



SPE 152865

Environmental Impact Evaluation of a Safe Drilling Mud

Fadairo Adesina, Ameloko Anthony, Adeyemi Gbadegesin, Ogidigbo Eseoghene, Airende Oyakhire
Department of Petroleum Engineering, Covenant University, Ota, Nigeria

Copyright 2012, Society of Petroleum Engineers

This paper was prepared for presentation at the SPE Middle East Health, Safety, Security, and Environment Conference and Exhibition held in Abu Dhabi, UAE, 2-4 April 2012.

This paper was selected for presentation by an SPE program committee following review of information contained in an abstract submitted by the author(s). Contents of the paper have not been reviewed by the Society of Petroleum Engineers and are subject to correction by the author(s). The material does not necessarily reflect any position of the Society of Petroleum Engineers, its officers, or members. Electronic reproduction, distribution, or storage of any part of this paper without the written consent of the Society of Petroleum Engineers is prohibited. Permission to reproduce in print is restricted to an abstract of not more than 300 words; illustrations may not be copied. The abstract must contain conspicuous acknowledgment of SPE copyright.

Abstract

Due to increase in environmental legislation against the disposition of oil based mud and an increase in environmental awareness, there is need for drilling companies to come up with a superior drilling mud with little or no aromatic content, which is biodegradable and environmentally friendly which poses no health hazard to oilfield workers and the host community.

For this study, oil extracted from the non food plant seeds (jatropha and canola seeds) were used as the base fluid for drilling mud samples in laboratory, oil in water emulsion was made using oil-water ratio of 70 to 30. 200ml of oil; 350ml of water, 50g of bentonite and barite was finally added to build the density up to 10ppg. Three mud samples were formulated with three different based fluids which are diesel, jatropha and canola oil based mud samples. Different mud laboratory tests such as toxicity, filtration, pH, viscosity and density were carried out on the three samples to ascertain their suitability properties for drilling operation and their degree of safety to the environment.

The results obtained show that jatropha has the lowest viscosity, which imply less resistance to flow and lower pressure losses. The outcome of toxicity test confirmed jatropha to be safer and less harmful to plant life and soil micro organism while diesel proved to be most toxic among the three samples. The overall results obtained from laboratory 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. The study serves as one of the ending solution to the environmental problem associated to oil based drilling operation especially in deep water exploitation.

Introduction

Oil-based drilling fluids have some advantages that make them especially desirable for drilling certain types of formations. Oil-based muds generally provide better performance in very hot or very cold environments. Oil-based muds cause fewer problems when drilling shale formations and allow drilling of salt zones with minimal dissolving of salt. However, there are greater costs and potential pollution problems which make it a bad choice for environmentally sensitive areas

Drilling mud is in varying degrees of toxicity. It is difficult and expensive to dispose in an environmentally friendly manner. Protection of the environment from pollutants has become a serious task. In most countries like Nigeria, the drilling fluids industries have had numerous restrictions placed on some materials they use and the methods of their disposal. Now, at the beginning of the 1990's, the restrictions are becoming more stringent and restraints are becoming worldwide issues. One of the products that have been particularly affected by restrictions is oil-based mud. This fluid has been the mud of choice for many environments because of their better qualities. Potential liability, latent cost, and negative publicity associated with an oil-mud spill are economic concerns. There is the urgent need for the drilling fluids industry to provide alternatives to diesel oil-based mud. Researches and surveys have been on track for the past two to three decades in response to harmful impact of diesel based mud on environment, and have come up with the new trend in the energy industry with the emergence of the use of plant oils as diesel substitutes. Over the years, plant oils have become increasingly popular in the raw materials market for diesel substitutes. The most popular being: Rapeseed oil, Jatropha oil, Mahua oil, Cottonseed oil, Sesame oil, Soya bean oil, palm oil etc. This brings about the importance of agro allied intervention in the energy industry.

In recent times, following the outcomes of the past researches carried out, synthetic oils are now considered more environmentally friendly than the conventional diesel or mineral oil based mud.

Among other researchers, Bailey et al¹ in 1986 examined fluid viscosities of muds formulated with a low toxicity mineral oil

(LTOBM) and diesel oil (OBM) with temperature and pressure. The use of mineral oils as replacements for diesel in drilling fluids was rapidly spreading at the time. They found that the greatest change in fluid apparent viscosity occurred when the testing temperatures were increased from 77°F (25°C) to 212°F (100°C), and at higher temperatures the rate of change was less.

In 1989, Fisk and Jamison² used a Dynamic HPHT testing unit to measure the behavior of OBM, LTOBM, and water-based muds with pressure and temperature. Equations were developed to predict fluid PV. Coefficients for fifteen OBM having different properties were averaged to obtain constants that could be used to predict the behavior of OBM on a general basis.

In 1991, Yassin et al³ 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. Tests were carried out on the physico-chemical properties of these oils such as flash point, pour point, aniline point, etc at varying temperatures and pressures.

Hemphil⁶ in 1996 carried out studies to predict the rheological properties of ester based drilling fluids under down hole conditions. Rheological tests that simulated field conditions were run in the laboratory on an ester-based drilling fluid from the field. The rheological behavior of the fluid was tested under varying ranges of temperature, pressure, and ester/water ratios. A predictive down hole rheological model of the ester-based drilling fluid was constructed using over eight hundred (800) fluid viscosity measurements. A general model has been developed to predict the downhole behavior of moderate-density ester-based drilling fluids with temperature and pressure.

Sundermann et al⁷ (1996) eliminated drilling problems with high temperature gas wells in northern Germany via the development and use of potassium formate (KCHO₂) biopolymer fluids. The formulated drilling fluid allowed a higher mud weight with fewer solids. It was then tested by drilling a 5 in section well at 16860 ft in 42 days. The ROP was 31.23 ft/D as against the 26.48 ft/D obtained using the CaCO₃ polymer mud. The biopolymer system proved to be very stable requiring only small chemical additions of viscosity and filtration control agents to keep the fluid properties within the desired range.

In 1999, Sanchez et al⁹ formulated drilling fluids from mineral oil (< 0.1% aromatics) and palm tree oil (without aromatic), both produced in Venezuela. Their work evaluated the toxicity and biodegradability of mineral and palm tree oil-based drilling fluids compared to those formulated with Diesel. Standard procedures were performed for both tests. The results indicate that mineral and palm tree oil based fluids are no toxic while Diesel showed high toxicity levels.

Sajjad et al¹⁰ (2008) implemented water based glycol muds as an alternative to diesel OBM's in Iranian oil fields. They focused on optimizing mud weight and overall environmental and economic advantages offered by these systems by emulsifying oil in the system and comparing its performance, environmental compatibility and cost with OBM's used in drilling low pressure zones in Iranian oil fields.

Xiaoqing et al¹¹ in 2009 developed environment acceptable modified natural macromolecule based drilling fluids, which are mainly composed of shale inhibitor agents, fluid loss control agent, bloomless white asphalt, and dry powders of poly alcohols. After series of rheological, performance and environment compatibility tests, formation damage control ability tests, inhibitive property test, they came up that the formulation is also suitable for both land and marine drilling activities, as its use did not disturb other field operations such as production, casing, and well logging.

Amin et al¹² in 2010 tested several esters as the external phase of an invert emulsion. The tests conducted with the esters included: elastomer compatibility testing, base oil viscosity, drilling fluid properties and toxicity. They also blended the esters with paraffin and mineral oils. These fluids were observed to be stable up to temperatures of about 121°C.

The contribution of non-edible oils such as jatropha oil, canola oil, algae oil, moringa seed oil and Soapnut have been significant as a plant oil source for diesel substitute production.

The paper formulates new environmental friendly oil based mud (using non food plant oil such as jatropha oil, canola oil) that can carry out the same function as diesel oil based drilling fluid and equally meeting up with the HSE (Health, safety and environment) standard.

EXPERIMENTAL PROCEDURE

PREPARATION OF SEEDS

The *Jatropha curcas* seeds were obtained from Ogun State, western part of Nigeria peeled, dried in an oven at about 80°C for seventy minutes. The dried seeds were then de-hulled, to remove the kernels. The brownish inner parts of the kernels were ground in a blender (to increase the surface area for the reaction)⁴⁻⁵.

EXTRACTION

The method employed in this is solvent extraction. Solvent Extraction is a process which involves extracting oil from oil-bearing materials by treating it with a low boiler solvent as opposed to extracting the oils by mechanical pressing methods (such as expellers, hydraulic presses, etc.) The solvent extraction method recovers almost all the oils and leaves behind only 0.5% to 0.7% residual oil in the raw material. In the case of mechanical pressing the residual oil left in the oil cake may be anywhere from 6% to 14%. (SRS Engineering manual). Here the equipment used was the Soxhlet extractor. A Soxhlet extractor is a piece of laboratory apparatus invented in 1879 by Franz von Soxhlet. It was originally designed for the extraction of a lipid from a solid material.

The extraction process went thus ^{4-5, 8}:

1. 50g of crushed *Jatropha curcas* seeds were measured out, and tied them in filter papers.
2. The sample was loaded into the main chamber of the Soxhlet extractor and poured in about 300ml of n-Hexane through the main chamber.
3. Placed the chamber into a flask containing the n-Hexane and made the other connections (the condenser, pipes, heating mantle, etc).
4. The heating mantle was turned on and the system was left to heat at 70° C. The solvent was heated to reflux. The solvent vapour travelled up a distillation arm, and flooded into the chamber housing the solid wrapped in filter papers. The condenser condensed the solvent vapour, and the vapour dripped back down into the chamber housing the solid material.
5. Then at a certain level, the siphon emptied the liquid into the flask.
6. This cycle was repeated until the sample in the chamber changed colour to a considerable extent, and collected the fluid mixture in glass reagent bottles.
7. The mixture was separated via the use of simple distillation, set up in the mud laboratory at Covenant University.
8. The distillation took place at 70°C; the hexane was recovered and re-used while the oil was stored.

MUD PREPARATION

Density

The densities of the various base fluids (water, canola oil, castor oil, *jatropha* oil and diesel) were measured using the mud balance.

1. Using the weighing balance, the various quantities of materials as shown in Table 1 were measured.
2. The quantities of water and oil were measured using measuring beakers.
3. Using the Hamilton Beach Mixer, the measured materials were thoroughly mixed until a homogenous mixture was obtained.
4. The mud samples were aged for 24 hours before measuring.

Viscosity

7. The mud was poured into the mud cup of the rotary viscometer, and the rotor sleeve was immersed exactly to the fill line on the sleeve by raising the platform. The lock knot on the platform was tightened.
8. The power switch located on the back panel of the viscometer was turned on.
9. The speed selector knob was first rotated to the stir setting, to stir the mud for a few seconds, and it was rotated to 600 RPM, waiting for the dial to reach a steady reading, the 600 RPM reading was recorded.
10. The above process was repeated for 300 RPM, 200 RPM, 100 RPM, 60 RPM, 30 RPM and 6 RPM.
11. Steps 7 to 10 were repeated for other samples.

Gel Strength

12. The speed selector knob was then rotated to the stir setting to stir the mud sample for a few seconds, then it was rotated to gel setting and the power was immediately shut off.
13. As soon as the sleeve stopped rotating, the power was turned on after 10 seconds and 10 minutes respectively. The maximum dial was recorded for each case.
14. Steps 12 and 13 were repeated for other samples.

Mud Filtration Properties

15. The assembly is as shown in the Diagram 4

16. Each part of the cell was cleaned dried, and the rubber gaskets were checked.
17. The cell was assembled as follows: base cap, rubber gasket, screen, filter paper, rubber gasket, and cell body.

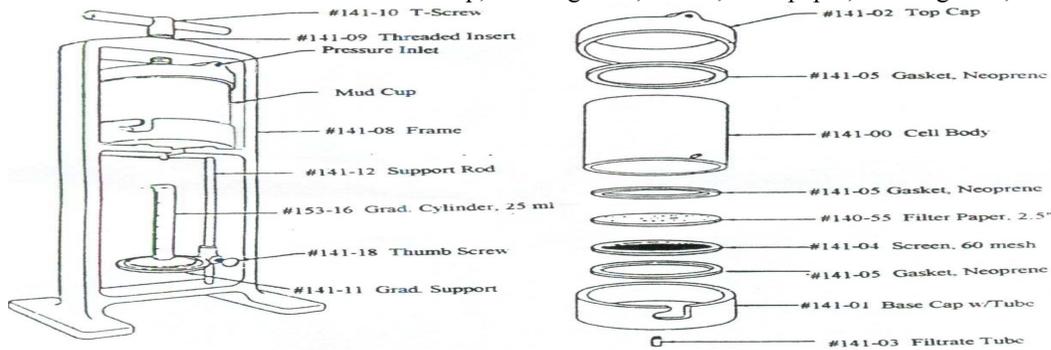


Diagram 4: API Filter Press⁸

18. A freshly stirred sample of mud was poured into the cell to within 0.5 inch (13 millimeters) to the top in order to minimize contamination of the filtrate. The top cap was checked to ensure that the rubber gasket was in place and seated all the way around and complete the assembly. The cell assembly was placed into the frame and secured with the T-screw.
19. A clean dry graduated glass cylinder was placed under the filtrate exit tube.
20. The regulator T-screw was turned counter-clockwise until the screw was in the right position and the diaphragm pressure was relieved. The Safety Bleeder Valve on the regulator was put in the closed position.
21. The air hose was connected to the designated pressure source. The valve on the pressure source was opened to initiate pressurization into the air hose. The regulator was adjusted by turning the T-screw clockwise so that a pressure was applied to the cell in 30 seconds or less. The test period begins at the time of initial pressurization.
22. At the end of 30 minutes the volume of filtrate collected was measured. The air flow through the pressure regulator was shut off by turning the T-screw in a counter-clockwise direction. The valve on the pressure source was then closed and the relief valve was carefully opened.
23. The assembly was then dis-mantled, and the mud was removed from the cup.
24. The filter cake was measured using a vernier caliper, and the measurements were recorded.
25. The above procedures were carried out for the other mud samples.

Hydrogen Ion Concentration (pH)- Colorimetric Paper Method

26. A short strip of pH paper was placed on the surface of the sample.
27. After the color of the test paper stabilized, the color of the upper side of the paper, which had not contacted the mud, was matched against the standard color chart on the side of the dispenser.
28. Steps 26 and 27 were carried out on other samples.

TOXICITY TEST

29. After the three oil based mud samples have been formulated, it is then tested on plants that is on beans seedling, to see the effect on the plant growth and the living organisms in the soil. Bean seed was planted and exposed to 100ml of the three different mud samples, with the following base fluids; diesel, canola and jatropha, the growth rate was measured, and the number of days of survival.

Discussion of Results

The results as obtained from measurements of density using the mud balance are tabulated in Table 1. The error differences between the calculated and measured densities all lie below 0.1, 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 Density Values

Sample	Measured Density(ppg)	Calculated Density(ppg)
Diesel (A)	8.26	8.261
Canola (B)	8.47	8.470
Jatropha (C)	8.32	8.326

Viscosity and Gel Strength

Viscosity readings obtained from the experiment carried out on the rotary viscometer are contained in Table 2. The Dial

reading values (in lb/100ft²) 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.

Apparent viscosity= $\theta_{600}/2$

Table 2 Viscometer Readings for diesel, canola and jatropa

Dial Speed(RPM)	Diesel mud	Canola mud	Jatropha mud
600	149	158	128
300	136	146	120
200	129	136	115
100	128	135	114
60	126	133	113
30	125	130	111
6	124	128	110
3	50	55	60

Table 3 Viscosities, Gel Strength, Yield Point, Apparent Viscosities

	Diesel	Canola	Jatropha
Plastic Viscosity	13	12	8
Apparent Viscosity	74.5	79	64
Yield Point	123	132	112
Gel Strength	50/50.5	55/56.5	60/72

Diesel mud had the highest viscosity, followed by Canola mud and then Jatropha mud. This infers that for reduced friction during drilling, Jatropha gives the best results, followed by Canola.

This means diesel mud offers the greatest resistance to fluid flow. Therefore, Canola and Jatropha pose better prospects in this area in the sense that their lower viscosities will mean less resistance to fluid flow. This will in turn lead to reduction in wearing and tearing of the drill string.

Comparism between the mud types

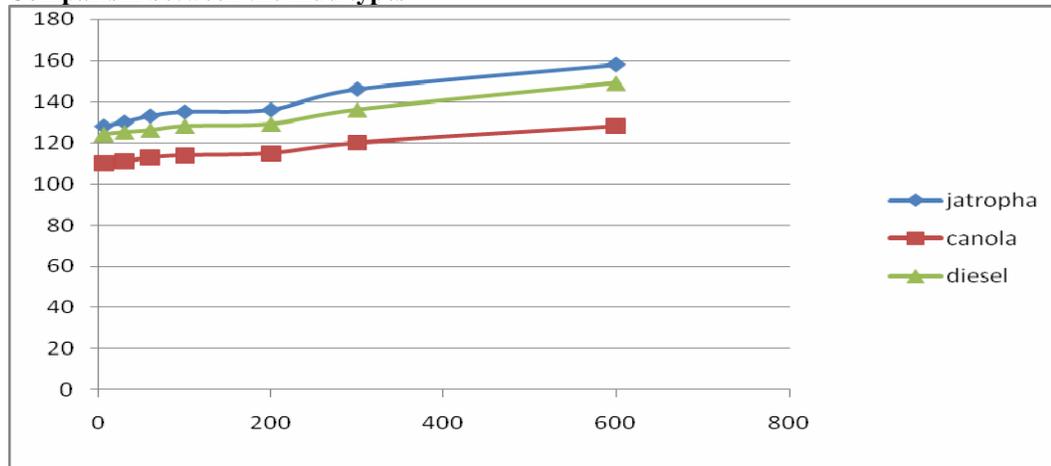


FIG 1: COMPARISM OF SHEAR RATE TO SHEAR STRESS OF THE THREE DIFFERENT MUD TYPES

From the above figure, it can be seen that the plot of shear stress to shear rate of the three different muds gave a graph similar to the bingham plastic model. The Bingham Plastic model is the standard viscosity model used throughout the industry, and it can be made to fit high shear- rate viscosity data reasonably well, and is generally associated with the viscosity of the base fluid and the number, size, and shape of solids in the slurry, while yield stress is associated with the tendency of components to build a shear-resistant. It can be seen from the table that jatropha and canola gave better pressure loss results than diesel as a result of lower plastic viscosities, and hence should be encouraged for use during drilling activities

Mud Filtration

The filtration tests were carried out at 350 kPa due to the low level of the gas in the cylinder.

Table 4 Filtration Properties

	Diesel mud	Jatropha	Sample C
Total Fluid Volume	6.8 ml	6.4 ml	6.0 ml
Oil Volume	2.5 ml	1.2 ml	1.0 ml
Water Volume	5.3 ml	5.2 ml	5.0 ml
Cake Thickness	1.0 mm	0.9mm	0.89mm

The filtration tests were carried out at 350 kPa due to the low level of the gas in the cylinder. The mud cakes obtained from the API filter press exhibited a slick, soft texture and spurt loss was calculated for each samples. From Table 4, it is inferred that Diesel OBM has the highest rate of filtration and spurt loss. Comparing this to a drilling scenario, this means that the mud cake from Diesel OBM is the most porous, and it is the thickest. From these inferences, Jatropha and Canola OBM's are better in filtration properties than Diesel OBM due to the factors of thickness and filtration volumes.

Hydrogen Ion Potential

Table 5, pH Values

	Diesel mud	Canola mud	Jatropha mud
pH Value	8	9.5	9

Drilling muds are always treated to be alkaline (i.e., a pH > 7). The pH will affect viscosity, bentonite is least affected if the pH is in the range of 7 to 9.5. Above this, the viscosity will increase and may give viscosities that are out of proportion for good drilling properties. For minimizing shale problems, a pH of 8.5 to 9.5 appears to give the best hole stability and control over mud properties. A high pH (10+) appears to cause shale problems.

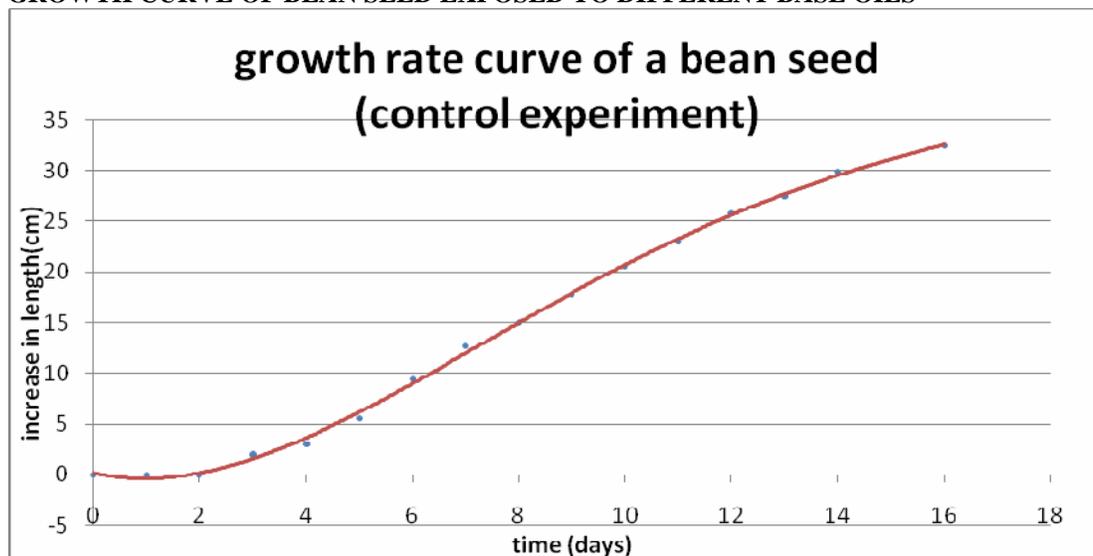
The corrosion of metal is increased if it comes into contact with an acidic fluid. From this point of view, the higher pH would be desirable to protect pipe and casing (Baker Hughes, 1995)

The pH values of all the samples meet a few of the requirements stated but diesel mud Sample A with a pH of less than 8.5 falls short. Canola and Jatropha mud samples show better results since their pH values fall within this range.

RESULT OF THE TOXICITY EXPERIMENT

Samples of 100ml of each of the selected oils were exposed to both corn seeds and bean seed and the no of days which the crop survived are as indicated in the graph below. The growth rate was also measured i.e the new length of the plant was measured at regular time intervals. For the graph of toxicity of diesel based mud the reduced growth rate indicates when the leaves began to yellow, and the zero static values indicate when the plant died.

GROWTH CURVE OF BEAN SEED EXPOSED TO DIFFERENT BASE OILS

**FIG 2: growth rate curve of a bean seed (control experiment)**

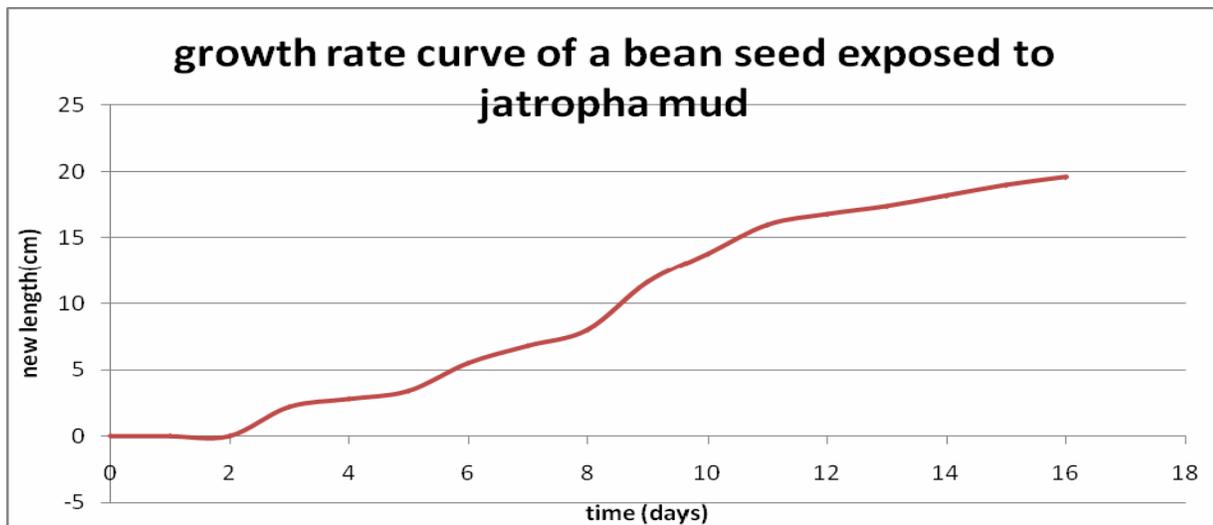


FIG. 3: Growth rate curve of a bean seed exposed to jatropha based mud

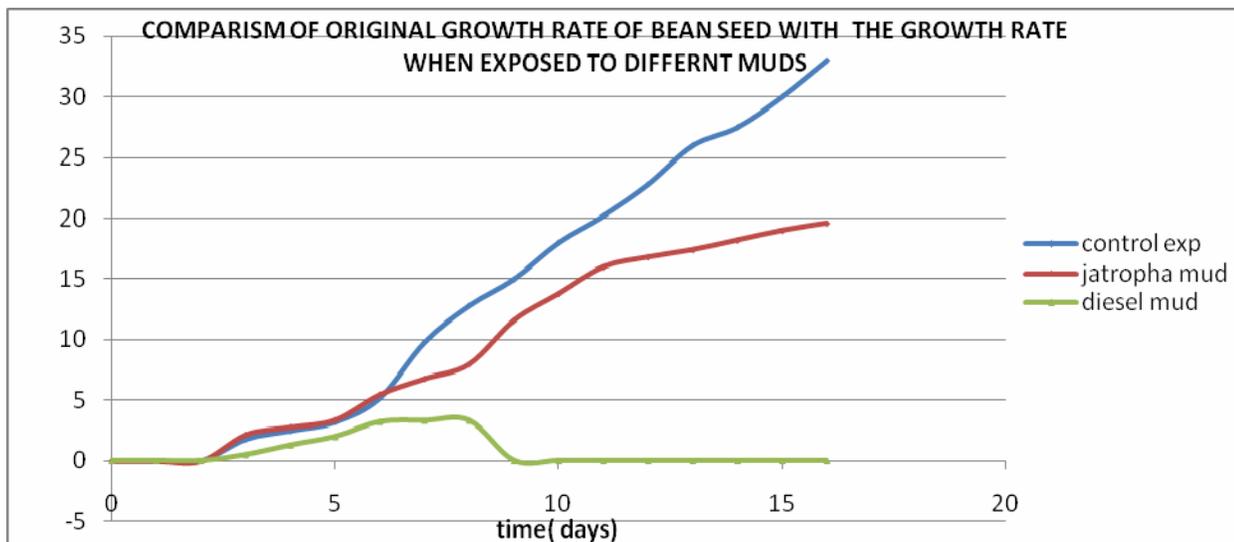


FIG. 4: COMPARISM OF GROWTH RATE CURVE OF DIFFERENT MUD TYPES

From the results indicated by the figure 4 above, it can be concluded that jathropha oil has less harmful effect on plant growth compared to canola and diesel. Bean seeds were planted and after one week, they were both exposed to 100ml of both jathropha formulated mud and diesel formulated mud. The seeds exposed to jathropha survived for 18 days, while that exposed to diesel mud survived for 6 days and then withered. When the soil was checked, there was no sign of any living organisms in diesel mud sample while that of the jathropha mud, there were signs of some living organisms such as earth worms, and other little insects. This shows that jathropha mud sample is environmentally safer for both plants and micro animals than diesel mud sample.

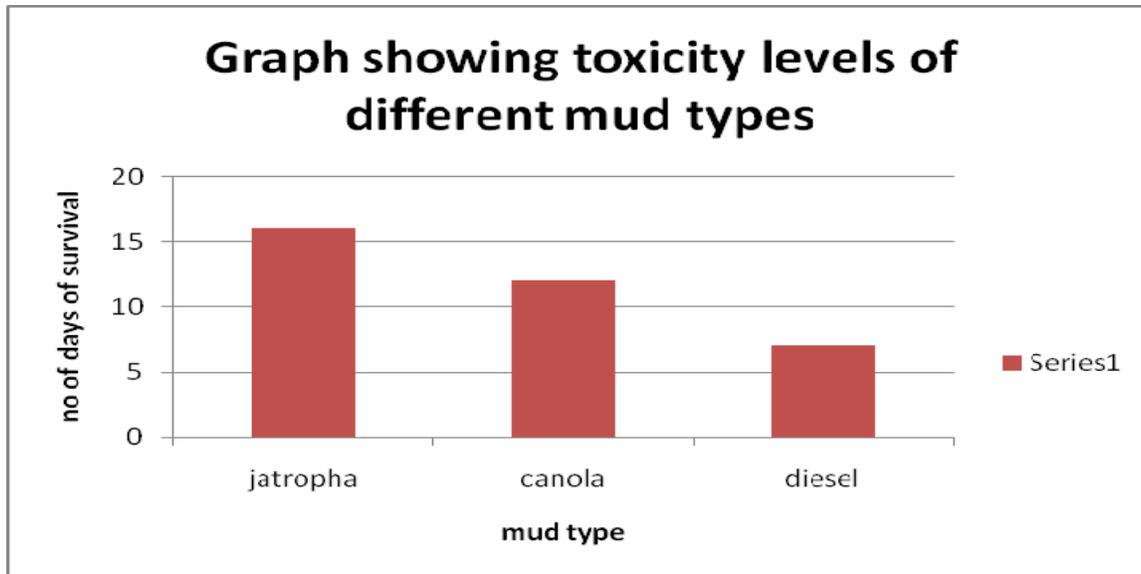


FIG. 5: Graph of toxicity of different mud types

From the figure 5 above it can be seen that the seeds exposed to jatropha had the highest number of days of survival which indicates its lower toxicity while that of diesel had the lowest days of survival which indicates its high toxicity. The toxicity of diesel can be traced to high aromatic hydrocarbon content. Therefore, replacements for diesel should either eliminate or minimize the aromatic contents thereby making the material non toxic or less toxic. Biodegradation and bioaccumulation however depend on the chemistry of the molecular character of the base fluids used. In general, green material i.e plant materials containing oxygen within their structure degrade easier.

CONCLUSIONS

SBMs are superior to OBMs in the following ways

- Better rheological properties
- Lower toxicity
- Less drilling waste is produced compared to oil based mud
- Natural gas is less soluble in SBFs than in most OBFs, making it easier to detect gas kicks
- SBMs have greater performance efficiency
- Lower pressure losses are recorded with sbms as compared with diesel(using jatropha as a case study)

RECOMMENDATIONS

Greater regulatory flexibility in encouraging innovation and new technology development for plant oil based mud as substitute to the conventional diesel based mud should be established. This would improve the alternative pollution prevention technology in oiland gas drilling operation. It is recommended that further tests should be carried out to formulate non food plant oil based mud under standard conditions and with suitable additives, and the mud should be used to drill so that precise and accurate data can be gotten and documented.

ACKNOWLEDGEMENTS

We wish to thank all members of staff Department of Petroleum Engineering Covenant University, Nigeria for their technical supports in carrying out this research work especially Prof. Churchill Ako. We also acknowledge the support of FatherHeroes Forte Technology Consult Nigeria for their commitment.

REFERENCES

1. Bailey, T., Bern, P., and McEwan, F., (1986) "Low Toxicity Oil Muds: A Knowledge of Downhole Rheological Behavior Assists Successful Field Application", *SPE Drilling Engineering* (April 1986) 107-114.
2. Fisk, J. and Jamison, D., (1989) "*Physical Properties of Drilling Fluids at High Temperatures and Pressures*". *Drilling Engineering* (December, *SPE* 1989) 341-346.

3. Yassin .A., Kamis .A., Mohamad .O.A., (1991) “*Formulation of an Environmentally Safe Oil Based Drilling Fluid*” SPE 23001, Paper presented at the SPE Asia Pacific Conference held in Perth, Western Australia, 4-7 November 1991.
4. Ogidigbo Esseoghene (2011) “*An Environmental Friendly And Cost Effective Alternative To Diesel Based Muds*” B.Sc Thesis, Department of petroleum Engineering, Covenant Un iversity, Nigeria, 2011.
5. Airende Oyakhire (2011) “*Predicting the Downhole Behavior of Environmentally Friendly Oil-Based Drilling Fluid at Varying Temperatures Using Artificial Neural Network*” B.Sc Thesis, Department of petroleum Engineering, Covenant University, Nigeria, 2011.
6. Terry Hemphil, (1996) “*Prediction of Rheological Behavior of Ester-Based Drilling Fluids under Downhole Conditions*” SPE 35330. Paper presented at .s1 The 1996 SPE International Petroleum Conference and Exhibition of Mexico held in Villahermosa, Tabasco 5-7 March 1996.
7. Sundermann .R., and Bungart .D., (1996) “*Potassium Formate Based Drilling Fluid Solves High-Temperature Drill-In Problem*” JPT November 1996
8. Fadairo A.S. Adesina, Adeyemi Abiodun and Ameloko Anthony (2011) “*Evaluation Of Environmentally Friendly Oil Based Drilling Mud*” Applied Clay Science (Under Review), 2011.
9. G. Sáchez; N. León, M. Esclapés; I. Galindo; A. Martínez; J. Bruzual; I. Siegert, (1999) “*Environmentally Safe Oil-Based Fluids for Drilling Activities*” SPE 52739, Paper presented at SPE/EPA Exploration and Production Environmental Conference held in Austin, Texas, 28 February–3 March 1999.
10. Sajjad .J.C., Tahmasbi .K, and Niloofar .A., (2008) “*The Possibility of Replacing OBM’s with Emulsified Glycol Systems in Drilling Low-Pressure Zones of Iranian Oilfields*” SPE 114067. Paper presented at the IADC/SPE Asia Pacific Drilling Technology Conference and Exhibition held in Jakarta, Indonesia, 25-27 August, 2008.
11. Xiaoqing .H. and Lihui .Z., (2009) “*Research on the Application of Environment Acceptable Natural Macromolecule Based Drilling Fluids*” SPE 123232, Paper presented at the SPE Asia Pacific Health, Safety, Security and Environment Conference and Exhibition held in Jarkata, Indonesia, 4-6 August 2009.
12. Amin .R.A.M., Clapper .D.K., Norfleet .J.E., Otto M.J., T. Xiang, C.A. Hood, J.E. Goodson, D.P. Gerrard, (2010) “*Joint Development of an Environmentally Acceptable Ester Based Drilling Fluid*” SPE 132693, Paper presented at the Trinidad and Tobago Energy Resource conference held in Port of Spain, Trinidad, 27-30 June 2010.
13. Adil Mohamed O. H. and Remy Azrai M. A., (2010) “*Density Measurement of Vegetable and Mineral Based Oil Used in Drilling Fluids*”. SPE 136974. Paper presented at the 34th Annual International Conference and Exhibition in Tinapa-Calabar, Nigeria, July 31st- August 7th, 2010.
14. Dosunmu .A. and Ogunrinde .J. (2010) “*Development of Environmentally Friendly Oil Based Mud using Palm Oil and Groundnut Oil*”. SPE 140720. Paper presented at the 34th Annual International Conference and Exhibition in Tinapa-Calabar, Nigeria, July 31st- August 7th, 2010.