89 ml	0.87 ml	0.87 ml
Thickness of filter paper	0.14 ml	0.14 ml	0.14 ml	0.14 ml

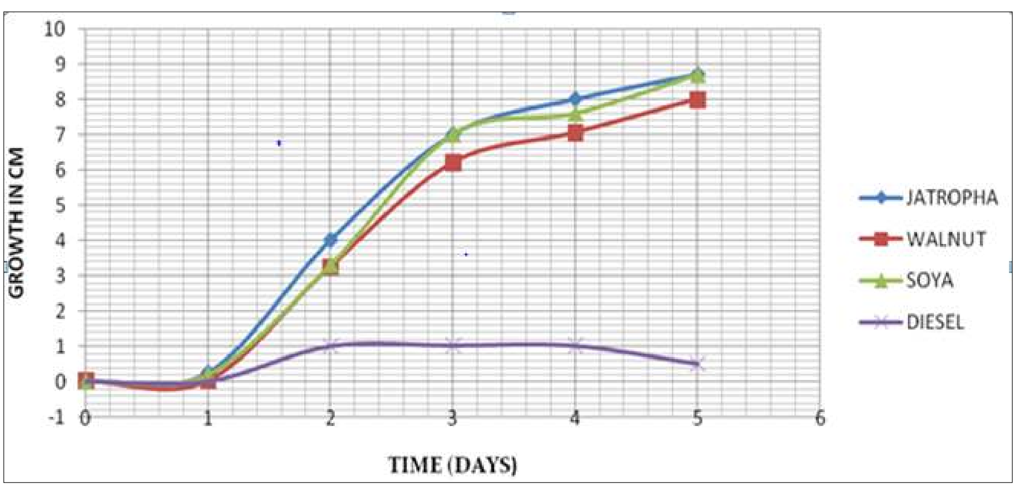

Fig. 1. Result of toxicity experiment showing growth rate of bean seed nurtured in different oil based mud samples

Table 5. Showing the Ph values

	Jatropha base mud	Walnut base mud	Soya base mud	Diesel base mud
PH value	9.0	9.0	9.0	8.0

8. CONCLUSION

The results of the tests carried out indicate that soya and walnut oil based SBMs poss great chances of being among the technically viable replacements of diesel OBMs. Also the beans that were nourished with synthesis based mud grow better (lower toxicity) than the beans nourished with diesel OBMs. The SBM have greater performance efficiency and lower pressure losses compared with diesel OBMs. Greater flexibility in encouraging innovation and new technology development for plant oil based mud as substitute to the conventional diesel based mud has been established.

9. RECOMMENDATION

This research should be further tested and investigated for the effect of temperature and pressure, during the solvent extraction an industrial scale should be used this would save a great lot of time.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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