INVESTIGATING ENVIRONMENTALLY FRIENDLY FLUID LOSS CONTROL AGENTS IN WATER BASED MUDS

BY

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DEPARTMENT OF PETROLEUM ENGINEERING

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**AN ORIGINAL PROJECT SUBMITTED TO THE DEPARTMENT OF ENGINEERING, FACULTY OF ENGINEERING.
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CERTIFICATION

This is to certify that this project was undertaken by **AGBROKO PRINCE ODIAKUGBEOGHENE** of the Department of Petroleum Engineering , Faculty of Engineering, University of Benin City, Edo state Nigeria.

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Prof. S. O. Isehunwa *External Supervisor*	DATE

DEDICATION

This project is dedicated to God Almighty for his infinite love and protection.

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I would like to give thanks and glory to the almighty God, my creator who has seen me through the various phases of my life, for His love, mercy and grace, intellect and good health to carry out this project/research.

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I thank my parents Miss Evelyn Okorigba for their love, also Mr. and Mrs. Richard Okorigba, Mr. and Mrs. Pius Okorigba, Mr. and Mrs Celestine Okorigba, Mr. James and to his late wife Mrs. Patricia Okorigba, Mrs. Patricia Osayanda for care and support. I thank them for their enormous sacrifices. I appreciate and I LOVE YOU ALL. May God continually bless and keep you people safe. Amen.

I render my thanks to my friends: Dennis Kelly, Dennis Kester, Simon Susan, Peace. Thanks to you guys for your encouragement, it was possible because of you.

TABLE OF CONTENTS

TABLE OF CONTENTS

ABSTRACT

In this study, the effect of two food waste materials, cassava peels, and plantain peels as local environmentally-friendly additives, on the pH, mud weight, viscosity and the fluid loss properties of water based mud was evaluated. The water based mud samples were formulated using bentonite, barite, distilled water with cassava peels and plantain peels in varying weight proportions. Mud weight and pH measurements, viscosity and the volume of fluid loss were measured. Experimental results indicated that at same concentration, the cassava peels had higher rheological properties compared with the plantain peels. However, the muds formed from the combination of cassava and plantain peels have better filtration control properties. Although the viscosity of the drilling fluid produced from the plantain peels were lower than that of the cassava peels, the cassava peels shows a lower fluid loss than the plantain peels. Therefore, with proper quality control efforts, they could be used as a drilling mud additive for exploration and exploitation of oil and gas in Nigeria. It is also hoped that this work will open new market for the use of cassava and plantain waste.

CHAPTER ONE

INTRODUCTION

1.1 Background of the study

Drilling operations are conducted to obtain oil and gas from natural reservoirs deep underground (Chen et al., 2021). To facilitate the extraction of hydrocarbons from the ground, a deep hole is drilled to form a wellbore. The use of drilling fluids is an important factor in the drilling process, and these fluids play many roles, such as to assist in removal of drill cuttings and formation pressure control (Li et al., 2021; Medhi et al., 2020). There are viable chemical additives used in the drilling fluid that have shown the desired features. However, these additives are non-biodegradable and environmentally hazardous (Zheng et al., 2020). As a result, researchers have sought to identify alternate additives that are environmentally friendly, biodegradable, and sustainable, while also maintaining the properties of efficient drilling fluids (Zhang et al., 2014).

The use of drilling fluids (DFs, also called drilling mud) is an essential part of a rotary drilling process. Different types of chemicals and polymers are used in designing a drilling fluid to meet functional requirements such as appropriate mud rheology, density, mud activity, fluid loss control property, etc. (Li et al., 2021). Today, the choice of drilling fluids and their additives has become complex (Caenn et al. 2011), considering both the technical and environmental factors (Caenn et al. 2011).

The preservation of the environment on a global level is now important as various organizations have set up initiatives to drive the usage of toxic chemicals as DF additives. Environmental pollution has been considered a serious threat while drilling complex wells or high-temperature deep wells, which are now managed by using oil-based DF systems and high-performance water-based DF systems. As environmental protection has become a consideration before any oil and gas resources exploration, people have paid more and more attention to the DF for environmental safety. Advances in recent technologies led to the development of novel environmentally friendly DF systems (Lan et al. 2010). However, problems such as complicated treating chemical synthesis technology, the lack of raw material for treatment agents, and high initial cost have limited the development of the DF (Li et al. 2014). The application of DF for environmental protection is limited in oil resources exploration as the treating chemicals from natural macromolecular materials are often of poor quality.

Generally, not much attention has been paid to the development of drilling fluids from biomaterial that has good filtration volume, impermeable filtered mud cake, cost effective, availability and environmentally friendly. In order to enhance the usage of drilling fluids, fluid loss additives were introduced and their design changed to have common characteristic features that aid in safe, economic and satisfactory completion of a well (Dosunmu and Joshua, 2010). In addition, drilling fluid loss additives are also required to perform the following functions: minimize reservoir damage; seal the formation pores by forming low-permeability filter cake to prevent inflow of formation fluids into the well; have minimum negative impact to the environment; aid in collection and interpretation of data available through drill cuttings, cores and electrical logs; provide frictionless environment between the drilling string and the sides of the hole; minimize any damaging effect on the sub-surface equipment and piping. Drilling fluids are designed to build a filter cake. The filter cake is intended to reduce filtrate loss to the formation, and give a thin impermeable mud cake at wall of the wellbore (Dosunmu and Joshua, 2010).

There are many factors that are to be weighed when choosing a DF. However, the key considerations are well design, anticipated formation pressures and rock mechanics, formation chemistry, the degree of damage the DF imparts to the formation, temperature, environmental effects and regulations, logistics, and economics (Medhi et al., 2020). To meet these key design factors, DFs offer a complex array of interrelated properties. Five basic properties are usually defined by the well program and monitored during drilling. These properties are listed as viscosity, density, filter cake or filtration of water loss, solids content, and quality of water make up. Once the properties and their parameters are determined, the DF can be controlled and adjusted accordingly (Medhi et al., 2020)

Minimization of the environmental impact as well as safety considerations of a drilling operation directly affects the choice of DF additive systems. Due to the environmental regulatory agencies, products that have been used in the past may no longer be acceptable. As more environmental laws are enacted and new safety rules are applied, the choices of additives and fluid systems must also be reevaluated. To meet the challenges of a changing environment, product knowledge and product testing become essential tools for selecting suitable additives and DF systems (Zhang et al., 2014)

1.2 Statement of Research problems

Due to the high environmental demands on the oil and gas industry in preventing the destruction of the marine resources and costal habitat, the need for environmentally friendly mud additives has become a priority. This has made the manufacturing of chemicals and mud additives very important by using local materials which are been disposed.

Water-based mud filtrates have a low salinity and a high pH and contain dispersants and polymers. Polymers are stable at circulating temperatures, but can decompose and form residues when subjected to static reservoir temperatures for long periods of time. High salinity water-base mud generates filtrates that can react with formation brines and precipitate various types of scale. Formations drilled at high circulation rates are invaded by filtrates with temperatures well below the reservoir temperature. The cooling they cause may provoke the deposition of paraffin and/or asphaltenes (Peden et al., 2012). These numerous drawbacks of water-base drilling fluid led to the development of oil-based mud for drilling through clayey sandstone (Methuen and Kemick, 2017). The initial conclusion was that this new mud was a safe, all-purpose drilling fluid. It is now recognized, however, that although the problems of oil-base mud are less numerous than those of water base mud, they are often much more severe (Goode et al., 2014). Oil based mud contain more solids than water-based mud. Consequently, particle invasion is more pronounced. Several types of materials are used to reduce particle invasion (filtration rate) and improve mud cake characteristics. Since filtration problems usually are related to flocculation of the active clay particles, deflocculants also aid filtration control. When clays cannot be used effectively as deflocculating agents, water-soluble polymers are substituted. The common water soluble polymers used for filtration control are Starch, Sodium carboxy methyl cellulose (CMC), and sodium polyacrylate. Polymers reduce water loss by increasing the effective water viscosity (Goode et al., 2014).

Particulate invasion of the region around the wellbore, and subsequent solid entrainment, as well as loss circulation are the major formation damage mechanisms associated with water-base drilling mud. These mechanisms usually lead to the formation of zone of altered permeability around the wellbore (skin effect), which adversely affects the productivity of such well (Boek et al., 2012). During hydrocarbon production, backflow with hydrocarbons may partially clean up the internal filter cakes, but in general, the permeability of the invaded region is seriously impaired such that hydrocarbon production is reduced. For this reason, several experimental works have been done to control solid entrainment in porous media due to drilling operation (Boek et al., 2012).

Various research works have been done on the formulation of drilling mud using locally available materials as additives. These research ranges from the use of locally available clay as a substitute for bentonite to the use of local starch as a fluid loss control additive. Olatude et al. (2012) formulated water based drilling fluid using bentonite, guar gum, polyanionic cellulose (PAC) and gum Arabic. The rheological behavior and the filtration loss property of each drilling fluid developed were measured using API recommended standard procedures. They noticed that Guar gum shows the highest gel strength and the most stable rheological properties with poor filtration loss property while gum Arabic had unstable rheological properties with stable gel strength and good filtration loss property (Olatude et al., 2012). However, gum Arabic is only found in the northern part of Nigeria and not in the southern part (Niger Delta region) where major drilling operations take place. This makes cassava and plantain (peels) waste product found in abundance in the Niger Delta region of Nigeria, more economical than the gum Arabic.

Omotioma et al. (2015) used locally sourced cassava starch to improve the rheological properties of water based mud. Their results show that the rheological properties of water based mud were improved with the addition of 4% locally sourced cassava starch addictive to it. Samavati et al. (2014) investigated the rheological and fluid loss properties of water based drilling mud containing acid modified fufu starch (cassava derivative). Their result show that the rheological properties, which (viscosity, plastic viscosity, yield point and gel strength) for the modified fufu showed significant improvement when 16% acid was employed. A significant amount of fluid loss reduction was also obtained within light and average mud weights formulation (75 pcf and 100 pcf). However, none of the samples (modified and unmodified) meet the fluid loss standard requirement for the applied temperature (Samavati et al., 2014). Also, Ademiluyi et al., (2011) compared local polymer (cassava starch) with an imported type in controlling viscosity and fluid loss in water-based mud. Five different cassava starches were tested as viscosifiers and fluid loss control additives in water based mud and compared with Barazan D, an imported sample. Their experimental results indicated that at same concentration, the imported sample had higher rheological properties compared with the local samples. They also discovered that some of the newly developed local starch products (with high amylose content and high water absorption capacity) have similar or better filtration control properties than the imported sample. However, the viscosity of the drilling fluid produced from the local starches was lower than that of the imported type (Ademiluyi et al., 2011). Amanullah and Yu (2014) investigated the use of corn-based starches for oil field application in terms of suitability as drilling fluid additives. Their experimental results showed that some of the newly developed starch products had similar filtration control properties than that of a widely modified starch.

Cassava and corn are major food items, and in high demand, in most part of Nigeria. It should be more economical and environmentally profitable to used non-food resources such as cassava and plantain peels (waste product) for drilling mud formulation (filtration control agent). Hence, the needs for this research work.

1.3 Problem of Statement

In Nigeria oil industry, materials used as viscosifiers and fluid loss agents are mostly imported therefore expensive and not readily available. However, Nigeria has the necessary materials to produce locally based drilling fluids, hence this has led to research into several local materials such as yam, cocoyam and corn cob cellulose that could be used as substitute for commercial additives in mud formulation.

Yet, little or no research have been conducted in an attempt to investigate the potential use of locally produced cassava and plantain waste in formulating drilling mud to serve as a secondary viscosifier and a possible fluid loss control. Therefore, it is imperative that comprehensive research is to be conducted into the cassava and plantain peels, to study their characteristics and formulate mud that can perform the same function as those with imported additives. This will reduce the cost of some expensive viscosifiers and fluid loss agents that are being imported and will create employment as well. Therefore the aim of this study Is to evaluates the environmentally friendly fluid loss control agent (cassava and plantain peels) in water-based mud for oil and gas drilling operations.

1.4 Aim of the Study

The novelty of this research was to evaluate the effect of locally sourced biodegradable and environmentally friendly materials such as the cassava peels obtained from *Manihot esculenta* and plantain peels from *Musa balbisiana* on the rheological properties which determines the performance of drilling mud. As the demand for oil and gas increases, so does the need for economic techniques to recover these resources. Therefore, there is a need to conduct research on environmentally friendly, cost effective, and technologically acceptable materials that could be used in enhancing the performance of drilling mud.

1.5 Objective of Study

The specific objectives of this study are;

1) Evaluate the potential of locally derived additives for improvement of mud rheology and filtration in comparison with industrial additives.
2) To investigate the utilization of cassava and plantain peels as fluid loss control agent in water based drilling mud (WBM)
3) To evaluate rheological properties of cassava and plantain peels water based drilling mud (WBM) in various formulation subjected to different drilling temperatures

1.6 Significance of the Study

The present consumption of bentonite in the drilling operations in Nigeria is put at over 50 thousand tons a year and all of it is imported from United states of America. This trend is expected to continue as drilling activity increases in the shores of Niger Delta. To this end, the establishment of Nigerian Local Content Initiative in the Oil and Gas Sector by the Federal Government of Nigeria has necessitated the need for local substitutes to foreign drilling fluid materials. Thus, it is imperative to source for locally available drilling fluid materials and evaluate their various characteristics, then formulate fluids that can be used in drilling process. Another significance of this study is establish the reduction in the cost of purchasing foreign viscosifiers and filtration control additives by patronizing locally derived additives hence reducing the overall cost of a mud program, and lastly to make sure that wastes like cassava and plantain peelings are recycled by usage in drilling mud formulations so as to prevent environmental problems such as heaping of refuse on the streets

CHAPTER TWO

LITERATURE REVIEW

2.1 Drilling Fluid

Drilling fluid is any fluid that is circulated in the borehole that helps in carrying out a cost-effective and efficient drilling operation, resulting in a more stable and gauged borehole to targeted depth with minimum possible damage to prospective formations. A major component in drilling operation success is drilling fluid performance. The successful completion of borehole and its cost depend, to a great extent, on the properties of the drilling fluid. Drilling fluids must address several challenges encountered during the drilling process and as such, a drilling fluid additive should possess the ability to help address such challenges (Zhang *et al*., 2012; de Oliveira *et al.,* 2020). The principal functions of drilling fluids include removal of drill cuttings and cleaning of the wellbore, lubricating and cooling the drill bit and string, maintaining wellbore formation, and preventing well blowout (Karakosta *et al.,* 2021; Werner *et al.,* 2017). Thus, drilling fluid plays a significant role in the upstream oil and gas industry. As a major success factor of drilling processes, the properties of drilling fluids are constantly monitored and adjusted.

The increase in the global demand for oil and gas led to a search for more energy resource in new areas, and as a result exploration towards marine sites began. As well as drilling techniques evolved from traditional vertical drilling to extended-reach drilling (ERD), which in addition to imposing challenges such as difficult to advance drilling under conditions of high pressure and high temperature (HPHT), increasing the possibility of environmental threat due to drilling fluids to be used to suit the conditions of this type of drilling from pressure and heat, as well as ensuring the protection of pipelines from potential malfunctions and the risk of corrosion, thus the exploration into drilling fluids began.

Since the 1990s, the development of drilling fluids includes; format fluid drilling system, polyvinyl alcohol (PVA)/silicate fluid drilling system, polyolefin fluid drilling system, ether-based fluid drilling system, ester-based fluid drilling system, etc. Both of these fluid systems have similar features, such as low toxicity, fast deterioration, and environmental effects. (Zhenjie, 2004; Jiankang and Jienian, 2003; Leliang and Guijuan, 2003). However, they have not been widely used, due to the high cost or unsatisfactory application effects (cannot fully satisfy engineering needs). After Strict rules on additive drilling have been released by the United States Environmental Protection Agency (EPA), it became imperative for the oil industry to come up with a new solution and change its practices to decrease the impact of drilling fluids on the environment. As a result, in contrast to non-environmentally safe drilling fluids such as oil-based muds, researchers have begun designing new eco-friendly drilling fluid systems (Chang *et al.,* 2019).

In compliance with the specifications of the engineering operation and the environment, developing and screening criteria for drilling fluid additives have been determined which includes: (1) environmentally-safe, i.e. light color, nontoxic (biologically and chemically non-toxic), easily degradable; (2) No debris for mixing with water forming, good anti-swelling and plugging ability, less environmental damage; (3) less forms of chemicals, easy-to-prepare drilling fluid; (4) The fluid system has good performance, consistent consistency, and simple maintenance. (Shuixiang et al., 2011). Thus, according to these fundamentals, the researchers began to try to find the best synthesis of an environmentally friendly, low-cost drilling fluid that meets the needs of drilling engineering.

2.2 Drilling Fluid Additives

To match the requirements of different depth intervals, the properties for drilling fluids are modified using various additives for the drilling process (Karakosta *et al.,* 2021). Properties such as density, flow properties or rheology, filtration and solid content as well as chemical properties must be accurately measured, controlled and appropriately maintained at their pre-selected level throughout drilling process (Jiankang and Jienian, 2003).

Additives commonly used in drilling muds are broadly classified into

1. Viscosifiers;
2. Viscosity reducers;
3. Weighting materials;
4. Fluid-loss reducers;
5. Emulsifiers;
6. Lost circulation materials;
7. Flocculants;
8. Corrosion control chemicals;
9. Defoamers; and
10. pH control additives.

2.3 Classification of Drilling Fluids

World Oil's annual classification of fluid systems (2004) lists nine distinct categories of drilling fluids, including:

1 Freshwater systems

2. Saltwater systems
3. Oil- or synthetic-based systems
4. Pneumatic (air, mist, foam, gas) “fluid” systems

Three key factors usually determine the type of fluid selected for a specific well:

1. Cost
2. Technical performance
3. Environmental impact

Water-based fluids (WBFs) are the most widely used systems, and are considered less expensive than oil-based fluids (OBFs) or synthetic-based fluids (SBFs). The OBFs and SBFs—also known as invert-emulsion systems—have an oil or synthetic base fluid as the continuous(or external) phase, and brine as the internal phase. Invert-emulsion systems have a higher cost per unit than most water-based fluids, so they often are selected when well conditions call for reliable shale inhibition and/or excellent lubricity (da Silva *et al.,* 2020). Water-based systems and invert-emulsion systems can be formulated to tolerate relatively high downhole temperatures. Pneumatic systems most commonly are implemented in areas where formation pressures are relatively low and the risk of lost circulation or formation damage is relatively high (Werner *et al.,* 2017). The use of these systems requires specialized pressure-management equipment to help prevent the development of hazardous conditions when hydrocarbons are encountered.

2.4 Rheology of Drilling Fluid

Rheology is the study of the deformation of fluids and flow of matter. Its importance is recognized in the analysis of fluid flow velocity profiles, fluid viscosity (marsh funnel viscosity, apparent viscosity and plastic viscosity), friction pressure losses and annular borehole cleaning. Rheological properties are basis for all analysis of well bore hydraulics and to assess the functionality of the mud system. Rheological characteristics of drilling mud also include yield point and gel strength. Rheological properties (such as density, viscosity, gel strength etc.) are tested throughout the drilling operations. It is critical to control and maintain rheological properties as a failure to do so can result in financial and loss of time, and in extreme cases, it could result in the abandonment of the well (Fazelabdolabadi *et al.,* 2015). Besides rheological other tests such as filtration tests, pH, chemical analysis (alkalinity and lime content, chloride, calcium, etc.), resistivity are conducted throughout drilling process.

2.5 Waste Materials in Drilling Fluids

A significant amount of research has been conducted regarding the use of food waste in the oil and gas drilling industry (Dankwa *et al.,* 2018). For instance, Al-Hameedi *et al.* (2020) investigated the use of mandarin peel powder (MPP) in an eco-friendly fluid additive, as an alternative to non-biodegradable additives that harm the environment. They utilized MPP as an eco-friendly alternative fluid additive in comparison to a reference polymer, PAC-LV. The MPP additive yielded better outcomes because it was able to significantly lower the pH and reduce the fluid circulation loss with a low concentration of the powder. Thus, MPP was shown to be a good additive for lowering the pH, viscosity control, and reducing circulation loss. This study encouraged the use of food waste as a suitable alternative to the non-biodegradable chemicals that are currently used in the drilling industry (Al-Hameedi *et al.,* 2020).

Furthermore, Al-Hameedi *et al.* (2019) recognized that grass, hay, and palm leaves are also viable candidates. The study verified that food waste can be repurposed to promote an environmentally friendly operation of the oil and gas drilling industry (Al-Hameedi *et al.,* 2019).

The oil and gas drilling industry uses additives in drilling fluids for a variety of uses, such as pH control, and to provide rheological properties, such as plastic viscosity, gel strength, and yield point (Bayat *et al.,* 2018; Fazelabdolabadi *et al.,* 2015). These additives must also address issues such as circulation loss control, wellbore integrity, wellbore completion, and inhibition of corrosion to ensure a smooth drilling operation (Hassani *et al.,* 2014). However, at present, the chemicals used for these purposes are non-biodegradable and can cause significant negative effects on the environment (Li *et al.,* 2020). A sustainable solution would use chemicals that are biodegradable and do not cause any environmental damage, while simultaneously providing the desired properties of a good drilling fluid.

Recent studies have shown the impact of various waste-derived additives for efficient rheological properties in drilling fluids (da Silva *et al.,* 2020). For example, Joshi *et al.* (2021) reported on the use of tamarind kernel powder as an alternative additive in drilling fluids. The study outlined the impact of using tamarind kernel powder on the mud density. Mud density is one of the significant properties of drilling fluids, and helps provide and regulate wellbore stability and control formation pressure. In the study, it was stated that the density of the mud sample increases with the addition of tamarind seed powder and the combination of bentonite. Increasing the concentration of tamarind seed powder resulted in a thicker mud sample and an increase in mud density. The mud density of the samples was observed to be in the range of 8.22–8.97 ppg, which has been considered to be a suitable range for use as an additive in the formulation of drilling fluids (Joshi *et al.,* 2021).

Moreover, Murtaza *et al.* (2021) demonstrated the use of environmentally-friendly okra as a viable alternative additive in drilling fluids. The performance of okra as an additive was evaluated with the absence and presence of clay in drilling fluids. Comparatively, the incorporation of okra in clay-based drilling fluids presented a greater improvement in the rheological properties compared to that in clay-free drilling fluids. In clay-based drilling fluids, the addition of 2 and 3 g of okra resulted in an increase in plastic viscosity (PV) of more than 100%, compared to the addition of 2 g of starch, which only yielded a 45.7% increment. Increasing the concentration of okra also led to an increase in the yield point of drilling fluids. However, was observed that starch is more efficient in improving the yield point than okra. Fluid loss was evaluated at different concentrations and observed to be reduced at different proportions for each concentration (Murtaza *et al.,* 2021). In addition, the filter cake thickness was reduced with the addition of okra, with further reductions evident at higher concentrations.

Similarly, Ghaderi *et al.* (2020) proposed sustainable saffron purple petals (SPP) as an ecofriendly alternative for additives in drilling fluids. The addition of SPP powder in drilling mud resulted in an effective increase in PV values. As the concentration of SPP powder increases, the PV value also increases. Additionally, the introduction of SPP powder to drilling mud also dramatically enhances the yield point compared to that of base mud. The incorporation of SPP powder into drilling mud demonstrated excellent filtrate loss, whereby the filtrate volume was reduced gradually with increasing concentration of SPP powder. The addition of

SPP powder in the drilling mud also resulted in the reduction of mud cake thickness compared to that in base mud (Ghaderi *et al.,* 2020; Wis'niowski *et al.,* 2020).

The above-mentioned studies have demonstrated the effectiveness of food waste in drilling fluid additives as a substitute for the environmentally hazardous materials currently in use within the industry (Magzoub *et al.,* 2020). In this regard, there is a need to promote the "waste to wealth" concept by studying the potential of using unused waste derivatives as additives in drilling fluids, and to address the issue by exploring the additives' rheological properties, which ensure it is viable and cost effective (Hailey *et al.,* 2021). Table 2.1 displays the role of varying waste materials used as additives for the improved rheological properties of water-based drilling fluids.

Table 2.1: Summary of rheological properties of waste-derived materials in drilling fluids

Types of Wastes Materials	Process Parameters	Range of Particle Size	Amount of Waste Used (g)	Yield Point (lb/100 ft^2)	Plastic Viscosity (cP)	Filtrate Loss (% Reduction)
Basil Seed Powder (BSP)	90–150 ˚C	5–10 µm	1	5–45 Pa	5–28 mPa.s	10.2–67.9%
Carboxymethyl cellulose carton waste (CMC)	-	-	1–5 g	-	-	0.4–10%
Wild Jujube Pit Powder (WJPP)	6.9 MPa	54, 75, 100 µm	-	1.5–2.5 Pa	3–4 mPa.s	30–47.5%
Banana Peel Powder (BPP)	-	-	6–18 g	10–16	6–12	39–54%
Black Sunflower Seeds Shell Powder	250 ˚F, 500 psi	52–400 µm	3.5–24.5 g	26–47	7–13	0.3–25%
Brachystegia eurycoma rice husk	-	-	20	-	-	35.62%
Detarium microcarpum rice husk	-	-	15	-	-	44.44%
Fibrous Food Waste Material (FFWM)	100 psi	2%	-	13	8	7.0 cc/30 min
Green Olive Pits' Powder (GOPP)	-	1.5%	9	26	7	11.5 cc/30 min
Henna leaf extract	78 ˚F, 300 ˚F, 100 psi	-	10–40	33–52	23–45	29.9- 32%
Hibiscus leaf extract	78 ˚F, 300 ˚F, 100 psi	-	10–40	73–148	41–75	31.0- 35.1%
Palm Tree Leaves Powder (PTLP)	55 ˚C	3%	22	5	9	8.9 cc/30 min
Potato Peels Powder (PPP)	73 ˚F	4%	6	6	10	8.75 cc/30 min
Saffron Purple Petals (SPP)	100 psi	-	50 g	6.04–10.67 Pa	0.016–0.039 Pa.s	23–45%
Durian rind	-	44–2000	5–10	2–75	10–80	17–60%

		µm	ppb			
Mandarin peels powder (MPP)	-	1–4%	-	14–57	14–63	44.0–68.0%
Date Seed Powder	100 psi	300 µm	0.25–2 ppb	4	9	8–20%
Pistachio Shell Powder (PSP)	104.44 °C, 3.45 MPa	75–150 µm	5–9 g	12.2–13.5	19.8–24	15.3–44%
Soybean Peel Powder (SB)	100 psi	-	5 ppb	23	4	60%
Grass	-	35–300 µm	0.25 -1 ppb	3.5–5	8–9	11.0–14.6%
Corn Starch	170–200 °F	<125 µm	6	-	2.67–5	31%
Rice husk	-	125µm	5–20	9.56 Pa	0.008 Pa.s	16.0–42.5%
Agarwood	-	45µm, 90µm	-	22	11.9	14.0
Sawdust	70 °C	1 mm	-	-	-	8.6%
Walnut shells	-	2–6 mm	20–60	110–180	55–80	11.0–14.5%

CHAPTER THREE

METHODOLOGY

The purpose of this research work is to investigate the effect of locally sourced biodegradable and environmentally friendly materials such as the cassava peels obtained from *Manihot esculenta* and plantain peels from *Musa balbisiana* on the rheological properties which determines the performance of drilling mud. All mud samples were prepared in the order of addition was deionised water to bentonite followed by the addition of additive and thorough mixing using a variable speed mixer.

3.1 Materials

The raw materials needed for this experiment are:

- (i) Cassava Peels
- (ii) Plantain peels
- (iii) Bentonite
- (iv) barite
- (v) water

Laboratory Equipment: The laboratory equipments needed for this experiment are:

- (i) Mud balance
- (ii) Rotary Viscometer
- (iii) Agitator
- (iv) Electronic Weighing balance
- (v) Spatula
- (vi) Wash bottle
- (vii) Measuring cylinder
- (viii) Mixer
- (ix) Stop watch
- (x) Beaker

(xi) Grinding machine
(xii) PH Kit or Meter
(xiii) Low Pressure Low Temperature Filter Press (LPLT)
(xiv) High pressure High Temperature Filter Press (HPHT)

Viscometer: Fann viscometer (Model 35A) was used to determine viscosity of the mud samples. The Fann rotational viscometer was calibrated as described in manual before being used for this project work.

Figure 3.1 Viscometer

- **Mud balance** used for calculating mud weight was manufactured by Fann (Model 140). It has a range of 7 to 24 pounds per gallon. The measurement reading were reported to the nearest 0.1 lb/gal

Figure 3.2 Mud balance

- **Variable Speed Mixer:** A single spindle Hamilton Beach Commercial mixer was utilized for preparing mud samples. Mixer used had 3 speed setting with an additional pulsating switch and is shown in Figure 3.4

Figure 3.3 Mixer

Cassava peels:

Figure 3.4: Cassava peels before and after grinding

Plantain peels:

Figure 3.5: Plantain peels before and after grinding

3.2 Methodology

This section outlines methodologies will be used to determine the effects of mud additives made from cassava and plantain peels on rheology of drilling mud.

3.2.1 Experimental Procedure

These locally sourced natural materials such cassava peels and plantain peels were prepared according to the method deployed by (Apkan et al., 2006). These raw materials were washed, dried and grinded to powder form using a grinding machine. These raw materials serving as the additives for mud formulation were measured with measuring cylinder and electronic weighing balance. The water based mud samples were formulated in this manner:

1. The mud samples prepared without these local materials.
2. The mud samples prepared with cassava peels only
3. The samples prepared with plantain peels only
4. The samples prepared with the combination of cassava peels and plantain peels

The local materials were measured and added one after the other in the interval of 5 - 10 minutes into a steel cup and which was properly mixed with the specify modern mixer containing a specific amount of water using measuring cylinder. The mixer was being powered to rotate while mixing mud samples and its additive for 30-45 minutes until homogeneous mixture was achieved. The first experiment were performed without cassava peels and plantain peels as shown above in order to properly compare and analyze the effect of these local materials. Further experiments were performed using these local materials in the step-wise shown above in different concentrations. The mud balance was used to measure the density of the mud. The rotary viscometer was used to estimate the viscosity when different local materials was added and also without the local materials in the mud samples, Then LPLT filter press was used to measure the fluid loss i.e. the filtrate volume from the drilling mud and also the HPHT filter press was used to measure the filtrate volume in order to ascertain the behavior of these local contents at reservoir conditions and then it is compare with that at LPLT conditions. The pH meter was used to test the pH of the mud without the local materials and when the local materials was added in order to predict the effect of these materials on the environment either onshore or offshore. The whole essence of this work was to investigate the effect of these local materials on water base mud system and their environmental impact, also to improve the concept of "waste to wealth and recyclable materials".

3.2.2 Mud Sample Parameter

Mud samples without cassava and plantain peels (control)

Mud samples with cassava peels (Mud A)

Mud sample with plantain peels (Mud B)

Mud samples with combination of cassava and plantain peels (Mud C)

Table 3.1: Concentration of Mud Samples

Mud samples	**Control**	**Mud A**	**Mud B**	**Mud C**
Bentonite (g)	20	20	20	20
Barite (g)	80	80	80	80
Water (ml)	350	350	350	350
Cassava peels (g)	NIL	2, 4, 6, 8, 10	NIL	NIL
Plantain peels (g)	NIL	NIL	2, 4, 6, 8, 10	NIL
Cassava and plantain peels (g)	NIL	NIL	NIL	2, 4, 6, 8, 10

Table 3.1 shows the sample materials used in formulating the mud samples without cassava and plantain peels, in the presence of cassava peels alone, presence of plantain peels alone, and combination of the cassava and plantain peels. It can be seen from the table that samples with cassava peels alone, plantain peels alone, and combination of cassava and plantain peels were varied in concentrations of 2 to 10 g. This is used to compare and investigate what impact cassava and/or plantain peels will have on the filtration properties of the water base mud.

CHAPTER FOUR

RESULT AND DISCUSSION

The impact of cassava peels and plantain peels applied as a fluid loss control agent in mitigating the filtration properties of water base mud in different concentrations was investigated at ambient temperature with 100psi and at 150^{0}F with 500psi. The result of the filtrate volume was measured to determine the most efficient fluid loss control agent between the cassava peels and plantain peels.

Table 4.1: Physical Properties of Muds

	Control	Mud A					Mud B					Mud C				
		2	4	6	8	10	2	4	6	8	10	2	4	6	8	10
pH	9.3	9.0	8.9	8.7	8.6	8.5	8.3	8.0	7.9	7.7	7.6	8.2	8.0	7.9	7.7	7.3
Mud Density (PPG)	8.7	9.5	9.5	9.7	9.8	9.8	9.0	9.1	9.2	9.4	9.4	9.3	9.5	9.5	9.7	9.7
Viscosity (CP)	0.51	0.99	0.97	0.96	0.93	0.91	0.83	0.80	0.79	0.77	0.77	0.93	0.92	0.87	0.86	0.86

4.1 The Effect of the Local Additives on Mud pH

The pH is defined as the negative log of the activity of the hydrogen ion in an aqueous solution. Solutions with less pH less than 7 are said to be acidic, and solutions with a pH greater than 7 are basic or alkaline. It was expected that both cassava peels and plantain peels would enhance the pH of drilling mud because of their high starch content. The pH measurements taken are shown in Figure 4.1 below. The addition of cassava peels and plantain peels shows no significant difference in the pH of the drilling mud, although the pH of the muds decreased with increase in concentration.

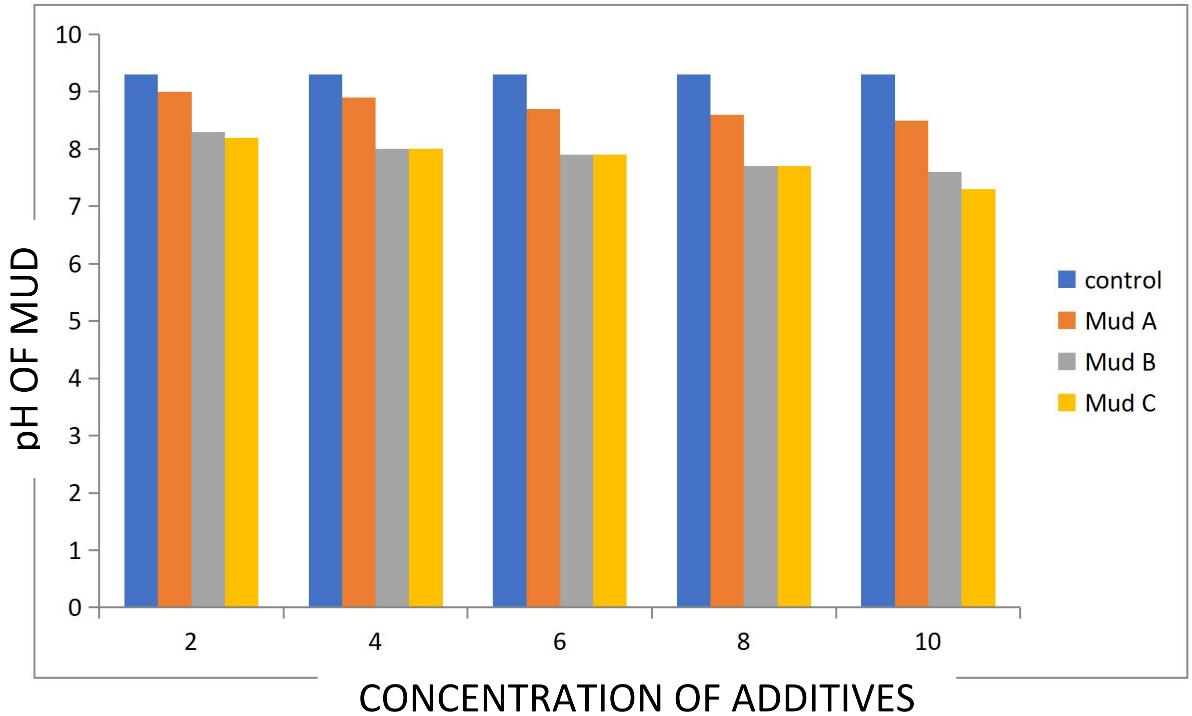

Figure 4.1: Effect of Additives on Mud pH

4.2 The Effect of the Local Additives on Mud Density

Additives are usually added to mud to enhance its properties to meet desired specification. Barite is usually added to drilling mud to increase its mud density. The pH measurements taken are shown in Figure 4.2. The chart shows a significant increase in the mud density of mud formed using cassava peels and plantain peels, although barite was used to increase the mud density of the samples, the presence of cassava and plantain peels further increased the mud density of the mud and this increased with concentration.

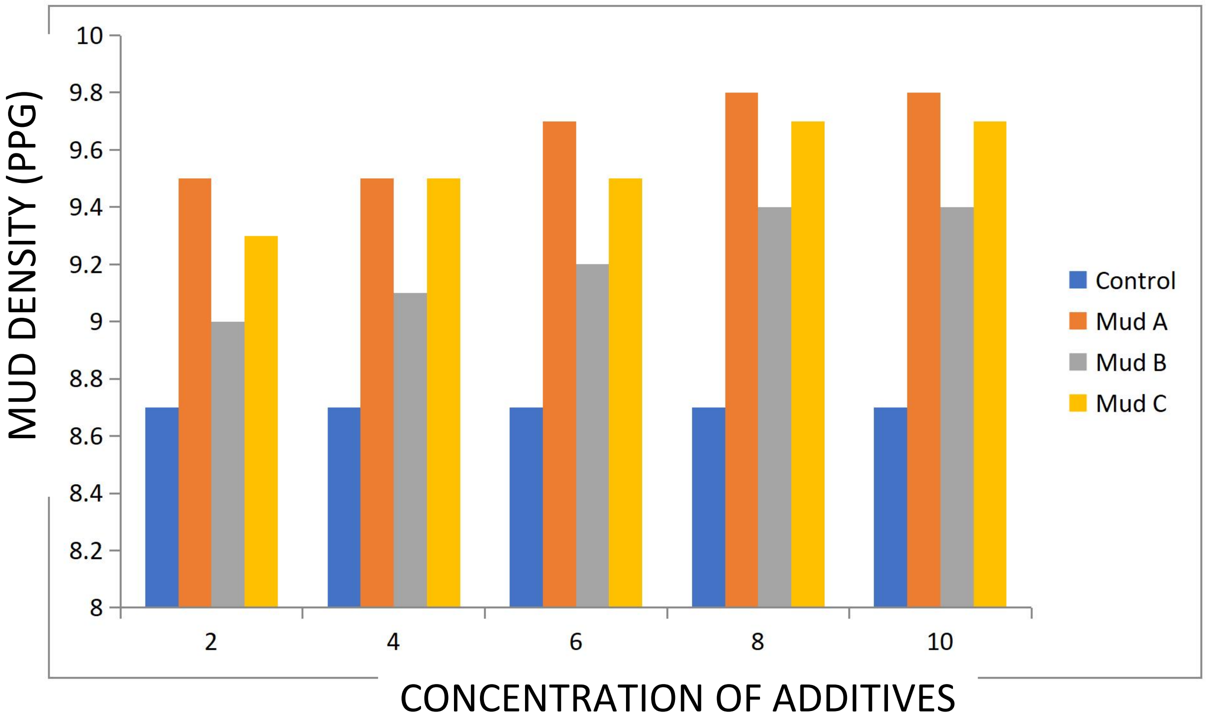

Figure 4.2: Effect of Additives on Mud Density

4.3 The Effect of the Local Additives on Mud Viscosity

The viscosity of the drilling fluids tested at different concentration is presented in Figure 4.3 below. Generally, the viscosity decreased with concentration for both the drilling fluid formulated using cassava peels and plantain peels. The viscosity of the drilling fluid formulated using cassava peels was slightly higher than those formulated using plantain peels and those formulated with the combination of cassava and plantain peels. This could be attributed to the variation of the constituents between the cassava peels and plantain peels. Amanullah and Long Yu (2004) reported that the short branching chains in the amylopectin are the main crystalline component in granular starch. Variation in the amount of amylose and amylopectin in a starch changes the behavior of the starch. The amylose component of starch controls the gelling behavior since gelling is the result of re-association of the linear chain molecules. Amylopectin is usually larger in size. The large size and the branched nature of amylopectin reduce the mobility of the polymer and their orientation in an aqueous environment. Amylose content of cassava increases the water absorption capacity and affects hydration (Eke et al., 2010). The viscosities of the drilling fluids produced from cassava peels (Mud A) vary slightly due to differences in amylose content of cassava starches. The abundance in hydroxyl groups in the starch molecules impart hydrophilic properties to the polymer and thus its potential to disperse in water (Amanullah et al., 1997).

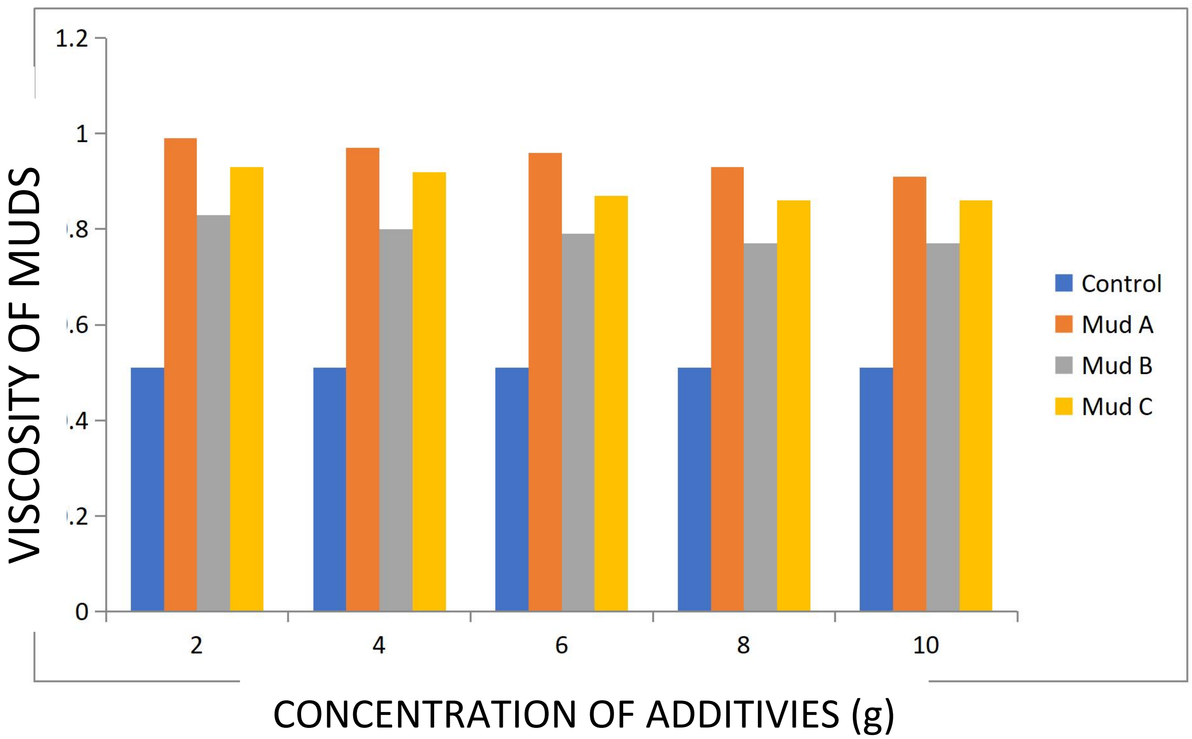

Figure 4.3: Effect of Additives on mud viscosity

4.4 The Effect of Local Additives on Fluid Loss Volume

The effect of cassava peels and plantain peels is shown in Figure 4.4 and 4.5 below. The result shows that the combination of cassava and plantain peels reveals a better fluid loss than cassava alone or plantain alone, but cassava peels shows a lower fluid loss than the plantain peels.

Table 4.2: Fluid Loss Test Outcome using Low Temperature and Low pressure (LTLP) press

Volume of fluid loss	Mud A	Mud B	Mud C
2	25	27	20
4	24	25	18
6	22	23	16
8	20	23	16
10	17	21	15

Table 4.3: Fluid Loss Test Outcome using High Temperature and High pressure (HTHP) press

Volume of fluid loss	Mud A	Mud B	Mud C
2	45	48	42
4	44	47	41
6	42	46	41
8	40	46	40
10	40	45	39

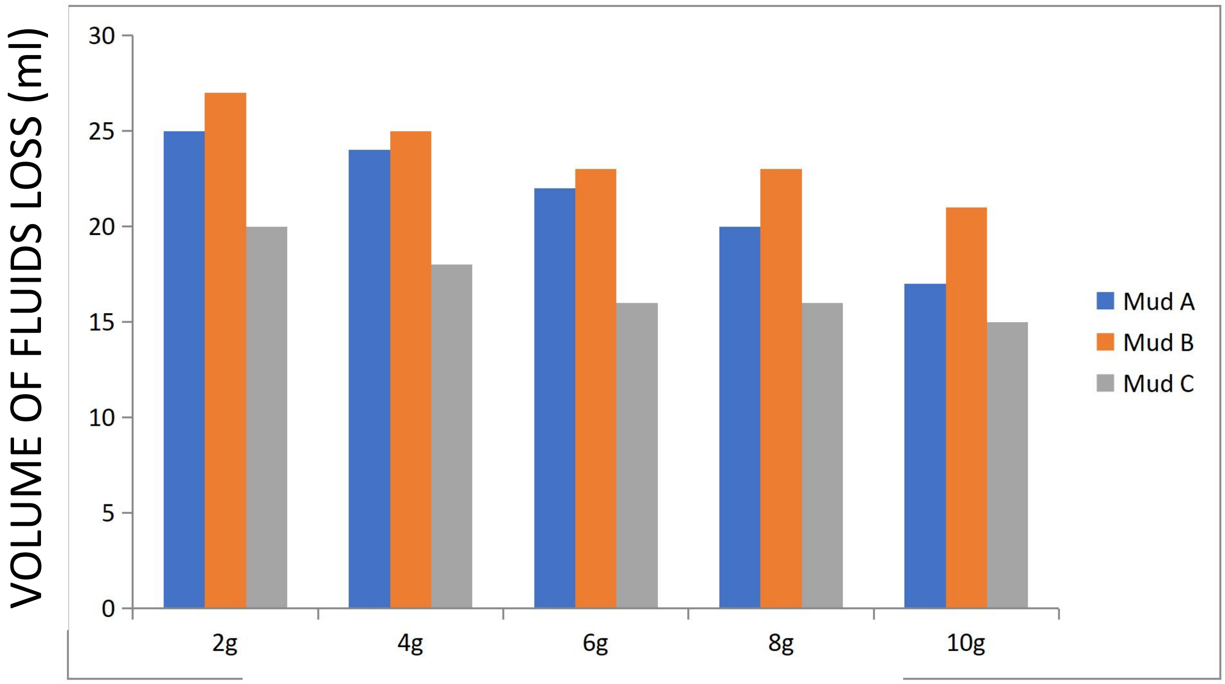

Figure 4.4: P press

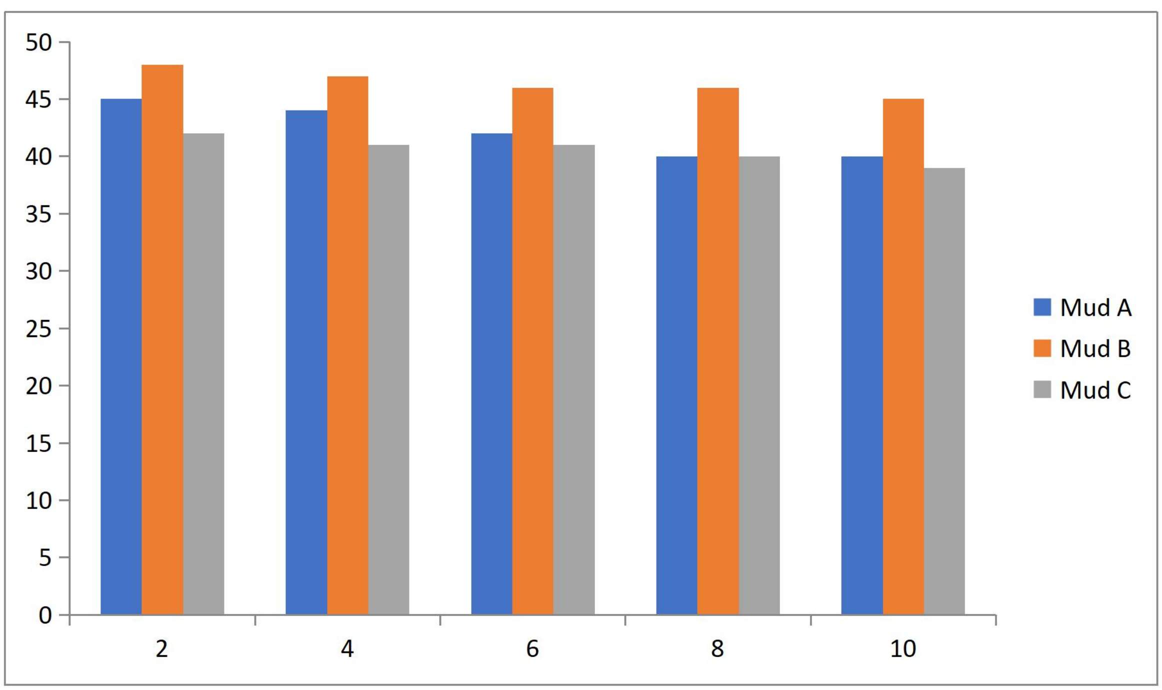

Figure 4.5: Effect of Additives on fluid loss using HTHP press

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

Cassava and plantain are crops which are frequently produced in quantities that exceed either export or local demand; it is readily available and accessible with its cost comparatively lower than the cost of industrialized additive. The experimental results indicated that at same concentration, the cassava peels had higher rheological properties compared with the plantain peels. However, the muds formed from the combination of cassava and plantain peels have better filtration control properties. Although the viscosity of the drilling fluid produced from the plantain peels were lower than that of the cassava peels, the cassava peels shows a lower fluid loss than the plantain peels.

5.2 Recommendations

This work should further be tested and investigated for the effect of temperature on other properties of the formulated drilling muds.

The temperature-density tests should also be carried out at varying pressures, to simulate down-hole conditions.

REFERENCES

Ademiluyi, T., Joel, O.F. and Amuda, A.K. (2011). Investigation of Local Polymer (Cassava Starches) as a Substitute for Imported Sample in Viscosity and FluidLoss Control of Water Based Drilling Mud, ARPN J. of Eng. and Appl. Sci., 6(12): 43-48.

Al-Hameedi, A.T.T., Alkinani, H.H., Dunn-Norman, S., Al-Alwani, M.A., Alshammari, A.F., Alkhamis, M.M., Mutar, R.A. and Al-Bazzaz, W.H. (2020). Experimental investigation of environmentally friendly drilling fluid additives (mandarin peels powder) to substitute the conventional chemicals used in water-based drilling fluid. *J. Pet. Explor. Prod. Technol. 10*: 407–417.

Al-Hameedi, A.T.T., Alkinani, H.H., Dunn-Norman, S., Al-Alwani, M.A., Alshammari, A.F., Albazzaz, H.W., Alkhamis, M.M., Alashwak, N.F. and Mutar, R.A. (2019). Insights into the application of new eco-friendly drilling fluid additive to improve the fluid properties in water-based drilling fluid systems. *J. Pet. Sci. Eng. 183:* 106-424.

Amanullah, M.D. and Yu, L. (2014). Superior Corn-Based Starches for Oil Field Application. CSIRO petroleum, Australian Resources Research Centre.

Bayat, A.E., Moghanloo, P.J., Piroozian, A. and Rafati, R. (2018). Experimental investigation of rheological and filtration properties of water-based drilling fluids in presence of various nanoparticles. *Colloids Surf. A. 555*: 256–263.

Boek, E.S., Hall, C. and Tardy, P.M.J. (2012). Deep Bed Filtration Modelling of Formation Damage Due To Particulate Invasion For Drilling Fluids In: Transport in Porous Media. 91(2), 479-508.

Caenn, R., Darley, H.C.H. and Gray, G.R. (2011). Composition and properties of drilling and completion fluids. 6th ed. Houston: Gulf Professional Publishing.

Chang, X., Sun, J., Xu, Z., Lv, K., Dai, Z., Zhang, F., Huang, X. and Liu, J. (2019). Synthesis of a novel environment-friendly filtration reducer and its application in water-based drilling fluids. *Colloids Surf. A.* 568: 284–293.

Chen, C., Li, C., Reniers, G. and Yang, F. (2021). Safety and security of oil and gas pipeline transportation: A systematic analysis of research trends and future needs using *WoS. J. Clean. Prod*. 3: 279-282.

da Silva, Í.G., Lucas, E.F. and Advincula, R. (2020). On the use of an agro waste, *Miscanthus x. Giganteus*, as filtrate reducer for water-based drilling fluids. *J. Disper. Sci. Technol.* 1–10.

Dankwa, O., Ackumey, S. and Amorin, R. (2018). Investigating the potential use of waste vegetable oils to produce synthetic base fluids for drilling mud formulation. In *SPE Nigeria Annual International Conference and Exhibition*; OnePetro: Kuala Lumpur, Malaysia.

de Oliveira, V., dos Santos, K., da Silva-Junior, A., Araújo, R., Balaban, R. and Hilliou, L. (2020). Testing carrageenans with different chemical structures for water-based drilling fluid application. *J. Mol. Liq.* 299: 112-139.

Dosunmu, A. and Joshua, O. (2010). Development of environmentally friendly oil based mud using Palm-oil and groundnut-oil. In 34th Annual SPE International Conference and Exhibition, Calabar: Society of Petroleum Engineers. pp. 1–9.

Fazelabdolabadi, B., Khodadadi, A.A. and Sedaghatzadeh, M. (2015). Thermal and rheological properties improvement of drilling fluids using functionalized carbon nanotubes. *Appl. Nanosci.* 5: 651–659.

Fazelabdolabadi, B., Khodadadi, A.A. and Sedaghatzadeh, M. (2015). Thermal and rheological properties improvement of drilling fluids using functionalized carbon nanotubes. *Appl. Nanosci. 5*: 651–659.

Ghaderi, S., Haddadi, S.A., Davoodi, S. and Arjmand, M. (2020). Application of sustainable saffron purple petals as an eco-friendly green additive for drilling fluids: A rheological, filtration, morphological, and corrosion inhibition study. *J. Mol. Liq. 315*: 113-707.

Goode, D.L., Berry, S.D. and Stacy, A.L. (2014). Aqueous-Based Remedial Treatments for Reservoirs Damaged by Oil-Phase Drilling muds. SPE Formation Damage Control Symposium, Bakersfield, California.

Haile, A., Gelebo, G.G., Tesfaye, T., Mengie, W., Mebrate, M.A., Abuhay, A. and Limeneh, D.Y. (2021). Pulp and paper mill wastes: Utilizations and prospects for high value-added biomaterials. *Bioresour. Bioprocess. 8*: 35.

Hassani, S., Vu, T.N., Rosli, N.R., Esmaeely, S.N., Choi, Y.S., Young, D. and Nesic, S. (2014). Wellbore integrity and corrosion of low alloy and stainless steels in high pressure CO2 geologic storage environments: An experimental study. *Int. J. Greenh. Gas Control. 23*: 30–43.

Jiankang, G. and Jienian, Y. (2003). Research advances in silicate-based drilling fluids and their applications. Oil Drilling and Production Technology, 25(5):20-24.

Joshi, P., Goyal, S., Singh, R. and Thakur, K. (2021). Development of water based drilling fluid using tamarind seed powder. *Mater. Today Proc.*

Karakosta, K., Mitropoulos, A.C.; and Kyzas, G.Z. (2021). A review in nanopolymers for drilling fluids applications. *J. Mol. Struct.* 1227: 129-702.

Lan, Q., Li, G.R. and Zhang, J.H. (2010). Applications of bio-enzymatic completion fluid in the tight sand gas reservoirs of Ordos Daniudi gas field. In: International oil conference and exhibition in China, 8 June, Beijing.

Leliang, C. and Guijuan, W. (2003). An overview of formate base drilling and completion fluids system: continued. Drilling Fluid and Completion Fluid, 20(2):33-38.

Li, F.X., Jiang, G.C., Wang, Z.K. and Cui, M.R. (2014). Drilling fluid from natural vegetable gum. *Pet Sci Technol.* 32(6): 738–744.

Li, X., Jiang, G., He, Y. and Chen, G. (2021). Novel starch composite fluid loss additives and their applications in environmentally friendly water-based drilling fluids. *Energy Fuels* 35: 2506–2513.

Li, X., Jiang, G., Shen, X. and Li, G. (2020). Poly-L-arginine as a high-performance and biodegradable shale inhibitor in water-based drilling fluids for stabilizing wellbore. *ACS Sustain. Chem. Eng. 8:* 1899–1907.

Magzoub, M.I., Ibrahim, M.H., Nasser, M.S., El-Naas, M.H. and Amani, M. (2020). Utilization of Steel-Making Dust in Drilling Fluids Formulations. *Processes 8*: 538.

Medhi, S., Chowdhury, S., Gupta, D.K. and Mazumdar, A. (2020). An investigation on the effects of silica and copper oxide nanoparticles on rheological and fluid loss property of drilling fluids. *J. Pet. Explor. Prod. Technol.* 10: 91–101.

Methven, N.E. and Kemick, J.G. (2017). Drilling and Gravel Packing with an oil base fluid system. *J. of Petro. Techn.,* 21(6): 671-679.

Murtaza, M., Tariq, Z., Zhou, X., Al-Shehri, D., Mahmoud, M. and Kamal, M.S. (2021). Okra as an environment-friendly fluid loss control additive for drilling fluids: Experimental & modeling studies. *J. Pet. Sci. Eng. 204*: 108743.

Olatunde, A.O., Usman, M.A., Olafadehan, O.A., Adeosun, T.A. and Ufot, O.E. (2012). Improving the Rheological Properties of Drilling Fluid Using Locally Based Materials, Petroleum and Coal, 54 (1): 65-75.

Omotioma, M., Ejikeme, P.C.N. and Ume, J.I. (2015). Improving the Rheological Properties of Water Based Mud with the Addition of Cassava Starch, *IOSR J. of Appl. Chemist. (IOSR-JAC)*, 8(8): 70-73.

Peden, J.M., Avalo, M.R. and Arthur, K.G. (2012). The Analysis of Dynamic Filtration and Permeability Impairment Characteristics of Inhibited water based mud.‖ SPE Fornation Damage Control Symposium, Lafayette, Louisiana.

Samavati, R., Abdullah, N., Tahmasbi, N.K., Hussain, S.A. and Awang, D.R. (2014). Rheological and Fluid Loss Properties of Water Based Drilling Mud Containing HCl-Modified Fufu as a Fluid Loss Control Agent, *Int. J. of Chem. Eng. and App.* 5(6): 446-450.

Shuixiang, X., Guancheng, J., Mian, C., Hao, D., Guangquan, L., Yu, X., Jianhua, W. and Kang, Q. (2011). An environment friendly drilling fluid system. Petroleum Exploration and Development, 369–378.

Werner, B., Myrseth, V. and Saasen, A. (2017). Viscoelastic properties of drilling fluids and their influence on cuttings transport. *J. Pet. Sci. Eng.* 156: 845–851.

Wis´niowski, R., Skrzypaszek, K. and Małachowski, T. (2020). Selection of a Suitable Rheological Model for Drilling Fluid Using Applied Numerical Methods. *Energies*, *13*: 3192.

World Oil 2004 Drilling, Completion and Workover Fluids. 2004. World Oil 225 (6): F-1

Zhang, J., Chen, G., Yang, N.W. and Wang, Y.G. (2012). Preparation and evaluation of sodium hydroxymethyl lignosulfonate as eco-friendly drilling fluid additive. *Adv. Mater. Res.* 415: 629–632.

Zhang, J., Chen, G., Yang, N.W. and Wang, Y.G. (2014). Preparation of nitration-oxidation lignosulfonate as an eco-friendly drilling fluid additive. *Pet. Sci. Technol.* 32: 1661–1668.

Zheng, Y., Amiri, A. and Polycarpou, A.A. (2020). Enhancements in the tribological performance of environmentally friendly water-based drilling fluids using additives. *Appl. Surf. Sci.* 527: 146822.

Zhenjie, Y. (2004). Present situation and its development direction of environmental protection drilling fluid. Drilling Fluid and Completion Fluid, 21(2): 39-42.