Formulation of Oil-Based Drilling Fluids (Muds) From Plant Seed Oil (GmelinaArborea Seed Oil)

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Abstract
Due to increase in environmental issues, there is need for drilling companies to come up with a safer, environmental friendly oil-based drilling fluid. For this study, oil extracted from non-food plant seed (Gmelina) was used as the base fluid for drilling mud samples in laboratory. The oil extracted was tested and compared with the standard requirements for oil needed for oil based drilling fluid. Results showed that the oil met the requirements and can be used in formulation of oil based muds. Oil in water emulsion was made using oil/water ratio of 60 to 40. 200ml of oil and 350 ml of water. 50g of bentonite and barite were finally added to build up the density to 10ppg. The mud sample was formulated with Gmelina seed oil as the base fluid and compared to a diesel based mud sample of same quantity. Different mud tests such as toxicity, filtration, pH, viscosity and density were carried out on the samples to ascertain the suitability of their properties for drilling operation and their degree of safety to the environment. The results obtained showed that Gmelina seed oil-based mud has the lowest viscosity which implies less resistance to flow and lower pressure losses. The outcome of the toxicity test confirmed Gmelina to be safer and less harmful while diesel is highly toxic as expected. The overall result obtained from the test indicates that Gmelina seed oil based muds stands a chance of being among the technically and environmentally viable replacement for the conventional diesel oil-based muds. The study serves as one of the solutions to the environmental problem associated with oil-based drilling operations.

Keywords: Formulation, Oil-Based Drilling Mud, Plant Seed Oil, Gmelina Arborea, Diesel Oil.

1. Introduction

Oil is one of the most important resources in the lives of many. Many of the products, ranging from transportation to household items to recreational items, are made from oil. In transportation for example, tires are made from oil. Synthetic rubber, one of the main raw materials of tires is produced from the polymers found in crude oil. Another example, one of the most obvious would be gasoline, which also comes from crude oil. It can also be used as base oil in the formulation of oil based drilling fluids which is the basis for this research.

Researchers have been carrying out studies on the possible uses of other oil producing substances found in people's everyday lives.

Oil can be produced from various sources. One of the most widely used sources of oil since the 18th century is fossil fuel. In 2004, 86% of human-produced energy came from burning fossil fuels. Fossil fuels are derived from fossilized remains of dead plants and animals exposed to heat and pressure in the Earth's crust over hundreds of millions of years. It takes that long to produce fossil fuels and today, it is depleting faster than new ones are being made. It is for this reason that people are looking for other alternative sources of oil and one of those resources is biomaterial.

Many sources of oil are being considered nowadays. It has been found that oil can be extracted from various plants such as Croton tiglium Linn, tuba-tuba, durian seeds and many others.

Oil produced from Gmelina seeds is being considered by this researcher because based on observations, these seeds aside from the fact that they are not proven to be edible to humans, seem to be neglected as they are left on the ground to rot and be trampled upon thereby making them useless. Now Gmelina seeds are already proven to produce oil. This fact itself is already useful information for researchers who seek to find alternative sources of oil. With this in mind, this research is to find out if this oil can be used in the production of oil based drilling fluids.

To give a brief background about the species, Gmelina (Gmelina Arborea Roxb., family Vernabaceae) is one of the abundant trees scattered in Nigeria. In fact, there are hundreds of hectares of plantation already established here in Nigeria. It is locally known as Gamhar, it is being planted extensively for experimental purposes these days.

GmelinaArborea is a fruit of the gmelinaarborea tree. It is a long green fruit that ripens to yellow color, the hairless fruits are 10 to 15mm in diameter and is glossy yellow when they mature; they are recorded as having a bittersweet taste. The fruit is mainly used to extract its juice for the making of polish. The chemical composition of the gmelinaarborea is a combination of arboreal and premnazole. Gmelina seed is also a non-food plant and asides from being used as polish; it basically has no other use which makes it a very good renewable source of oils for biodiesels.

Gmelina is mainly grown for its wood which is used for plywood furniture, paper, matches, musical instruments, ornaments, etc. Some livestock holders use its fruits as one of their feeds. But most often, these fruits are just left to scatter around the trees.

Through some particular processes, Gmelina seed oil could be proven to be one of the possible sources of biofuel. Over the years, scientists and researchers have discovered the presence of oil in gmelina seed and its oil has been said to be of a good quality which can equal that of the conventional diesel oil. The oil from the gmelina seed will appear to be even better than that of diesel oil as it has a low aromatic content which makes its toxicity levels very low.

This study however, is limited to using the extracted oil from the Gmelina seed to formulate an oil based drilling fluid. The fig below shows the image of a typical Gmelina seed.

Figure 1.0: Gmelina seeds

Current Trends In The FormulationofWBDF

The water based drilling fluids, which simulate the performance of the oil-based drilling fluid are commonly referred to as high performance water based fluids (HPWBF) (Morton, 2005; West and Morales, 2006; Dye, 2006; Patel, 2007; Marin et al, 2009). The main benefits of HPWBF include the reduction of environmental impacts, and lower down costs associated with cuttings and fluids disposal. Reid et al. (1992) evaluated a novel inhibitive water-based fluid for tertiary shale that was formulated primarily from tetra-potassium pyrophosphate (TKPP or K4P207). They observed that the formulation was considerably more inhibitive than other mud systems (even approached the level of that observed with oil based mud). Kjonses et al. (2003) designed a water-based drilling fluid from a mixture of potassium chloride and polymers such as poly-anioniccelluoses/xathan gum. When this mud is applied, they observed that the formulation resulted in improved hole-cleaning optimization, and hole-stability. Al-Ansari et al. (2005) formulated a HPWBM comprising of partially hydrolyzed polyacrylamide (PHPA, for cuttingencapsulation) and polyamide derivatives (for suppressing the hydration and dispersion tendency of reactive clays). In their conclusions, they stressed the fact that the formulation which had been used successfully to drill several wells in the Arabian Gulf is an environmentally friendly and performance driven alternative to OBM.

Young and Ramses (2006) developed a unique water-based fluid by blending a hydration suppressant, a dispersion suppressant, a rheology controller (xathan gum), a filtration controller, and an accretion suppressant. The formulation according to them delivered an invert emulsion-like drilling performance. Ramirez et al. (2007)

developed an aluminum-based HPWBM that was used successfully to drill an exploratory well in the Magellan Strait, Argentina. They claimed that not only did the HPWBM replace the oil-based mud, it is also environmentally friendly. Marin et al. (2009) formulated a HPWBF from a blend of salt and polymers at different mud weights. They recommended the inclusion of sized calcium carbonate if drilling through high permeability sands.

1.2 Materials and Method

Materials

The researcher had earlier carried out extraction and characterization of oil from gmelina seed. The seeds used in the experiment were gathered from the litters (fallen seeds) around the gmelina trees in the researchers University premises.Oil obtained from this research seemed to satisfy the requirements as a potential replacement for base oil in the formulation of oil-based drilling mud.
Other materials used include bentonite and barite as builders.

Methods

Preparation of Oil-Based Drilling Mud.

The density of the base fluid (gmelina seed oil) was measured using the mud balance.

- Using the weighing balance, the various quantities of materials as shown in Table 2 below were measured.
- The quantities of water and oil were measured using measuring beakers.
- Using the manual mixing method (mixing in a bowl with a spatula), the measured materials were thoroughly mixed until a homogenous mixture was obtained.
- The mud samples (gmelina and diesel based) were aged for 24hours.

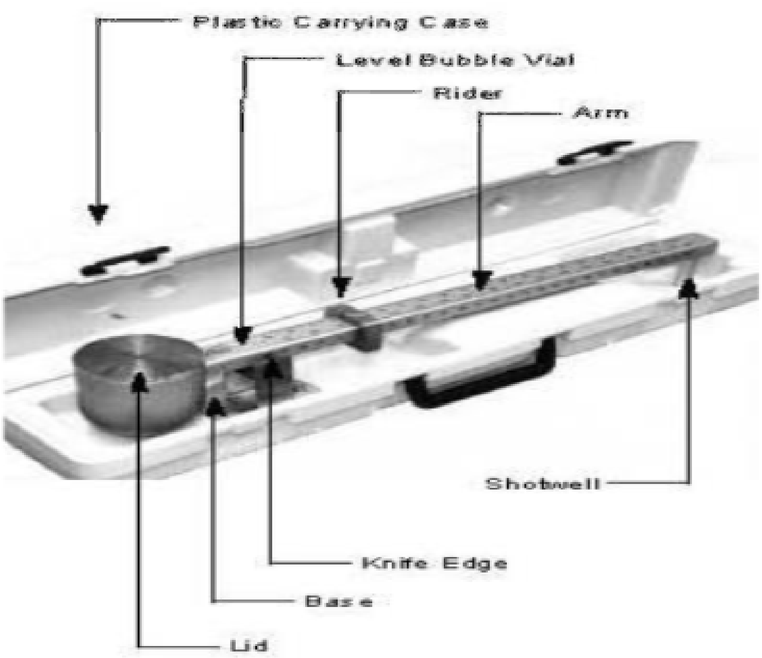

Figure 1.1: Mud balance

Determination of Mud Density.

- The aged mud samples were agitated for 2 minutes using the spatula.
- The clean, dry mud balance cup was filled to the top with the newly agitated mud.

- The lid was placed on the cup and the balance was washed and wiped clean of overflowing mud while covering the hole in the lid.
- The balance was placed on a knife edge and the rider moved along the arm until the cup and arm were balanced as indicated by the bubble.
- The mud weight was read at the edge of the rider towards the mud cup as indicated by the arrow on the rider and was recorded.
- Steps 1 to 5 were repeated for the other sample.

Determination of Mud Viscosity.

- 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.
- The power switch located on the back panel of the viscometer was turned on.
- The speed selector knob was first rotated to the stir setting, to stir the mud for a few seconds, and it was rotated at 600RPM, waiting for the dial to reach a steady reading, the 600 RPM reading was recorded.
- The above process was repeated for 300 RPM, 200 RPM, 100 RPM, 60 RPM, 30 RPM, 6 RPM and 3 RPM.
- Steps 7 to 10 were repeated for the other sample.

Figure 1.2: Rotational viscometer.

Determination of Mud Gel strength.

- The speed selector knob was then rotated to stir the mud sample for a few seconds, then it was rotated to gel setting and the power was immediately shut off.
- 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.
- Steps 12 to 13 were repeated for the other sample.

Determination of Mud Filtration Properties.

- The assembly is a shown in figure 4.0.
- Each part of the cell was cleaned, dried and the rubber gaskets were checked.
- The cell was assembled as follows: base cap, rubber gasket, screen, filter paper, rubber gasket and cell body.

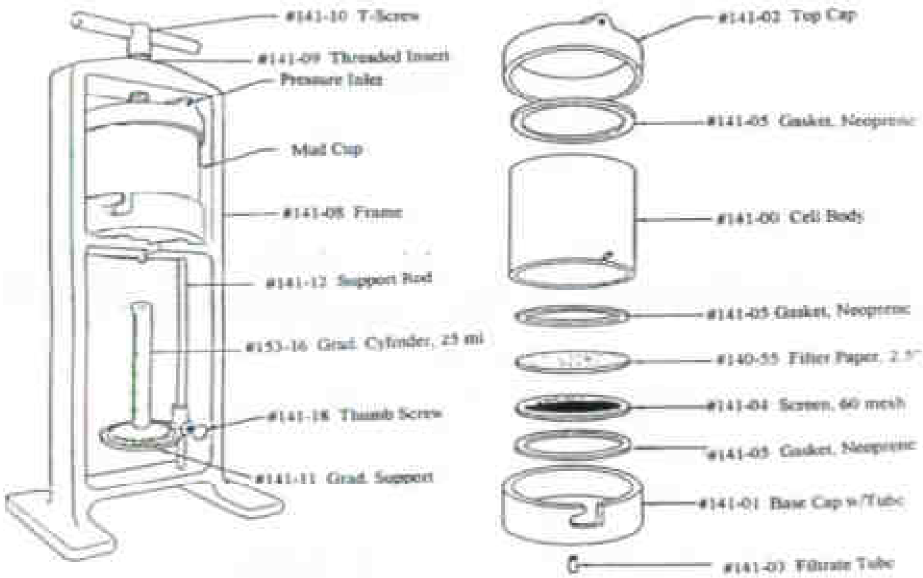

Figure 1.3: API Filter Press.

- 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.
- A clean dry graduated glass cylinder was placed under the filtrate exit tube.
- 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.
- 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.
- 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 counterclockwise direction. The valve on the pressure source was then closed and the relief valve was carefully opened.
- The assembly was then dismantled, and the mud was removed from the cup.
- The filter cake was measured using a vernier caliper, and the measurements were recorded.
- The above approach was repeated for the other sample.

Determination of Mud Hydrogen ion concentration (pH) - Calorimetric paper method.

- A short strip of pH paper was placed on the surface of the sample.
- 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.
- Steps 26 and 27 were carried for the other sample.

Determination of the Toxicity Level of the Mud.

- After the oil based mud samples have been formulated, each is then tested on a growing plant (that is on beans seedling), to see the effects on the plant growth and the living organisms in the soil. Bean seed was planted and exposed to 100ml of two different mud samples, with the following base fluids; diesel and gmelina, the growth rate was measured, and the number of days of survival.

1.2.1 Results of Analysis Of The Formulated Mud

Mud Density Measurement.

The results obtained from measurements of density using the mud balance are contained in the table below.

SAMPLE	MEASURED DENSITY (ppg.)	CALCULATED DENSITY (ppg.)	ERROR	BARITE (g)
Diesel	8.26	8.261	0.01	119.1
Gmelina	8.32	8.326	0.06	154.5

Table 1.0: Mud Density Values.

Mud Viscosity and Gel Strength.

Viscosity readings obtained from the experiment carried out on the rotary viscometer are contained in the table 2.0.

The dial reading values (in lb./100sq.ft) are tabulated against the viscometer speeds in RPM.

DIAL SPEED	DIESEL	GMELINA
600	185	154
300	170	133
200	169	124
100	163	114
60	152	107
30	145	98
6	122	92
3	81	76

Table 2.0: Viscometer Readings for Diesel and Gmelina Oil-Based Muds.

The values for the rheological properties (Plastic viscosity, apparent viscosity, Gel strength, Yield point, consistency index and flow index) of both the gmelina and diesel oil based muds are contained in the table below.

RHEOLOGICALPROPERTIES	DIESEL	GMELINA
PLASTIC VISCOSITY	15	21
APPARENT VISCOSITY	92.5	77
GEL STRENGHT	50/51	54/55
YIELD POINT	92.5	77.0
CONSISTENCY INDEX	0.1219	0.2113
FLOW INDEX	79.51	35.61

Table 3.0: Plastic Viscosities, Apparent Viscosities and Gel Strength.

Diesel Oil-Based Mud has the highest apparent viscosity.

Mud Filtration Results.
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.

FILTRATION PROPERTIES	DIESEL	GMELINA
TOTAL FLUID VOLUME	6.9ml	6.3ml
OIL VOLUME	2.3ml	1.1ml
WATER VOLUME	4.6ml	4.2ml
CAKE THICKNESS	1.0mm	0.8mm

Table 4.0: Mud Filtration Results.

Hydrogen ion potential Results.
The table below is the results from the hydrogen ion potential tests carried out on the mud samples.

TYPE OF OIL	DIESEL	GMELINA
pH VALUE	8	11.06

Table 3.5 pH Values.

3.4 Results for Cuttings Carrying Index (CCI).
The table below shows the results obtained from the cuttings carrying index test.

OBMs	DIESEL	GMELINA
CCI	15.901	19.067

Table 5.0: Cuttings Carrying Indices (CCI,s)

Results on Toxicity Measurements of Mud.
The seeds exposed to gmelina 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 gmelina mud, there were signs of some living organisms such as earth worms, and other little insects.

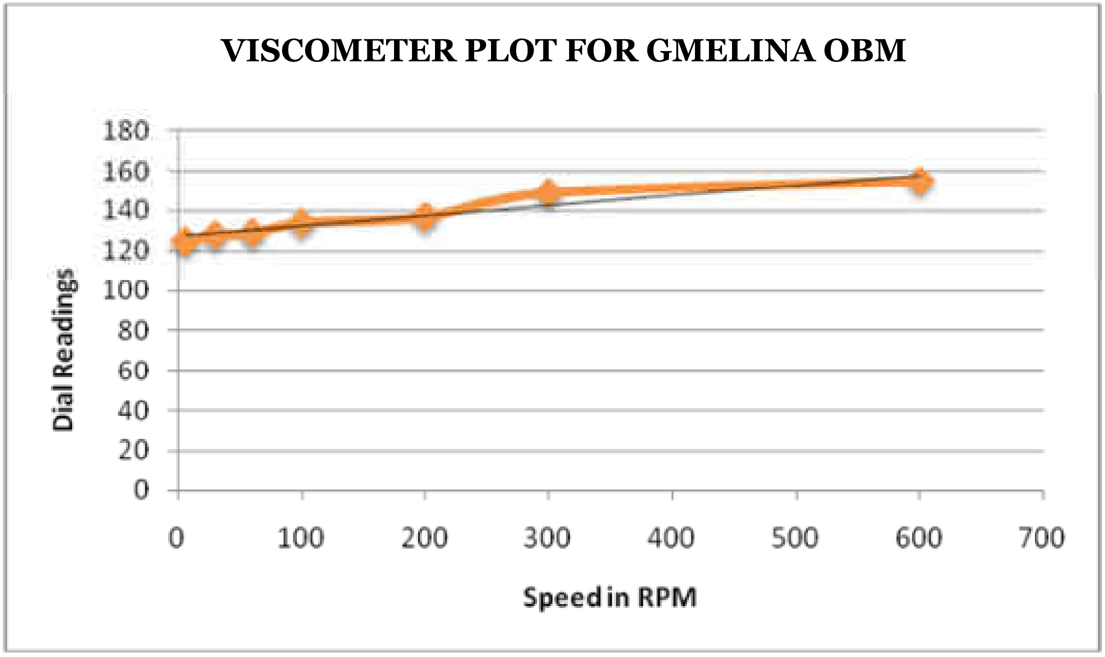

Figure.1.4: Viscometer Plot for Gmelina Oil-Based Mud.

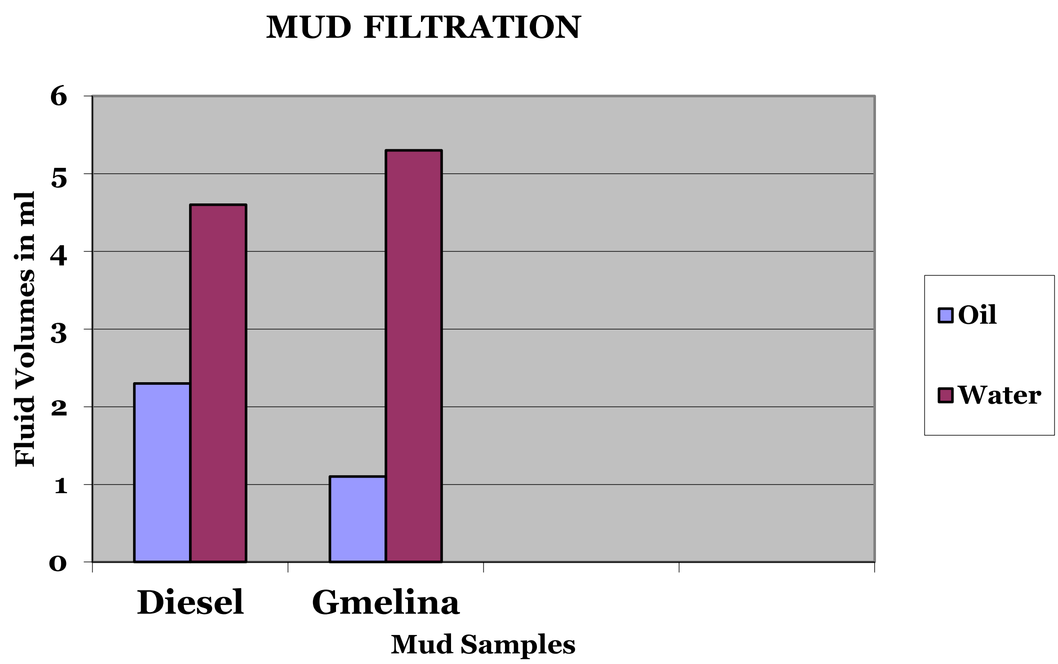

Figure.1.5: Mud Filtration Volumes for Diesel and Gmelina OBMs.

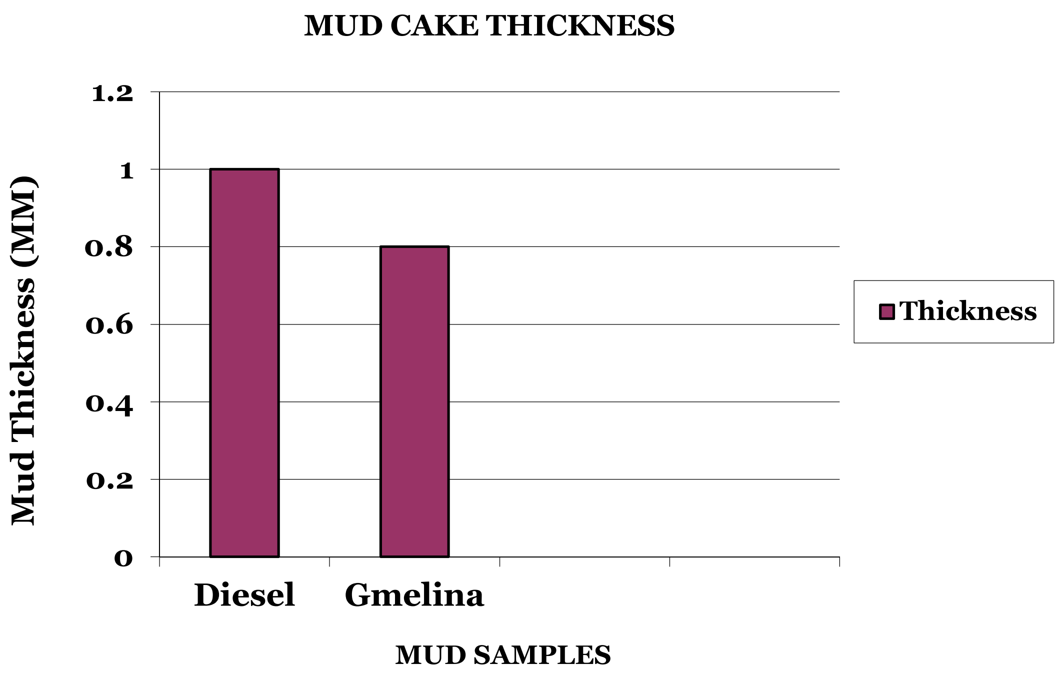

Figure.1.6: Mud Cake Thicknesses for Gmelina and Diesel OBMs

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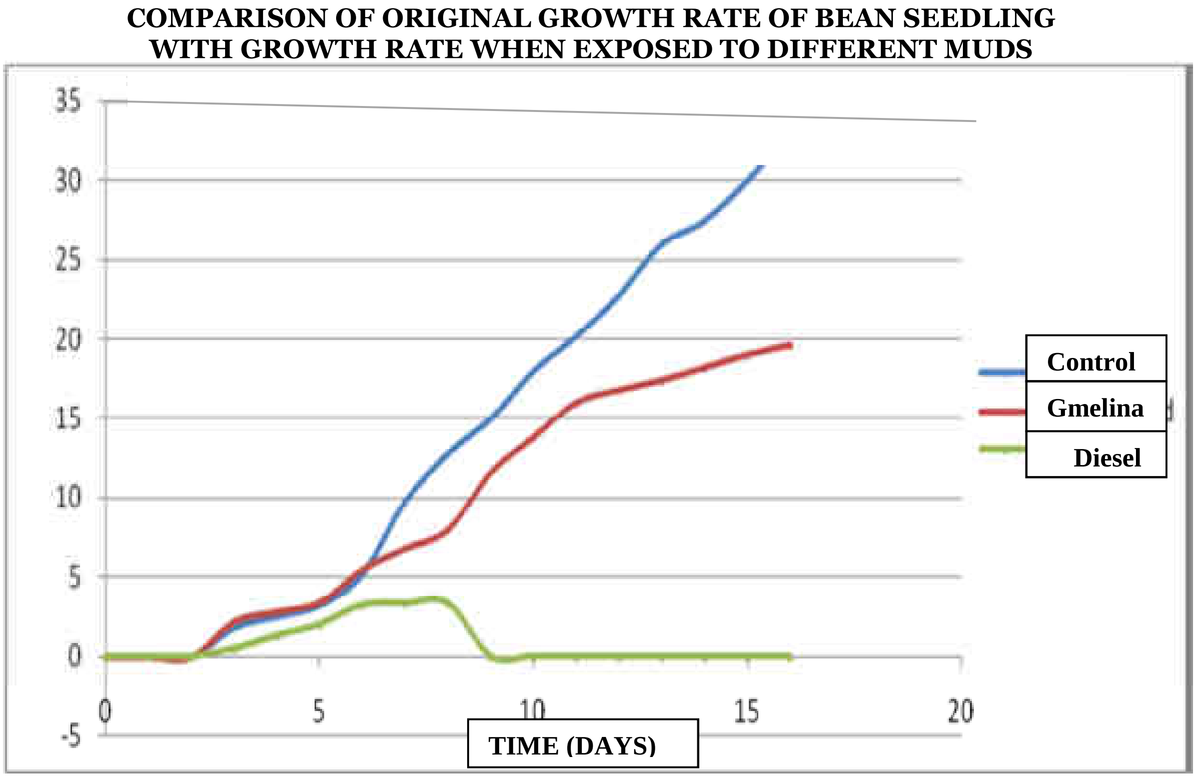

Figure 1.7: Comparison of Growth Rate Curve of Different Mud Types

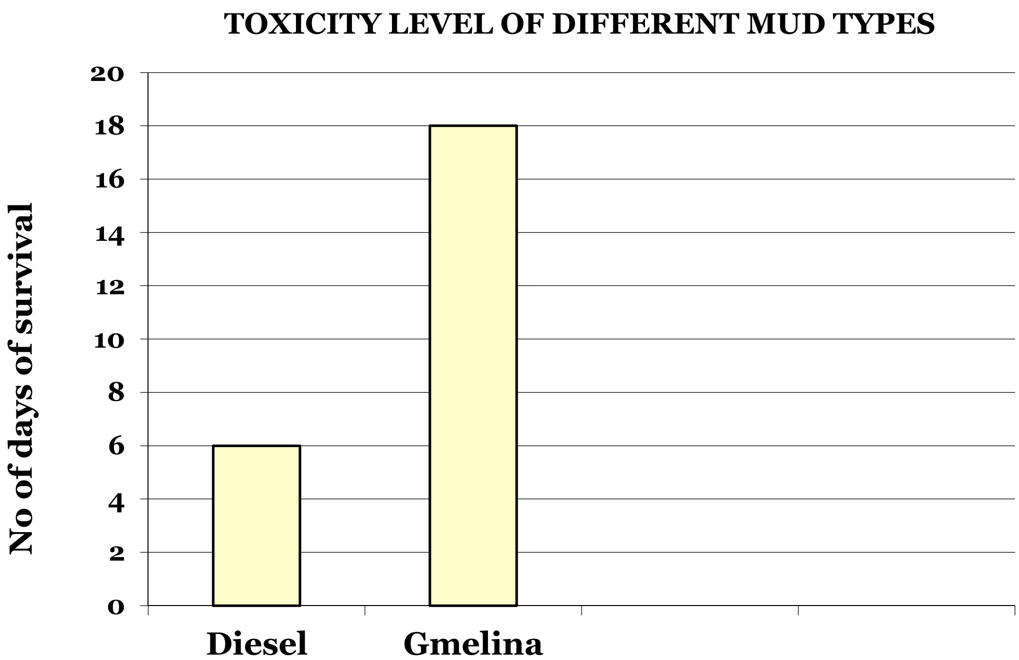

Figure 1.8: Toxicity level of Different Mud Types.

1.2.3 Discussions on the Formulated Mud

Discussions on the Mud Density measurements.

Mud density ρ is calculated using the equation

$$\rho_{m}= \frac{M_{ben} + M_{oil} + M_{water}}{V_{ben} + V_{oil} + V_{water}}$$

Where

ρ_m = mud density
M_{ben} = mass of bentonite
M_{oil} = mass of oil
M_{water} = Mass of water
V_{ben} = volume of bentonite
V_{oil} = Volume of oil
V_{water} = volume of water

From the mud density values table, 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 amount of barite needed to build.

Discussions on Mud Viscosity and Gel Strength.

It can be seen that the plots on Graphs 1 and 2 generated from the dial readings of all the mud samples are similar to the Bingham plastic model. This goes to prove that the muds have similar rheological behavior.

However, not all the lines of the plot are as straight as the Bingham plastic model. This can be explained by a number of factors such as possible presence of contaminants and the possibility of behaving like a different model such as Herschel Bulkley.

A Bingham plastic fluid will not flow until the shear stress τ exceeds a certain minimum value τy known as the yield point (Bourgoyne et al 1991). After the yield has been exceeded, the changes in shear stress are proportional to changes in shear rate and the constant of proportionality is known as the plastic viscosity μp.

For reduced friction during drilling, Gmelina OBM gives the best results. This means Diesel OBM offers the greatest resistance to fluid flow. Gmelina poses a better prospect in the sense that its lower viscosity will mean less resistance to fluid flow. This will in turn lead to reduced wear in the drill string.

Discussions on Mud Filtration.

From the results of the filtration test we can infer that Diesel OBM had 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 the thickest.

From these inferences, we can see that gmelina OBM is better in filtration properties than Diesel OBM as inferred from thickness and filtration volumes.

Problems caused as a result of excessive thickness include:

i. Tight spots in the hole that cause excessive drag.
ii. Increased surges and swabbing due to reduced annular clearance.
iii. Differential sticking of the drill-string due to increased contact area and rapid development of sticking forces caused by higher filtration rate.
iv. Primary cementing difficulties due to inadequate displacement of filter cake.
v. Increased difficulty in running casing.

The problems as a result of excessive filtration volumes include:

i. Formation damage due to filtrate and solids invasion and damaged zone too deep to be remedied by perforation or acidization. Damage may be precipitation of insoluble compounds, changes in wettability, and changes in relative permeability to oil or gas, formation plugging with fines or solids, and swelling of clays.
ii. Invalid formation-fluid sampling test. Formation-fluid flow tests may give results for the filtrate rather than for the reservoir fluids.
iii. Formation-evaluation difficulties caused by excessive filtrate invasion, poor transmission of electrical properties through thick cakes, and potential mechanical problems running and retrieving logging tools.
iv. Erroneous properties measured by logging tools (measuring filtrate altered properties rather than reservoir fluid properties).
v. Oil and gas zones may be overlooked because the filtrate is flushing hydrocarbons away from the wellbore, making detection more difficult.

Discussions on Hydrogen ion Potential.

Drilling muds are always treated to be alkaline (i.e., a pH greater than 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 the samples meet a few of the requirements stated but Diesel OBM with a pH of less than 8.5 does not meet with specification. Gmelina OBM shows better result since its pH value falls within this range.

Discussions on Cuttings Carrying Index (CCI).
Only three drilling-fluid parameters are controllable to enhance moving drilled solids from the wellbore: Apparent Viscosity (AV), Density (mud weight (MW)) and Viscosity. Cuttings Carrying Index (CCI) is a measure of a drilling fluid's ability to conduct drilled cuttings in the hole. Higher CCI's, mean better-hole cleaning capacities.
From the Table, we can see that Gmelina OBM showed best results for CCI iterations.
Discussion on Toxicity Measurements on the Mud.
From the results of the toxicity test, it can be concluded that gmelina oil based mud has less harmful effect on plant growth compared to diesel oil based mud. This shows that gmelina mud sample is environmentally safer for both plants and micro animals than diesel mud sample.
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.

1.2.4 Conclusion.
It has been proven that Gmelina seed which has been hithato treated as waste can be economically viable. The similarity in the characteristics of the Gmelina seed oil and the conventional diesel oil has proved that gmelina seed oil can be used as a viable substitute for the conventional diesel oil in the formulation of oil based drilling mud. Therefore attention has to be focused on the use of oil from non-edible plant seeds for drilling mud production instead of edible oils. However, the reliability of the oil can be properly harnessed if it is subjected to trans-esterification reaction.
The low viscosity of gmelina oil-based mud makes it very attractive prospects in drilling activities. The results of the tests carried out indicate that gmelina OBM has a great chance of being among the technically viable replacement of diesel OBM. The results also show that additive chemistry must be employed in the mud formulation, to make them more technically feasible. In addition, the following conclusions were drawn:
From the viscosity test results, it can be inferred that the plastic viscosity of gmelina OBM can be further stepped down by adding an adequate concentration of thinner. This method can also be used to reduce the gel strengths of gmelina OBM.
The tests of temperature effects on density: The densities increased and became constant at some point, and began increasing again (these temperature points of constant density varied for the different samples). The diesel OBM showed the highest variation range.

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