International Journal of Academic and Applied Research (IJAAR)
ISSN: 2643-9603
Vol. 8 Issue 4 April - 2024, Pages: 125-132

Formulation of Drilling Mud Using Neem Seed Oil (*AzadirachtaIndica) and* Refined Waste Lubricating Oil as Base Oil

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Abstract: *The study investigated the formulation of drilling mud using Neem seed oil and refined waste lubricating oil as an alternate to diesel oil in the formulation of oil-based mud. Different tests conducted to ascertain the suitability of their properties for drilling operation include toxicity, filtration, pH, viscosity and density were conducted to. Also, the rheological and other physicochemical parameters of this formulation were compared with formulations from diesel oil, Neem seed oil and waste lubricating oil. The study demonstrates that the mud formulated from diesel oil gave a higher stability of Neem seed oil mud. The pH of Neem seed oil-based mud lower than diesel oil-based mud (OBM). Again, the neem seed OBM had a plastic viscosity of 27cp, yield point of 246Ib/100ft2 and 30minutes fluid loss of 5.6ml with a filter cake of 1.4mm. On the overall, the Neem seed oil-based muds are a viable replacement for the diesel oil-based muds. Meanwhile the refined waste lubricating oil mud had a plastic viscosity of 18cP, yield point of 150lb/100ft^2 and 30minutes fluid loss of 5.2ml with a filter cake of 1.2mm while the diesel oil based mud had a plastic viscosity of 40cP, yield point of 50lb/100ft^2 and 30minutes fluid loss of 10.8ml with a filter cake of 3.1mm. The toxicity test showed that refined waste lubricating oil mud was the most eco-friendly when compared with diesel oil based mud. Hence, the paper conclude that, the formulated muds when compared with standard mud (i.e. diesel oil base mud), the formulated muds (i.e. Neem seed oil-based muds and refined waste lubricating oil mud) stand a chance of being a viable replacement for the conventional diesel oil-based muds due to their better and more durable characteristics than conventional diesel oil-based muds. As such, the temperature effects on the mud rheological properties and also on other properties of the formulated mud should be checked.*

Keywords: **Formulation of Drilling Mud, Neem Seed Oil (*AzadirachtaIndica)*, Refined Waste Lubricating Oil, Base Oil**

INTRODUCTION

Over the years**,** in an attempt to find the "black gold," drillers are venturing into hazardous environments like the deep sea, which has increased demand for oil-based mud. This mud is used to drill problematic formations with shale swellings, where water-based muds (WBM) cannot be used. Oil-based drilling fluids are, quite rightly, largely utilized to drill problematic shale and to increase hole stability. Drilling fluid with an oil-or water-based continuous phase and a dispersed phase consisting of clay is known as oil-based mud. Mineral oil, kerosene, diesel, or crude oil can all be used to make this mud (Benett, Chromally, & Clifford, 2012). They can also be used for extremely deviated drilling. They are also used in wells with high temperatures. Udeagbara et al. (2021) stressed that, oil-based mud made from diesel oil has shown to be highly costly and ecologically unfriendly.

Again, research has been done on the formation of oil-based mud using less expensive oils besides diesel oil, and a comparison of their qualities with diesel oil has been made. To reduce the related relatively high cost of drilling, particularly on offshore areas, there is an urgent need to create more affordable oils for the formulation of oil-based drilling fluids. Therefore, a greater commitment in this area will result in the production of less costly muds, which may eventually displace diesel as the primary oil-based mud in the oil business. This justification stems from the expense and handling of conventional diesel oil-based drilling mud.

Additionally, the overall expense of drilling can be decreased by substituting re-refined waste lubricating oil for diesel oil when making oil-based mud. Waste lubricating oil, which is inexpensive, can be used in place of diesel oil, which is more costly, while plant oil, which is more environmentally friendly, is typically not accessible in commercial quantities. But this is predicated on the necessity that used lubricating oil fulfill the fundamental environmental standards before it can be used (Nweke & Okpowasili, 2003). Because environmental rules are not strictly enforced, used lubricating oil is now a source of environmental nuisance in Nigeria, where it is carelessly thrown into rivers, soil, and other natural areas (Oghenejoboh & Ohimor 2012). For the purpose of creating oil-based mud, spent lubricating oil may thus be gathered from vehicle repair shops and other establishments that do routine maintenance and repairs for almost nothing.

Aim and Objective of the Paper

The aim of this paper is to formulate a low-cost and eco-friendly oil-based drilling mud using Neem seed oil *and* refined waste lubricating oil as base oil in place of standard diesel. Specifically, the paper seeks to:

i. conduct a series of laboratory tests to investigate the rheological properties, filtration control and lubricity of Neem seed;
ii. refine waste lubricating oil;

iii. formulate oil-based mud using the refined waste lubricating oil and the Neem seed;
iv. characterize the formulated mud; and
v. compare the result obtained with standard.

LITERATUREREVIEW

A crucial part of the drilling procedure for the extraction of oil and gas is referred to as "drilling fluid" or "drilling mud." It is a sophisticated concoction of minerals and chemicals intended to convey rock shavings to the surface, regulate wellbore pressure, and lubricate the drill bit. Drilling mud has a lengthy history that dates back to the first days of oil and gas drilling. Due to its many uses, drilling mud is an essential part of the drilling process. It aids in cooling the drilling site, transporting rock cuttings to the surface, lubricating the drill bit, and regulating pressure in the wellbore (Bourgoyne et al., 2019).
Drilling mud was first used approximately 2,000 years ago in China, according to historical records. Chinese drillers cooled the drilling site and lubricated the drill bit with a mixture of clay, water, and other elements. Later, in the 1800s, clay and water mud was used in the United States' first oil wells to lubricate the drill bit and regulate wellbore pressure. Drilling mud has been around for thousands of years; early drillers lubricated the drill bit and cooled the drilling site using a mixture of water, clay, and other minerals (Petroleum Engineering Handbook, 2006).

Drilling mud composition evolved along with drilling technology. Drillers of oil and gas started utilizing oil-based drilling muds in the early 1900s because they offered superior lubricating and pressure management over water-based muds. On the other hand, oil-based muds were more costly and had environmental risks. Drilling mud composition has changed along with advancements in drilling technology. According to Bourgoyne et al. (2019), oil-based drilling muds were created to offer superior lubricating and pressure management over water-based muds.
Muds with a synthetic foundation were created in the middle of the 20th century. These muds have less of an impact on the environment than oil-based muds yet have many of the same advantages. They are manufactured from synthetic fluids like esters and olefins. Additionally, because of their improved heat stability, they may be utilized in deeper, hotter
In recent years, drilling mud technology has continued to evolve. Water-based muds have been improved with the addition of polymers and other chemicals to enhance their performance. New types of muds have been developed, including foam-based and air-based muds, which can be used in specific drilling environments. Drilling mud technology continues to evolve, with water-based muds being improved with the addition of polymers and other chemicals (Ibrahim *et al*., 2013).
Different varieties of drilling muds exist, depending on the composition and formulation technique. They may be categorized as water-based mud (WBM), oil-based mud (OBM), synthetic based mud (SBM), and pneumatic or air-based fluid. They are employed on the geological formation in which drilling would occur (Medhiet al., 2019). Notably, scattered and non-dispersed water-based muds are further classifications for water-based muds (Jung &Culen, 2018). Conversely, two types of oil-based muds are Invert-Emulsion Muds and Synthetic-Based Muds (sometimes referred to as Low Toxicity Oil Based Mud, or LTOBM). Due to their similar qualities to oil-based mud, but much lower toxicity of the fluid fumes than oil-based fluid, the latter are more often utilized on offshore rigs (Ikeh, 2014). Nonetheless, there are three types of air/gas and mist drilling mud: compressed air, air/water, and air/polymer (Ikeh, 2014).

METHODOLOGY

3.1. Materials and Equipment Used

Table 1 presents the material and equipment that was used for the analysis:

Table 1: Equipment and model

Experiment 1: Neem fruit	**Experiment 2: Waste Lubricating Oil**	
Equipment	**Equipment**	**Model**
Ripe-dried Neem seed	Multimixer	Hamilton beach mixer model HMD-200
N-hexane as the solvent for the extraction of the Neem seed (5 litres)	Rotational viscometer	Fann viscometer model 35A
Aniline	Mud balance	Ofitie mud balance
1MNaOH solution	Filter press	API filter press

6.5ml of Emulsifiers	Electrical stability meter	Fann electrical tester
6.5g of Geltone (Viscosifier)	Flash point apparatus	Tag closed cup tester
5g of Calcium oxide	Measuring cylinder	Pyrex, U.S.A
35.7g of Calcium chloride	Beaker	Pyrex, U.S.A
30.7g of Bentonite		
48.4g of Barite		
70ml of Water (for mud preparation)		
1MNaOH solution		

Source: Researcher's Compilation (2024)

3.2 Test Procedure

3.2.1 Preparation of Oil Based Mud using Neem Fruit

Neem fruit was immediately de-pulped while it was still fresh. The seed was thoroughly washed to remove pulp around it and also dirt and impurity. The seeds were decorticated by winnowing to remove the hull from the seeds. The seed was then placed in an oven until a constant weight was obtained. The dried seeds were crushed in a mortar and the sample was expressed on a standard sieve screen of the required mesh size (0.425-0.71mm) to obtain the required particle sizes.

To extract oil from the Neem fruit, 15kg of neem seeds, was weighed and put into the thimble of the Soxhlet extractor. 250ml of the solvent (n-hexane) was measured with a measuring cylinder and poured into the still pot of the Soxhlet extractor, the apparatus was then coupled and the condenser unit was connected to an overhead water tank to cool rising solvent vapor. The heat source was a heating mantle operating at a temperature of 80°C. To ensure that, the process is efficient, the process was repeated severally for about nine refluxes in 3 hours after which the extraction process was completed. Temperature was regulated using a thermometer.

After extraction, the resulting liquid was a mixture of the solvent (n-hexane) used for extraction and the oil extract. The liquid was discharged into a Liebig condenser to separate the solvent from the oil extract. The mixture was distilled at a temperature of 68^0C until the oil extract was completely free of the solvent. The oil extract was then exposed to the atmosphere for a while to ensure elimination of the solvent odor. The various processes considered are: determination of Density of Neem Seed Oil (ASTM D 1298-85), Aniline point of Neem seed oil (ASTM D611), Flash Point (ASTM D93), and Viscosity of Neem Seed Oil (ASTM D 445)
Oil based fluid was formulated in the ratio of 80:20 consisting of 280ml of the oil and 70ml of water making up 350ml of laboratory mud barrel. Various processes considered include the Determination of Mud Weight (Density), Mud Viscosity using Rheometer, Mud Filtration, Electronic Stability (ES), Mud Hydrogen ion concentration (pH) - Calorimetric paper method, and Toxicity Level of the Mud.

3.2.2. Preparation of Refined Waste Lubricating Oil

300ml of used engine oil was measured in a 500ml beaker. Also, 30ml of acetic acid was measured in a separate 50ml beaker. The regulator hot plate was switched on and the measured base oil was placed on top. The temperature of the used engine oil was maintained at 45^0c. at this temperature, the acetic acid was introduced into the used engine oil simultaneously with stirring of the mixture for 10minutes.

At the end of the acid treatment step, the acidic oil was allowed to settle for 24hours to form sediment at the bottom of the beaker. After this period, the acidic oil was properly sedimented and was decanted into another 500ml beaker using a piece of cloth while the residue (acidic sludge) at the bottom of the beaker was discarded.

200g of kaolin clay was made into slurry with distilled water of $80cm^3$. $50cm^3$ of acid in $0.35mol/cm^3$ concentration was added to the slurry made. The slurry was transported into an aluminum pan and left for one hour at temperature between 90 and 1000^0c. after the time duration, the mixture was washed with distilled water in order to remove any excess acid. The washed clay mixture was dried in an oven for one hour and grounded into powdery form.

The acidic oil in beaker was then subjected to bleaching. The oil was placed on a regulator hot plate and the temperature was maintained at a temperature of 1100c. 10wt% of activated clay was introduced into the oil and the mixture was continuously stirred for 15minutes. At the end of the bleaching step, the bleached oil was neutralized.

The bleached oil was neutralized to adjust the pH of the oil to neutrality. At this step, 4wt% of the oil of hydrated lime was introduced into the bleached oil by taking into consideration the pH of the bleached oil at a given point in time. The bleached oil was neutralized with a continuous manual stirring for 10minutes.

During this stage the oil was allowed to sediment in the beaker the 24hours and was decanted into another beaker, while the residue at the bottom of the beaker was discarded. The sedimented oil was finally filtered using a filter cloth and the filtrate was collected in a filtration flask and was observed to be clear while the residue was discarded (Kwao-Boateng, Anokye-Poku, Agyemang, &Kwadwo-Fokuo, 2022).

The various test procedure include the determination of Flash Point (ASTM D56) and aniline point. Oil based fluid was formulated in the ratio of 80:20 consisting of 280ml of the oil and 70ml of water making up 350ml of laboratory mud barrel. The formulated oil-based mud was poured into a 500ml beaker and the beaker was held carefully as the mud was hot to touch. The drilling mud density of each of the formulated mud sample was measured using the Ofitie mud balance.

3.3 Experimental Techniques

3.3.1 Physicochemical Propertiess of Formulated Based Oil

The physicochemical properties of the based oil were first considered. These include Specific gravity @60^{0}F, Kinematic viscosity, @40^{0}c (mm^2/s), Flash point (^{0}c), and Aniline point (^{0}c).

3.3.2 Physicochemical Parameters of Formulated Oil Based Mud (OBM) Samples

The physicochemical parameters of the formulated oil based mud (OBM) samples were compared with formulations from diesel oil. This is with a view to develop a comprehensive and critical analysis that may be used in developing and validating sound analytical techniques. Specifically, the physicochemical parameters of the formulated OBM include Density (ppg) Ph, Electrical Stability (ES), Filtration Loss (ml), Filter cake thickness and Toxicity (survival days)

3.3.3 Rheological Behavior of the Three Formulated Oil Based Mud (OBM)

Rheological behavior of the three formulated oil based mud (Diesel oil OBM, Neem seed OBM and Refined WLO OBM) using dial speed (RPM) of 600, 300, 200, 100, 6, 3, Gel strength, 10secs (lb/100ft^2), Gel strength, 10mins (lb/100ft^2), Plastic viscosity (cP) and Yield point (lb/100ft^2). The essence of using this approach is to quantifies the relationship among deformation, flow behavior, viscosity, imposed stress, elasticity and recovery of a substance (Asghar, Riaz, Mannan, Khan, & Butt, 2024)

RESULTS AND DISCUSSION

The result of the research work findings was presented in this section.

4.1 Extracted Neem Seed Oil Result

The rheological and other physicochemical parameters of this formulation were compared with formulations from diesel oil and waste lubricating oil. The estimate is presented in table 1

Table 4.1 Physicochemical parameters of waste lube oil, refined waste lube oil and fresh lube oil.

Parameters	NSO	Refined WLO	Diesel Oil
Specific gravity @60^{0}F	0.916	0.88	0.85
Kinematic viscosity @40^{0}c (mm^2/s)	59	73.99	94
Flash point (^{0}c)	176	178	152
Aniline point (^{0}c)	118	157	5.5

***WLO**: waste lubricating oil*

***NSO**: Neem seed oil*

Table 4.2 Physicochemical parameters of the formulated oil based mud (OBM) samples

	Diesel OBM	Neem seed OBM	Refined waste lube OBM	API Specification

Density (ppg)	8.7	9.4	8.3	7.5 - over 22.0
pH	8	7	8.5	8.5 -10
Electrical Stability (ES)	357	406.4	480	>400
Filtration Loss (ml)	10.5	5.6	5.2	15.0ml (maximum)
Filter cake thickness	3.1	1.4	1.2	
Toxicity (survival days)	8	24	13	

***OBM:** Oil Based Mud*

Table 4.3 Rheological behavior of the three formulated oil based mud

dial speed (RPM)	Dial readings		
	Diesel oil OBM	Neem seedOBM	Refined WLO OBM
600	130	300	186
300	90	273	168
200	75	193	159
100	55	109	151
6	24	16	22
3	21	12	19
Gel strength, 10secs (lb/100ft^2)	15	10	17
Gel strength, 10mins (lb/100ft^2)	20	17	26
Plastic viscosity (cP)	40	27	18
Yield point (lb/100ft^2)	50	246	150

***OBM:** oil-based mud*

Discussion

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 80 to 20; 280ml of oil and 70ml of water. The rheological and other properties of this formulation were compared with standard diesel oil. The experimental study demonstrate that the electrical stability of the mud formulated from Neem seed oil was 407v while refined waste lubricating oil was 480v. Comparatively, mud formulated from diesel oil gave a stability value of 357v thus indicating higher stability of Refined Waste lubricating oil mud. The pH of Neem seed oil-based mud was 7 while waste lubricating oil mud was 8.5 and diesel OBM which was 8 and also within the range of the specified pH for drilling muds. Having a higher pH that is within the specified range would ensure that metal parts of the drill bits are not easily corroded.

Furthermore, the Neem seed OBM had a plastic viscosity of 27cp, yield point of 246Ib/100ft2 and 30minutes fluid loss of 5.6ml with a filter cake of 1.4mm. The refined waste lubricating oil mud had a plastic viscosity of 18cP, yield point of 150lb/100ft^2 and 30minutes fluid loss of 5.2ml with a filter cake of 1.2mm while the diesel oil based mud had a plastic viscosity of 40cP, yield point of 50lb/100ft^2 and 30minutes fluid loss of 10.8ml with a filter cake of 3.1mm. The diesel OBM had a plastic viscosity of 40cp, yield point of 50lb/100ft^2 and 30minutes fluid loss of 10.5ml with a filter cake of 3.1mm. The implication of the low plastic viscosity is that, the formulated mud will enhance rate of penetration during the drilling process while the high yield point suggests the possibility of increasing the mud carrying capacity. Such case will lead to increase in the pressure drop circulating within the annulus.

CONCLUSION AND RECOMMENDATION

The study concludes that, the formulated muds when compared with standard mud (i.e. diesel oil base mud), the formulated muds (i.e. Neem seed oil-based muds and refined waste lubricating oil mud) stand a chance of being a viable replacement for the conventional diesel oil-based muds due to their better and more durable characteristics than conventional diesel oil-based muds. Hence, the following submissions were made:

i. Temperature effects on the mud rheological properties and also on other properties of the formulated mud should be checked. This is to strengthen the theory that refined waste lubricating oil mud can be used at different down hole operating conditions.
ii. Further test like pour point should be carried out on extracted Neem seed oil. Further test should also be carried out on the newly formulated mud to determine the exact region the mud can be used for drilling operation.
iii. The effects of oil based mud formulated from refined waste lubricating oil on different drilling formations should be further researched on. This is to understand what formations are best suited for this oil based mud.

Contributions to Knowledge

The study contributed to extant body of knowledge by reaffirming that, low-cost and eco-friendly oil-based drilling mud using Neem seed oil *and* refined waste lubricating oil as base oil in place of standard diesel.

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APPENDIX

Viscometer

Source: (Fanninstrument company, 2013)

mud balance

Source: (NL Scientific, 2023)

Filter press

Source: (Anderen limited, 2017)

Electrical stability tester

International Journal of Academic and Applied Research (IJAAR)
ISSN: 2643-9603
Vol. 8 Issue 4 April - 2024, Pages: 125-132

Source: (Ihenacho, Burby, Nasr &Enyi, 2016)