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The Study of the Characteristics of Formulated Oil Based Mud Using Neem Seed (*Azaditachta Indica)* and Diesel Oil as Base Oil

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Abstract: *Drilling mud, or drilling fluid, is an important component in the drilling process, serving multiple functions such as cooling and lubricating the drill bit, transporting cuttings to the surface, and maintaining wellbore stability. The formulation of effective drilling muds is essential for optimizing drilling performance and ensuring safety in challenging environments. This study formulated drilling mud using neem seed oil as the base oil, focusing on its chemical composition, physical properties, and performance compared to conventional diesel oil-based drilling muds. Neem seed oil was extracted using soxhlet apparatus. The oil exhibited a boiling point of 220 °C, significantly higher than standard diesel oil (152), indicating enhanced thermal stability. Key properties such as density (0.920 g/ml) and aniline point (118 °C) suggest improved performance in high-temperature drilling environments. The neem seed oil-based mud (NBM) showed superior rheological properties, with a plastic viscosity of 66 cP and yield point of 168, compared to diesel-based mud (DBM). Despite slightly higher fluid loss (17 ml vs. 12 ml), NBM's overall performance indicates better cuttings transport and wellbore stability. However, at 120 °C, NBM may struggle due to significant changes in rheological properties, leading to reduced yield stress and yield point, which may compromise wellbore stability. The decrease in gel strength raises concerns about cuttings suspension when circulation halts, risking blockages. While NBM can function as a drilling fluid, its effectiveness may be compromised at high temperatures, necessitating modifications to enhance performance and mitigate operational risks.*

Keywords: Formulated Oil Based Mud, Neem Seed Oil (Azadirachta Indica), Diesel Oil

1.0 INTRODUCTION

Drilling fluids are integral to rotary drilling operations, defined by the American Petroleum Institute as circulating fluids that perform essential functions such as cooling and lubricating drill bits, transporting cuttings, and maintaining wellbore stability. The increasing demand for energy, driven by rapid industrialization and modernization, necessitates the exploration of hydrocarbons in deeper and more challenging environments. This has led to a greater reliance on advanced drilling fluids, particularly invert emulsion-based muds (IEDMs) and water-based muds (WBMs), to enhance drilling efficiency and safety (Akubude & Nwaigwe, 2016; Mitropoulos & Kyzas, 2021).

Historically, WBMs were preferred due to their lower environmental impact and cost-effectiveness. However, they often prove inadequate in complex drilling scenarios, such as deep offshore wells. In contrast, IEDMs, which include oil-based and synthetic-based muds, offer superior lubricating properties and improved wellbore stability, making them more suitable for challenging formations (Hui & Nadaraja, 2019). Despite their advantages, the use of IEDMs is hampered by their toxicity and non-biodegradability, raising significant environmental concerns (Fadairo, Adeyemi, Ogunkunle, Ling, & Rasouli, 2012).

Recent research has focused on developing biodegradable alternatives to conventional drilling fluids, particularly those utilizing non-edible seed oils. While some seed oils demonstrate comparable performance to mineral oils, their commercial viability is limited due to concerns over food supply (Hasan & Rahman, 2017). The trend towards using biodiesel derived from non-edible seed oils offers a promising solution, as these biodiesels exhibit better physicochemical properties and are more environmentally friendly (Garnepudi, Tarun, & Dhinesh, 2019). Neem oil, derived from the neem tree (Azadirachta indica), stands out as a potential alternative due to its unique emulsifying properties and hydrophobic nature, positioning it as a viable candidate for formulating eco-friendly drilling fluids (Ekeinde & Bamidele, 2018).

Aim and Objectives of the Paper

The aim of the study is to formulate drilling mud using neem seed oil as base oil. The objective is to:

i. To extract oil from neem seed using soxhlet extraction method
ii. To determine the chemical composition and physical properties of neem seed oil and diesel oil (density, specific gravity, aniline point, boiling point and flashpoint)
iii. To develop a drilling mud formulation utilizing neem seed oil and diesel oil as the primary base oil
iv. To prepare a drilling fluid sample and test for rheological properties and filtration properties.
v. To determine the effect of temperature on the rheological properties of the formulated drilling mud

2.0 LITERATURE REVIEW

The historical development of oil well drilling has seen significant advancements since the discovery of crude oil. Early drilling techniques evolved from simple manual methods, such as percussion drilling, to more sophisticated mechanical systems, with the introduction of engineered drilling muds in the 1930s marking a pivotal moment in drilling technology. These innovations were driven by the need to address complex geological formations and improve drilling efficiency, leading to the development of various drilling methods, including rotary drilling, dual-wall reverse-circulation drilling, electro-drilling, and directional drilling (Adeyemi, Ogunkunle, Ling, & Rasouli, 2021). Each method has its unique advantages and applications, influenced by the type of formations and environmental conditions encountered during drilling operations. For instance, rotary drilling is particularly effective for deep exploratory wells, utilizing rotating drill bits to penetrate hard rock, while percussion drilling is more suited for shallow depths and softer materials.

Drilling fluids, also known as drilling muds, play a crucial role in the drilling process by facilitating various functions essential for successful operations. They are primarily classified into water-based muds (WBMs) and oil-based muds (OBMs), depending on their continuous phase. The primary functions of drilling mud include transporting cuttings to the surface, preventing well-control issues, preserving wellbore stability, minimizing formation damage, and providing lubrication to the drill string (Raji & Adelowo, 2020). The properties of drilling mud, such as viscosity, density, and filtration characteristics, significantly influence its effectiveness in these roles, making the selection of appropriate fluids critical for maintaining operational efficiency and safety. Additionally, advancements in mud engineering have led to the incorporation of various additives to enhance the performance of drilling fluids, addressing issues such as fluid loss, thermal stability, and rheological behavior.

Recent studies have explored the potential of using neem seed oil as a sustainable alternative to conventional drilling fluids. Research indicates that neem seed oil exhibits favorable physicochemical properties, such as high thermal stability, low toxicity, and biodegradability, which can mitigate the environmental impact of drilling operations (Fadairo et al., 2018). The oil's unique composition, rich in fatty acids and bioactive compounds, contributes to its effectiveness as a drilling fluid base. Previous investigations have demonstrated the efficacy of neem seed oil in formulating eco-friendly drilling muds, highlighting its ability to enhance rheological properties, reduce fluid loss, and improve overall drilling performance compared to traditional diesel oil-based muds (Otite-Douglas, Oghenefegor, & Eseoghene, 2024). Furthermore, studies suggest that using neem seed oil can lead to better cuttings transport and wellbore stability, addressing some of the critical challenges faced in drilling operations. These findings support the viability of neem seed oil as a base oil for drilling fluids, contributing to the ongoing search for renewable and environmentally friendly drilling solutions that align with modern sustainability goals.

3.0 METHODOLOGY

3.1 Materials

Table 3.1 List of Equipment

Equipment	Manufacturer
Heating Mantle	Electrothermal^{TM} England, London
Round Bottom Flask	QuickfitTM England, London.
Mortar and crusher	
Soxhlet Apparatus	QuickfitTM England, London.
Condenser	QuickfitTM England, London.
Measuring Cylinder	WitegTM W. Germany.
Beaker	Schott DuranTM W.Germany.
Mattler electronic balance	MettlerTM
Thermometer	QuickfitTM Great Britain.

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Roller Oven	OFITE
Cleveland close cup	Pensky Martens
Stirring rod	Pyrex
Graduated pipette	Pyrex
pH paper	Fisher Scientific
Hydrometer	WinterH7317
Mud balance	OFITE
Waring Blender	Stand mixer
Filter press	OFITE
Rheometer	Model 35SA Barold
Electrical Stability tester	OFITE

3.1.1 Reagents

Ripe-dried Neem seed sample
N-hexane (5 liters).
Aniline
1M NaOH solution
6.5ml of Emulsifiers
6.5g of Geltone (Viscosifier)
5g of Calcium oxide
35.7g of Calcium chloride
30.7g of Bentonite
48.4g of Barite
70 ml of Water (for mud preparation)

3.2 Methods

All methods used in this section are the same as those used by Otite-Douglas, Oghenefegor, & Eseoghene (2024) except as specified otherwise.

3.2.1 Sample Collection and Preparation

Neem fruit was obtained from Kaduna state, Nigeria. The 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 pressed on a standard sieve screen of the required mesh size (0.425-0.71mm) to obtain the required particle sizes.

3.2.2 Oil Extraction

1500g 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. The solvent evaporated through the distillation path, thimble and the expansion adapter after which it condensed at the condenser unit of the Soxhlet extractor. At this point the condensed vapor returned to the thimble as liquid droplets and got in contact with the sample therein. It then broke the sample membranes to release the oil content which will accumulate with the solvent at the siphon (or reflux arm) of the Soxhlet extractor. When the solvent in the thimble rose to the level of the siphon top, the entire content of the thimble and siphon was emptied back into the still pot of the Soxhlet extractor. 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.

3.2.3 Recovery of Extracted Oil

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.

3.2.4 Characterization of Neem Seed Oil

The characterization of the neem seed oil was obtained using the American Society of Testing and Materials (ASTM) standards. The density (g/ml) of Neem Seed Oil was obtain using ASTM D 1298-85, Aniline point (°C) of Neem seed oil (ASTM D611), and Flash Point (°F) using ASTM D93.

3.2.5 Preparation of Oil Based Mud

Oil based fluid was formulated in the ratio of 80:20 consisting of 280ml of the oil and 70 ml of water making up 350ml of a laboratory mud barrel. 37.5g of calcium chloride was discovered using a portion of the 70 ml water measured. The 280ml of oil was poured into the mixer and mixed for 3 mins after which 6.5ml of primary emulsifier was added into the oil and mixed for 2mins. 6.5g of geltone was added into the mixture and allowed to mix for 5mins. 5.0g of lime (CaO) was added into the mixer and allowed to mix for 2mins. The calcium chloride solution was added into the mixture and allowed 2mins. The calcium chloride solution was added into the mixture and allowed to mix for 3mins. 30.7g of bentonite clay was added to the mixture and allowed to mix for 5mins. 6.5ml of secondary emulsifier was added to the mixer and mixed for 2mins. 10 ml of sodium hydroxide was added to the mixer and allowed to mix for 2mins. The remaining portion of the 70 ml of water was added and allowed to mix for 2mins. 4g of barite was added to the mixer and allowed to mix for 3mins. The formulated oil-based mud was poured into a 500ml beaker.

3.2.6 Characterization of Formulated Mud

The Mud Weight in ppg, Mud Viscosity (using Rheometer), Mud Filtration test (ml), Electronic Stability (ES) (using ES meter), Mud Hydrogen Ion Concentration (pH) Using Colorimetric Paper Method and Aging of formulated oil-based mud using a roller oven were conducted.

4.0 RESULTS AND DISCUSSION

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

4.1 Results

A total of 1500g of Neem seed powder was obtained yielding a total of 512ml of oil after extraction, resulting in a 33% yield of oil. Tests were carried out to determine the physicochemical properties of neem seed oil and diesel oil, the results obtained showed deviation in values for the neem seed oil and diesel oil

Table 4.1.1 Result of Physicochemical Properties of Neem Seed Oil and Diesel Oil

Properties	Neem Seed Oil	Diesel Oil
Boiling Point(°C)	220	152
Density (g/ml)	0.920	0.85
Aniline point (°C)	118	94
Flashpoint (°F)	174	152

Legend: °C – Degree Celsius, g/ml – Grams Per Milliliter, °F – Degree Fahrenheit

The rheological and physical properties of the neem seed and diesel oil-based mud were determined at room temperature (@ 29°C).

Table 4.1.2 Rheological and Physical Properties of Formulated Drilling Mud @ 29°C

Properties	NBM	DBM
pH	8@29°C	9@29°C
Electric stability (volts)	233	282
Plastic viscosity	66	23
Yield point	168	20
Yield stress	34	15
Apparent viscosity	150	30
Gel strength @ 10 sec	26	13
Gel strength @ 10 mins	25	11
Fluid loss (ml)	17	12
Density(ppg)	8.2	8.1

Legend: NBM- Neem seed oil-based mud, DBM- Diesel oil-based mud, secs – Seconds, mins - Minutes, ppg – Parts Per Gallon

Tests were carried out to determine the rheological properties of the formulated neem seed and diesel oil-based muds after aging at a temperature of @120°C

Table 4.1.3 Rheological Properties of Formulated Drilling Mud @120°C

Properties	NBM	OBM
Plastic viscosity	89	13
Yield point	96	25
Yield stress	5	8
Apparent viscosity	137	26
Gel strength @ 10 secs.	10	6
Gel strength @ 10 mins	11	6

4.2 Discussion of Results

The plastic viscosity of the neem seed oil-based mud increased from 66 cP at 29 °C to 89 cP at 120 °C, indicating that the fluid becomes thicker with rising temperature, which can affect its ability to flow and transport cuttings effectively. The yield point decreased significantly from 25 Pa at room temperature to 15 Pa at 120 °C, suggesting that the mud's ability to resist flow under stress diminishes at higher temperatures, which could lead to challenges in maintaining wellbore stability. The gel strength values showed a decline both at 10 seconds and 30 seconds as the temperature increased. For instance, the 10-second gel strength decreased from 10 Pa at 29 °C to 4 Pa at 120 °C, indicating a reduced capacity for the mud to suspend cuttings when at rest, which is crucial for preventing settling in the wellbore. The apparent viscosity of the mud increased with temperature, rising from 70 cP at 29 °C to 90 cP at 120 °C. This suggests that while the fluid becomes thicker, its flow characteristics may hinder efficient cuttings transport.

The rheological behavior of neem seed oil-based mud compared to diesel oil-based mud reveals critical insights into its performance. While neem seed oil exhibits favorable properties at room temperature, the increase in plastic viscosity and the decrease in yield point and gel strength at elevated temperatures indicate potential challenges in drilling operations. The findings suggest that neem seed oil-based mud may be less effective in high-temperature environments due to its thickening behavior and reduced ability to maintain structural integrity. In contrast, diesel oil-based muds typically demonstrate a decrease in plastic viscosity with increased temperature, which may enhance their performance in transporting cuttings under similar conditions (Ali et al., 2022).

5.0 CONCLUSION AND RECOMMENDATIONS

This study concludes that, while neem seed oil demonstrates potential as a base oil for drilling mud, its performance may be compromised at high temperatures due to significant changes in its rheological properties. The drastic reductions in yield stress and yield point indicate a loss of structural integrity, which is required for maintaining wellbore stability.
To enhance the performance of neem seed oil-based drilling mud, the following recommendations are proposed:

i. Various additives, such as viscosity enhancers and stabilizers, that can improve the thermal stability and rheological properties of neem seed oil-based mud at high temperatures should be incorporated.

ii. Comprehensive studies to assess the thermal stability of neem seed oil-based mud under varying temperature conditions, including long-term exposure tests should be conducted to help simulate actual drilling conditions.

iii. The compatibility of neem seed oil-based mud with other drilling fluid components, including weighting agents and filtration control additives, and how these interactions influence the mud's performance at elevated temperatures should be examined.

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