EVALUATION OF OKUAGHE CLAY AS A POTENTIAL MATERIAL FOR WATER-BASED DRILLING MUD FORMULATION

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CERTIFICATION

This is to certify that this project work titled **"EVALUATION OF OKUAGHE CLAY AS A POTENTIAL MATERIAL FOR WATER-BASED DRILLING MUD FORMULATION"** was carried out by **AGBONTAEN VICTOR IKPONMWOSA** with matriculation number **ENG2002594,** Faculty of Engineering, Department of Petroleum Engineering, University of Benin, Benin City under my supervision.

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DEDICATION

This project work is dedicated to God Almighty, for providence, guidance, and grace in seeing me through this study; I give Him all the glory. I also dedicate this project to my parents Barr. And Mrs. Agbontaen for without them, I would not have come this far.

ACKNOWLEDGEMENT

My sincere gratitude goes to God Almighty, for granting me this grace and mental powers to complete this project. This project completes another milestone in my academy career. I sincerely appreciate the Head of Department and also my project supervisor, Petroleum Engineering, for his support and guidance throughout the course of this project.

I also thank the laboratory technologists and my colleagues for their assistance during the experimental work. Finally, I appreciate my family and friends for their encouragements and prayers and also offering their supports and listening ears in my time of weakness.

May God in His infinite mercy, bless you all.

ABSTRACT

Drilling mud , otherwise known as drilling fluid, is a vital component in the oil and gas industry. As the primary medium for drilling oil and gas wells, its importance cannot be overstated. However, in Nigeria, the procurement of drilling mud is often costly, as bentonite clay, the conventional material used in its formulation is largely imported.

This project investigates the suitability of a locally sourced clay, Okuaghe, obtained from one of the countries numerous clay deposits, as a potential substitute for imported bentonite in drilling mud formulation. The study aims to promote local material utilization, reduce import dependency, and minimize overall operational costs.

The clay sample was collected from Uhunmwonde local government area in Edo State, then prepared through drying, crushing, and sieving. Portions of the total sample were activated using soda ash (sodium carbonate) to enable comparative analysis. Guided by API specifications, rheological properties such as plastic viscosity, apparent viscosity, yield point and gel strength were determined using standard procedures. Additionally, carboxymethyl cellukose (CMC) was incorporated in some samples to enhance performance toward API standards.

The results indicates that the local clay possesses promising potential for drilling mud formulation, provided adequate beneficiation and optimization of activation conditions are applied. The findings also emphasize the importance of maintaining optimal base concentration during chemical activation, as excessive amounts may yield adverse effects.

Overall, this laboratory-based study demonstrates that certain local clays, when properly treated and modified with suitable additives, can perform comparably to imported bentonite. It further underscores the need for field-scale evaluation to validate laboratory results and support the wider adoption of local materials in drilling fluid formulation.

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CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND TO THE STUDY

The effectiveness of the drilling fluid to execute its major functions is based on its properties, which are formulated continually to suit the formation conditions encountered during drilling operations. Failure of the drilling fluid to satisfy its specified purpose can prove extremely costly in terms of materials and time and may threaten the successful completion of the well and potentially result in serious difficulties such as stuck pipes, kicks, or blowouts. In other words, since drilling fluid is a vital part of the drilling process, many of the difficulties experienced during the drilling of a well can be directly or indirectly related to the drilling fluids. Therefore, these fluids must be carefully selected and/or created to fulfill their role in the drilling process.

However, it is a well-known fact that clay material and other additives, such as bentonite, are added to water or oil to make them appropriate as a drilling fluid. The existing use of bentonite in the drilling operations in Nigeria is above 50 thousand tons a year and all of it is imported from the USA. This tendency is projected to continue as drilling activity expands on the coasts of the Niger Delta. To this aim, the development of the Nigerian local content initiative in the oil and gas sector by the Federal Government of Nigeria has prompted the need for local substitutes for international drilling fluid ingredients. Thus, it is necessary to obtain locally available drilling fluid components and assess their varied qualities, then manufacture fluids that may be employed in the drilling process.

The exploration for hydrocarbon in the Niger Delta region dates back to the early 1950s when the first oil (hydrocarbon) reserve was discovered at OLOIBIRI in the present day BAYELSA State in 1956 (Etu-Efeotor, 1997). Drilling is the process of creating a passage for the discovered hydrocarbon to be produced at the surface. It involves the penetration of the earth's crust to several thousand feet where the hydrocarbons are accumulated in the reservoir using rotary drilling process.

A water-based drilling mud can be formulated and evaluated using materials like clay, CMC, and agro-waste products. The process involves preparing the materials, formulating the mud with desired properties, and then testing its performance based on parameters like density, viscosity, filtration, and pH evaluation.

In recent years, there has been growing interest in exploring locally available materials as potential substitutes for conventional drilling mud additives. This interest is driven by:

- The need to reduce the cost of drilling operations.
- The desire to promote local content in the oil and gas sector.
- The quest for self-sufficiency and innovation in drilling fluid technology

1.2 STATEMENT OF THE PROBLEM

Formulating water-based drilling MUDS from the evaluation of local clay faces challenges, leading to unpredictable performance; limited thermal and salinity stability of some natural polymers, causing degradation and operational issues; difficulty in achieving optimal rheological properties (like viscosity and gel strength) for effective hole cleaning and cuttings transport; problems with fluid loss control, resulting in thick filter cakes and stuck pipes; and issues with the physiochemical properties, such as the variable pH of some materials.

1.3 AIM AND OBJECTIVES OF THE STUDY

The primary aim of the study is to evaluate local clay (okuaghe) as a potential material for water based drilling mud formulation.

The main aims and objectives shared across the studies are:

- To optimize the formulation of water-based drilling mud using entirely or mostly locally sourced materials, particularly for developing countries.
- To compare the performance of locally formulated mud with that of standard API mud.
- To formulate muds with specific physio-chemical and rheological properties.
- To formulate mud using activated clay and CMC.
- Activation of the clay with sodium carbonate (soda ash).

1.4 RESEARCH QUESTIONS:

To achieve the above objectives, the following research questions are addressed:

- What are the physicochemical properties of the local clay sample, and how do they compare with standard bentonite?
- What concentrations of these materials and beneficiation agents (e.g., soda ash) are optimal?
- How do formulated MUDS' physical, chemical, and rheological properties (density, pH, viscosity, fluid loss) compare to industry standards like API?
- What effect does varying CMC concentration have on the rheological and filtration behavior of the formulated drilling MUDS?
- How does sodium carbonate activation influence the properties of the local clay?
- At what concentration of CMC does the activated local clay yield optimal drilling mud performance?
- Can sodium carbonate activated local clay serve as an effective and economic alternative to imported BENTONITE for water-based drilling MUDS?

1.5 SIGNIFICANCE OF THE STUDY

Studying water-based drilling mud formulated from the evaluation of local clay has benefits such as reduced costs by replacing expensive imported product. The use of locally sourced clay as a substitute for imported bentonite can significantly reduce drilling costs in petroleum industry. It will minimize the foreign exchange expenditure on bentonite importation and enhance the profitability of drilling operations. It also improves environmental sustainability by utilizing local clay deposits; It reduces the need for long-distance transportation of imported bentonite, thereby lowering the carbon footprint associated with drilling operations. It enhances operational efficiency through the discovery of local alternatives with performance comparable or superior to conventional materials. Research also provides insights into local geological formations, leading to better engineered drilling fluids and contributing to economic development by fostering local industries and reducing reliance on foreign imports.

1.6 SCOPE OF THE STUDY

The scope of this research covers the collection, activation, formulation, and laboratory evaluation of local clay as potential drilling mud material. The overall objective is to reduce costs and environmental impact while maintaining or improving drilling efficiency and wellbore stability.

Specifically, the study includes:

- Collection and characterization of local clay from the study area.
- Activation of the clay using sodium carbonate to enhance its swelling and rheological properties.
- Formulation of water-based drilling MUDS using CMC as a VISCOSIFIER.

- Measurement of key drilling mud properties, including plastic viscosity, yield point, gel strength, pH, density, and filtration loss.
- Comparison of the formulated mud properties with those standard BENTONITE mud and API specifications

1.7 STUDY AREA

The local clay used in this study was obtained from (UHUNMWONDE in Benin City, Edo state) Nigeria.

This area is known for its deposit of kaolinite, montmorillonite, and illite clays. This region has alternating wet and dry seasons that influence clay mineralogy through weathering and leaching processes.

The clay was collected from small-scale clay pits, dried, crushed, and sieved to remove impurities. The mineralogical composition is typical of calcium-based clay, requiring activation to enhance its swelling and dispersion behavior.

The study area is significant because it has abundant, underutilized clay deposits that could serve as substitutes for imported BENTONITE. And also, it provides representative local material for evaluating the effect of sodium carbonate activation and polymer modification.

CHAPTER TWO

LITERATURE REVIEW

2.1 THEORETICAL REVIEW

This chapter reviews relevant literature on the properties of drilling MUDS, the characteristics of local clays, and the use of sodium carbonate activation and CARBOXYLMETHYL cellulose (CMC) to enhance local clay performance. It also reviews the roles of bentonite and viscosifiers.

Drilling is the action of making a hole in something by boring with a drill. In oil exploration or wells, drilling involves creating a passage for the discovered hydrocarbon to be produced at the surface. It has to do with the penetration of the earth's crust to thousands of feet where the hydrocarbons are stored in the reservoir utilizing the drilling procedure. Up till now, from the era of cable tool rigs to the use of rotary drilling rigs, a lot of development in technology has been put forth on how best drilling operations can be carried out in the best methods that are affordable and environmentally viable.

Drilling fluids are heterogeneous combinations of oil, water, or chemical clay elements that enhance drilling operations. They are vital in effective well drilling as they have similar features that permit safe and satisfying completion of the well, such as bottom-hole cleaning, managing high-pressure zones, and removal of cuttings to the surface. In Nigeria, drilling businesses commonly import bulk drilling fluid ingredients to carry out their different activities. This has been a big burden and major concern to the industry since some of these drilling fluid materials cannot be recycled. Secondly, the foreign exchange involved, and the high cost of drilling fluid ingredients also create a difficulty for the petroleum business.

Water-based drilling mud (WBM) is a type of drilling fluid that uses water as its continuous (base) phase. It is the most commonly used type of drilling mud in oil and gas explorations.

Water-based drilling mud is a fluid mixture primarily composed of water, clay (such as BENTONITE or local clay), and various additives (such as polymers, starch, and weighting materials) that help cool the drill bit, carry rock cuttings to the surface, stabilize the borehole, and control formation pressures.

BENTONITE, a naturally occurring clay dominated by the mineral MONTMORILLONITE, has been the most widely used base material for water-based drilling MUDS due to its high swelling capacity and excellent rheological properties. However, in many developing countries, bentonite is imported at high cost, creating a need to explore and develop local clay resources as potential substitutes.

FUNCTIONS OF WATER-BASED DRILLING MUD:

According to the American Petroleum Institute (API, 2010), drilling mud is a circulating fluid used in rotary drilling operations. It serves the following main purposes:

1.) Cooling and lubricating the drill bit
2.) Removing drill cuttings from the wellbore
3.) Controlling subsurface pressure by adjusting mud weight
4.) Preventing formation damage
5.) Forming a thin filter cake on the borehole wall to minimize
6.) Supporting the walls of the well to prevent collapse.

The efficiency of a drilling mud depends on its rheological, filtration, and density properties, which are controlled by the type and treatment of clay used.

ADVANTAGES OF WATER BASED DRILLING MUD:

1.) Environmentally friendly (easier to dispose of than oil-based MUDS)
2.) Cost-effective
3.) Easier to clean up and reclaim
4.) Widely available materials (like water, clay, starch, etc.)

LIMITATIONS OF WATER-BASED DRILLING MUD:

1.) Poor performance in reactive shale (may cause wellbore instability)
2.) Limited thermal stability at high temperatures
3.) Lower lubricity compared to oil-based MUDS
4.) Susceptible to contamination (e.g., by salts, cement, or formation fluids)

TYPES OF WATER-BASED MUDS (WBM):

- Freshwater mud
- Saltwater mud
- KCI/polymer mud
- Gypsum/lime mud
- PHPA mud

COMPONENTS OF WATER-BASED DRILLING MUD:

Water-based MUDS consist of several components that collectively provide the desired physical and chemical properties:

- **Base Fluid (Water):** Serves as the continuous phase for the dispersion of solids.
- **VISCOSIFIERS:** Provide adequate viscosity and suspension capability.
- **Filtration Control Agents:** Minimize filtrate loss and form thin, impermeable filter cakes.
- **pH Control Additives:** Regulate alkalinity to stabilize clays.
- **Weighting Materials:** Increase density when necessary to control formation pressure.

2.1.1 BENTONITE AS A DRILLING MUD MATERIAL:

BENTONITE is a naturally occurring clay formed from volcanic ash alteration. It is primarily composed of montmorillonite, a smectite mineral characterized by a 2:1 layer silicate structure that allows for high water absorption and swelling. There are two main types of bentonite:

1.) Sodium bentonite (Na-BENTONITE): Exhibits high swelling, plasticity, and THIXOTROPY-ideal for drilling MUDS.
2.) Calcium bentonite (Ca-BENTONITE): Has lower swelling capacity and poorer rheological behavior, but can be converted to sodium BENTONITE through sodium activation.

Sodium bentonite has the ability to form viscous suspensions with high yield points and low filtration losses. However, due to limited deposits in many regions, local clays (which are often calcium-based) must be activated or modified to achieve similar properties.

2.1.2 LOCAL CLAY AS AN ALTERNATIVE MATERIAL

Local clays are widely available in many countries and represent a cost-effective alternative to imported bentonite. Studies have shown that these clays often contain kaolinite, illite, or monmorillonite minerals in varying proportions.

For example:

- **Abdullahi et al. (2017)** reported that Nigerian clays from Borno and Edo states contain montmorillonitic structures suitable for drilling fluid formulation after proper treatment.
- **Okunade (2019)** found that local clays with illitic composition can be improved through beneficiation and chemical modification.

However the main limitation of local clays is its low swelling index and poor dispersion in water, leading to weak viscosity and high fluid loss. To overcome these challenges, sodium carbonate activation and polymer additives are commonly employed.

2.1.3 LOCAL CLAY AS VISCOSIFIER

Clays such as bentonite are widely used due to their swelling and gel-forming ability. However, in regions where BENTONITE is not naturally abundant, local clay can be evaluated for similar properties.

2.1.4 ACTIVATION OF LOCAL CLAY WITH SODIUM CARBONATE

Activation of beneficiation is the process of improving the physiochemical and rheological properties of natural clay to make it suitable for industrial applications. For drilling mud formulation, the most effective activation method is sodium activation using sodium carbonate, also known as soda ash.

2.1.4.1 Mechanism of Sodium Activation

Calcium bentonite contains calcium ions in the interlayer spaces of the clay structure. When sodium carbonate is added, the following ion-exchange reaction occurs:

$Ca2+$ (clay) + $Na2CO3 \rightarrow 2Na+$ (clay) + $CaCO3$

The calcium ions are replaced by sodium ions, and insoluble calcium carbonate precipitates out. The resulting sodium-exchanged clay (Na-clay) exhibits:

Higher swelling capacity

Improved dispersion in water

Better viscosity and yield strength

Reduced filtration loss

2.1.4.2 FACTORS AFFECTING ACTIVATION EFFICIENCY

The effectiveness of sodium activation depends on:

- Type of clay mineral (montmorillonite, illite, kaolinite, etc.)

- Concentration of sodium carbonate (typically 2-5% by weight of clay)
- Mixing and aging time after treatment
- Moisture content and temperature

According to **Abdulrazak et al. (2020),** optimum results are obtained when local clay is treated with 3-4 wt.% sodium carbonate and aged for at least 24 hours before mud preparation.

2.1.5 ROLE OF CARBOXYMETHYL CELLULOSE (CMC) AS A VISCOSIFIER

Carboxymethyl cellulose (CMC) is a water-soluble cellulose derivative commonly used as a VISCOSIFIER and fluid loss control agent in water-based drilling muds.

Its functions include:

- Increasing the viscosity and yield point of muds
- Reducing filtration loss by forming thin, impermeable filter cakes
- Stabilizing the clay suspension and preventing particle settling
- Enhancing the lubricating properties of the mud.

When combined with activated local clay, CMC forms a polymer-clay network that enhances inter-particle bonding, leading to improved rheological and filtration properties.

Studies (e.g., Osinowo et al., 2021) have shown that CMC-modified local clay MUDS can achieve comparable performance to bentonite based muds when properly optimized.

2.2 EMPIRICAL ANALYSIS

Empirical analysis in this study involves the quantitative evaluation of drilling mud properties formulated using local clay. The experimental approach followed API-recommended practices and was focused on key performance indicators (KPIs) for drilling mud, such as viscosity, yield point, gel strength, fluid loss, and filter cake thickness.

It summarizes findings from prior experimental studies related to clay activation, polymer modification, and performance comparison.

Several researchers have reported successful activation and use of local clay for drilling mud formulation:

- **Egunjobi et al. (2018):** Activated Nigerian calcium BENTONITE with sodium carbonate and achieved 70-80% improvement in swelling and viscosity.
- **Ibrahim et al.(2020):** Reported that activated local clay treated with 4 wt.% sodium carbonate and 0.5 wt.% CMC met API standards for plastic viscosity and filtration loss.
- **Abdullahi et al.(2022):** Demonstrated that sodium carbonate activation and polymer addition significantly enhance the yield point and reduce fluid loss in local clays.
- **Osinowo et al.(2021):** Use of CMC in local clay mud. CMC improved viscosity and reduced filtration loss by forming polymer-clay network.
- **Rahman & Wan Nik (2019):** Effect of polymer additives on mud rheology. Polymer addition increased viscosity and decreased filtrate volume significantly.
- **Abdulrazak et al.(2020):** Optimization of activation parameters. Best activation achieved at 3-4 wt. % sodium carbonate, 24hr aging, and adequate mixing.

Studies confirm that sodium carbonate activation and polymer enhancement (particularly CMC) significantly improve the performance of local clay, enabling it to meet API requirements for water-based drilling muds.

2.2.1 AIM OF THE EXPERIMENT:

The aim of this experiment is to evaluate the performance of sodium carbonate activated local clay as a base material for water-based drilling MUDS, using CMC as a VISCOSIFIER to improve rheological and filtration characteristics.

The main aims shared across the studies are:

1.) To optimize the formulation of water-based drilling mud using entirely or mostly locally sourced materials, particularly for developing countries.

2.) To compare the performance of locally formulated mud with that of standard API mud.

2.2.2 MUD EVALUATION PARAMETERS

1.) Rheological Properties:

- Apparent Viscosity (AV)
- Plastic Viscosity (PV)
- Yield Point (YP): Indicate suspension and carrying capacity

Equipment: Marsh Funnel, Rotational Viscometer

2.) MUD DENSITY:

- Measured using a Mud balance: It controls hydrostatic pressure

3.) pH : Reflects chemical stability

- Measured using pH meter or pH paper

4.) Filtration Loss / Fluid Loss

- Measuring using API Filter Press
- Record volume of filtrate in 30 minutes

5.) GEL STRENGTH

- Initial (10 sec) and 10-minutes values using viscometer

6.) SAND CONTENT

- Optional: Sand Content Kit

2.2.3 API STANDARDS FOR DRILLING MUD

The American Petroleum Institute (API Specification 13A) provides standardized requirements for performance of drilling mud materials. According to API:

- Yield Point: 10 – 30 lb/100ft^2
- Plastic Viscosity: 8 – 25 Cp
- Filtrate Volume: less than equal to 15ml after 30 minutes (at 100 psi, 25 degree)

- pH: 8.5-9.5

These parameters serve as benchmarks for evaluating the suitability of locally formulated drilling muds.

2.2.4 RELEVANCE OF REVIEW TO PRESENT STUDY AND IDENTIFIED GAPS IN LITERATURE

The reviewed literature provides a strong foundation for understanding the principles, materials, and mechanisms involved in drilling mud formulation. It establishes the relevant to this study:

1.) UNDERSTANDING OF DRILLING MUD BEHAVIOR: The review has clarified how rheological and filtration characteristics of drilling fluids depend primarily on the properties of the clay base and the type of viscosifier used.

2.) ROLE OF SODIUM CARBONATE ACTIVATION: Studies confirm that sodium carbonate activation significantly improves the swelling and viscosity of calcium-based local clays by replacing divalent CATION with sodium ions. This directly supports the approach adopted in the present research.

3.) IMPORTANCE OF POLYMER ADDITIVES (CMC): The literature highlights the effectiveness of carboxymethyl cellulose (CMC) as a viscosifier and fluid loss control agent in water-based muds. Its compatibility with local clay enhances the mud's rheological and filtration properties.

4.) BENCHMARK FOR COMPARISON: The API standards reviewed serve as the basis for evaluating the performance of the locally formulated muds, ensuring that results can be compared to internationally accepted specifications.

5.) SUPPORT INDIGENOUS RESOURCE UTILIZATION: The reviewed studies underscore the economic and strategic importance developing indigenous clay materials for drilling fluid applications, aligning with current industry efforts to promote local content development.

Thus, the literature review provides a scientific and practical justification for evaluating sodium carbonate activated local clay combined with CMC as viable alternative to imported bentonite.

The identified gaps in this literature review are listed below;

Despite numerous studies on local clay modification, several research gaps remain:

- LIMITED DATA ON COMBINED ACTIVATION POLYMER SYATEMS: While past studies have explored sodium carbonate activation and polymer modification separately, fewer works have systematically evaluated the combined effect of sodium carbonate activation and CMC addition on local clay performance in drilling mud.
- INSUFFICIENT CHARACTERIZATION OF LOCAL CLAYS FROM SPECIFIC REGIONS: Many studies focus on selected Nigerian or regional clay deposits without extensive physiochemical comparison. This study adds to the database by characterizing another specific local clay source and assessing its potential for drilling mud formulation.
- INCONSISTENT OPTIMIZATION OF ACTIVATION CONDITIONS: There is no consensus on the optimal sodium carbonate dosage, aging period, or CMC concentration for the best rheological results. The research provides controlled experimental data to identify the most effective concentration ranges.
- LACK OF COMPREHENSIVE RHEOLOGICAL AND FILTRATION EVALUATION: Some previous studies report only limited parameters (e.g., viscosity or fluid loss). The present work evaluates a complete suite of drilling

mud properties-density, pH, plastic viscosity, yield point, gel strength, and filtration loss-under controlled laboratory conditions.

- APPLICATION GAP BETWEEN LABORATORY AND FIELD PERFORMANCE: Most available data are laboratory-based, with little linkage to potential field implementation. By comparing results directly with API standard, this study bridges the gap between laboratory outcomes and industrial requirements.
- ECONOMIC AND SUSTAINABILITY ASSESSMENT: Few studies have quantitatively discussed cost-effectiveness or sustainability implications of replacing imported BENTONITE with locally sourced, activated clays. This study discusses such economic and practical relevance, providing insight for local content policy support.

2.3 REVIEW OF METHODS OF INSTRUMENTATION

A review of instrumentation and procedures used in similar studies provides context for methods adopted in this project.

2.3.1 CLAY ACTIVATION PROCEDURE

Previous researchers (e.g., Abdulrazak et al., 2020; Egunjobi et al., 2018) used dry or wet activation methods.

- Dry activation: Sodium Carbonate (2-5 wt. %) is dry-mixed with clay, then hydrated and aged for 24-48 hours.
- WET ACTIVATION: Sodium carbonate is dissolved in water and mixed with clay slurry before drying and pulverizing.

Both methods facilitate ion exchange and improve clay swelling.

2.3.2 MUD FORMULATION

STANDARD PROCEDURES FOLLOW API RP 13B-1:

* Clay or activated clay is dispersed in water

* CMC or other polymers are added at specific concentrations (e.g., 0.2-0.6 wt. %).

* The mixture is agitated for uniform blending using a mechanical mixer.

TABLE 2.1 LABORATORY TESTS AND INSTRUMENTATION

PROPERTY	INSTRUMENT/STANDARD	DESCRIPTION
RHEOLOGY (PV, YP, Gel Strength)	Rotational Viscometer (Model 35 or equivalent)	Measures shear stress vs. shear rate to determine viscosity and yield point
Density	Mud Balance (API Standard)	Determines the mass per unit volume of drilling fluid.
pH	Digital pH meter	Indicates the alkalinity of mud for chemical stability.
Filtration loss	API Filter press (100 psi, 30 min)	Measures volume of filtrate and thickness of filter cake.

These instruments are standard in drilling mud laboratories and ensure data consistency across studies.

2.4 REVIEW OF SPECIALIZED TECHNICAL TERMS

To aid understanding of drilling fluid formulation and evaluation, the following are key technical terms used throughout the report.

1.) PLASTIC VISCOSITY (PV)

- Definition: The resistance of a fluid to flow due to mechanical friction between solid particles and the liquid.
- Importance: Indicates the solids concentration and helps evaluate mud cleaning efficiency.

2.) YIELD POINT (YP)

- Definition: The stress required to start fluid flow; measures the electrochemical or attractive forces between particles.
- Importance: Higher YP indicates better cutting-carrying capacity and hole-cleaning.

3.) GEL STRENGTH

- Definition: The measure of a fluid's ability to suspend cuttings during static conditions.
- Units: lb/100 ft2
- Importance: Prevents setting of solids when circulation stops.

4.) FLUID LOSS (FILTRATE VOLUME)

- Definition: The amount of liquid phase lost from the mud to the formation.
- Importance: Excessive fluid loss can lead to formation damage, differential sticking, and wellbore instability.

5.) FILTER CAKE

- Definition: A layer of solid particles deposited on the borehole wall due to fluid loss.
- Importance: A thin, firm, and impermeable filter cake is desirable to reduce permeability invasion.

6.) FLUID LOSS CONTROL AGENT

- Definition: An additive used to reduce the rate at which the liquid portion of the mud escapes into permeable formations.

7.) VISCOSIFIER

- Definition: A material added to drilling mud to increase viscosity. In this study, local clay served as the viscosifier.

8.) API STANDARDS

- Definition: Specifications and recommended practices by the American Petroleum Institute to ensure standardization consistency in oilfield practices.

9.) BIOPOLYMER

- Definition: A naturally occurring polymer derived from renewable biological sources. Cassava starch is an example used in mud formulations.

10.) BENTONITE

- Definition: A clay dominated by monmorillonite with high swelling capacity; standard for drilling mud formulation.

11.) LOCAL CLAY

- Definition: Natural occurring clay deposits of regional origin, often calcium-rich, requiring beneficiation to meet API standards.

12.) ACTIVATION (Beneficiation)

- Definition: Chemical treatment of clay (commonly with sodium carbonate) to improve swelling and rheology.

13.) SODIUM CARBONATE

- Definition: A reagent used to replace calcium ion with sodium ion in clay, enhancing swelling and viscosity.

14.) CMC (CARBOXYLMETHYL Cellulose)

- Definition: A water-soluble polymer used as viscosifier and fluid loss control additive in drilling fluids.

15.) RHEOLOGY

- Definition: Study of flow behavior; In drilling mud, it determines viscosity, yield point and Gel strength.

2.4.1 REVIEW OF SPECIALIZED TECHNICAL TERMS (WITH SODIUM CARBONATE CONTEXT)

TERMS

- **CLAY ACTIVATION:**

  Treatment used to improve the swelling and DISPERSIBILITY property of the clay.

- **SODIUM CARBONATE:**

  Alkaline salt used to soften water and activate clays

- **PLASTIC VISCOSITY (PV):**

  Viscous resistance from internal flow friction

- **YIELD POINT (YP):**

  Stress needed to initiate mud flow

- **GEL STRENGTH:**

  Mud's ability to suspend solids static periods

- **CATION EXCHANGE CAPACITY (CEC):**

  Ability of clay to exchange CATION

- **FILTER CAKE:**

  Solid residue on borehole wall and fluid loss

- **BIOPOLYMER STABILITY:**

  Resistance of polymers to degradation

- **PRE-HYDRATION:**

  Soak additives with water before use.

CHAPTER THREE

MATERIALS AND METHODS

3.1 LIST OF MAJOR MATERIALS/EQUIPMENTS

3.1.1 MATERIALS USED:

1.)Local clay (Okuaghe) gotten from Uhunmwonde L.G.A

2.) Sodium carbonate – Activation agent to activate the clay

3.) Distilled water -- Base fluid for mud formation

4.) CMC – It was used as a viscosifier

3.1.2 EQUIPMENTS:

1.) Oven – The oven was used for drying of clay samples

2.) Sealed Plastic Containers – For storing our samples before analysis

3.) MORTAR and pestle – For crushing clay samples

4.) Beakers, graduated cylinders – For measuring liquid and mud volume

5.) Weighing balance – For weighing reagents

6.) Viscometer – To measure mud rheology (PV, YP, Gel Strength)

7.) API Filter Press – To measure fluid loss and Filter cake thickness

8.) Mud Balance – To determine Mud density

9.) pH strips – To measure the pH of the mud samples

10.) Sieve shaker – For sample particle size uniformly

11.) Sand content kit – For checking the sand content of the samples

3.2 RESEARCH DESIGN

This study follows an experimental research design, with emphasis on comparative analysis and optimization. This study was also designed as an experimental laboratory-based research aimed at formulating, and activating a water-based drilling mud prepared from locally sourced materials (clay) etc. This study involves the activation and enhancement of local clay with sodium carbonate and CMC respectively. And also API standard procedures for different analysis to be done on clay samples were adopted to enable comparison.

In this study, the research approach taken is the quantitative experimental design which talks about testing and comparing the physical properties of different mud samples under controlled laboratory conditions.

3.3 SAMPLE PREPARATION

3.3.1 METHOD OF SAMPLE COLLECTION AND PREPARATION OF RAW CLAY

1.) The local clay was collected by digging of the area where the clay was present and collecting the clay from the ground. Then after collecting the raw clay, I proceeded to sun-drying the clay before use because the raw clay was not dry when collected from the dug area.

2.) The dried clay was taken to the lab for crushing which was crushed with mortar and pestle and sieved with a sieve shaker to acquire uniform sample particles and the mesh size of the sieve used was BSS 22. This process was done because the clay is needed in powder form.

3.) The powder clay was shared into different portions for different purposes. A portion of the clay was left raw without activation for baseline test. While the remaining portions was activated with sodium carbonate.

3.3.2 ACTIVATION PROCESS OF CLAY WITH SODIUM CARBONATE (SODA ASH)

In the lab, 3% and 5% of sodium carbonate was use to activate the clay samples now having two activated clay samples.

In the activation process;

1.) 150g of clay was weighed for each clay sample

2.) To get the required amount of sodium carbonate to be used, calculations were made for each samples both the 3% and 5%. Calculation; for the 3 % → 3/100 x 150 =4.5g. For the 5% → 5/100 x 150 = 7.5g.

3.) The specific amount of sodium carbonate which was calculated for was dissolved in 100ml of water i.e. 100ml each for both samples. Then the solution was poured gradually into the samples in their labeled container.

4.) After the solution was poured and mixed with the clay sample, each samples were sealed and left to age for 24 hours at room temperature.

5.) After ageing for 24 hours, the samples were put into an oven (180 degrees) for drying and left to dry for 48 hours.

6.) After drying, the samples were crushed and sieved because the samples were needed in powder form.

3.3.3 FORMULATION OF DRILLING MUD SAMPLES FOR LABORATORY TEST

Four samples were formulated for this process. One sample was left raw (i.e., just local clay), while the remaining three samples were formulated with varying concentrations of CMC and two of the samples were activated with sodium carbonate.

Preparation Steps:

1.) Measure 350ml of water into a mixing cup.

2.) Gradually add the measured clay 25g. In which two are raw clay and the remaining two are already activated with sodium carbonate (4.5g and 7.5g).

3.) Add the CMC and continue stirring until evenly dispersed.

4.) Proceed to performing the different test.

3.3.4 LABORATORY TESTS AND PROCEDURES

3.3.4.1 MUD DENSITY TEST

- **Equipment:** Mud Balance

figure3.1: Mud Balance

- **Procedure:**

a) Fill the mud balance cup with the formulated mud sample.

b) Level the beam and record the reading directly from the calibrated scale.

3.3.4.2 RHEOLOGICAL PROPERTY TESTS

- **Equipment:** Multi-speed rotational viscometer
- **Parameters Measured:** Plastic Viscosity, Yield Point, Apparent Viscosity and Gel strength.
- **Procedure:**

a) Pour the mud sample into the viscometer cup

b) Take dial reading at 600 rpm and 300 rpm speeds.

c) Compute plastic viscosity, yield point and apparent viscosity using the formulas;

Plastic viscosity = dial reading at 600 rpm – dial reading at 300 rpm

Yield point = dial reading at 300 rpm – plastic viscosity

Apparent viscosity = dial reading at 600 rpm / 2

- Gel strength: After static intervals of 10 seconds and 10 minutes, measure the maximum dial deflection to determine initial and final gel strengths.

figure3.2: Multi speed rotational viscometer

3.3.4.3 FILTRATION TEST

- **Equipment:** API Filter press (30mins)
- **Procedure:**

a) Assemble the filter press and pour in a 350ml mud sample.

b) Apply pressure for 30 minutes.

c) Measure the filtrate volume collected in a graduated cylinder.

The purpose of this is to evaluate the mud's ability to minimize filtrate loss through permeable formations.

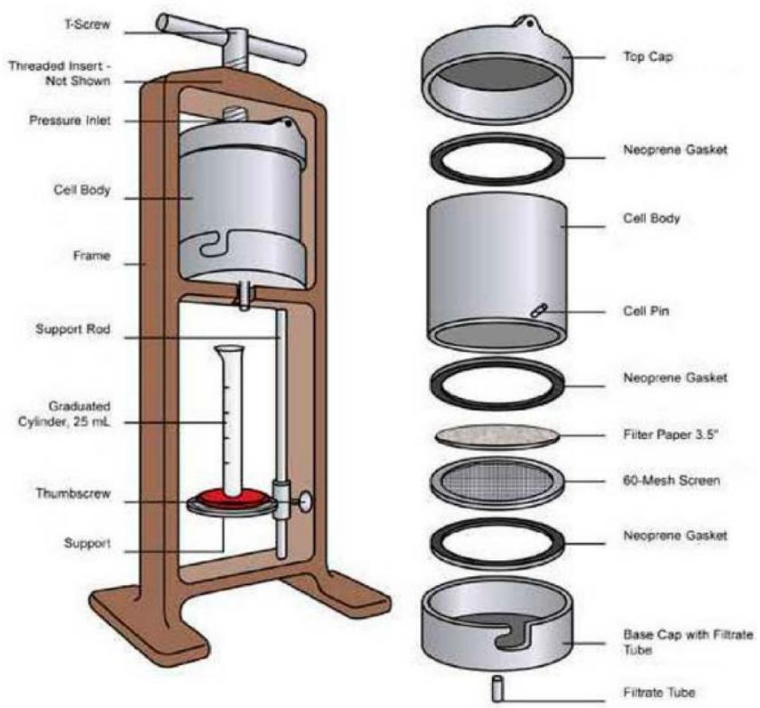

figure3.3: API Filter press

3.3.4.4 pH TEST

- **Equipment:** pH strip
- **Procedure:**

a) Dip or immerse the pH strip in the sample, then a change of color will occur

b) Take the paper and compare the color change to the colors showing on a chart showing different colors and the pH value.

c) Record the pH value on the chart showing same color change as the pH strip.

The purpose of this is to determine the alkalinity or acidity of the mud system.

figure3.4: pH strip

3.3.4.5 Sand content test

- **Equipment:** Sand content kit
- **Procedure:**

a) Stir the mud sample thoroughly to ensure uniformity before taking a representative portion.

b) Pour the mud sample into the sand content tube up to the marked line at the bottom of the tube.

c) Add clean water to the marked line at the top of the tube.

d) Place thumb over the open end and shake the tube to mix the contents completely.

e) Pour the mixture onto the mesh screen, using the funnel to avoid spillage.

f) Use the wash bottle to thoroughly rinse the material through the screen until only the sand remains on top.

g) Rinse the retained sand on the sieve carefully into the clean sand content tube using a gentle water stream.

h) Allow the sand to settle in the graduated tube and read the sand content. The percentage reading on the tube corresponds directly to percentage sand by volume in the drilling mud.

figure3.5: Sand content kit

3.4 METHODS OF DATA ANALYSIS

3.4.1 EXPERIMENTAL ANALYSIS

The purpose of this is to evaluate mud properties. The methods related to the experimental analysis are; rheology, pH, Filtration, Density etc.

3.4.2 COMPARATIVE ANALYSIS

Compare the performance of locally formulated muds and commercial/standard water-based.

Benchmarking against API Standards:

Determine if the samples meet minimum API specifications for; viscosity, fluid loss, gel strength, pH range etc.

The benchmark concentration was set at 25g clay in 350ml water.

CHAPTER FOUR

RESULTS AND DISCUSSIONS

This chapter presents the results obtained from the Evaluation of OKUAGHE clay as a potential material for water-based drilling mud formulation. The materials utilized include Okuaghe clay (from Uhunmwonde, Benin City, Edo state), CMC as a viscosity enhancer, sodium carbonate (soda ash) was used to activate the mud sample. The data presented include the results of density, viscosity, filtration loss, pH test, sand content, and gel strength test carried out under standard laboratory conditions. This chapter also presents the analysis and interpretation of the data obtained from the laboratory tests on the formulated water-based drilling mud samples. The results are discussed in relation to the standard requirements for drilling fluids as recommended by the American Petroleum Institute (API). The aim is to determine whether the mud samples formulated with local clay exhibit acceptable properties for drilling operations.

4.1 PRESENTATION OF DATA

4.1.1 FORMULATED MUD SAMPLES

Different samples of drilling mud were formulated. One of the samples was left as it was without being concentrated. The remaining samples were formulated with varying concentration of sodium carbonate and CMC. The composition of each of the mud samples is shown in a tabular form;

TABLE 4.1: Formulation of water-based drilling mud samples

Components	**Sample A**	**Sample B**	**Sample C**	**Sample D**
Water(ml)	350	350	350	350

Local clay(g) (OKUAGHE)	25	25	25	25
Sodium Carbonate(g)	0	0	4.5	7.5
CMC(g)	0	1.25	1.25	1.25

4.1.2 MUD DENSITY

The mud density was determined using the mud balance. The results obtained are shown below;

TABLE 4.2: Mud Density Results

Parameters	Sample A	Sample B	Sample C	Sample D
Mud density(lb/gal)	8.7	8.7	8.8	8.9

4.1.3 RHEOLOGICAL PROPERTIES

The rheological properties such as plastic viscosity, yield point, apparent viscosity and gel strength were determined using the viscometer. The results are summarized in a tabular form;

TABLE 4.3: Rheological properties of formulated drilling mud samples

Parameters	Sample A	Sample B	Sample C	Sample D
Plastic viscosity(cP)	2	9	9.5	10
Yield point	1.5	12	4	5
Apparent				

viscosity(cP)	2.75	15	11.5	12.5
Gel strength (10ses/10mins)	3.5/4	17.5/19	12/13	16/32

From the table, it can be observed that the plastic viscosity increases as the concentration on the local clay increases. This indicates better suspension capability and improved carrying capacity of the mud with higher clay content.

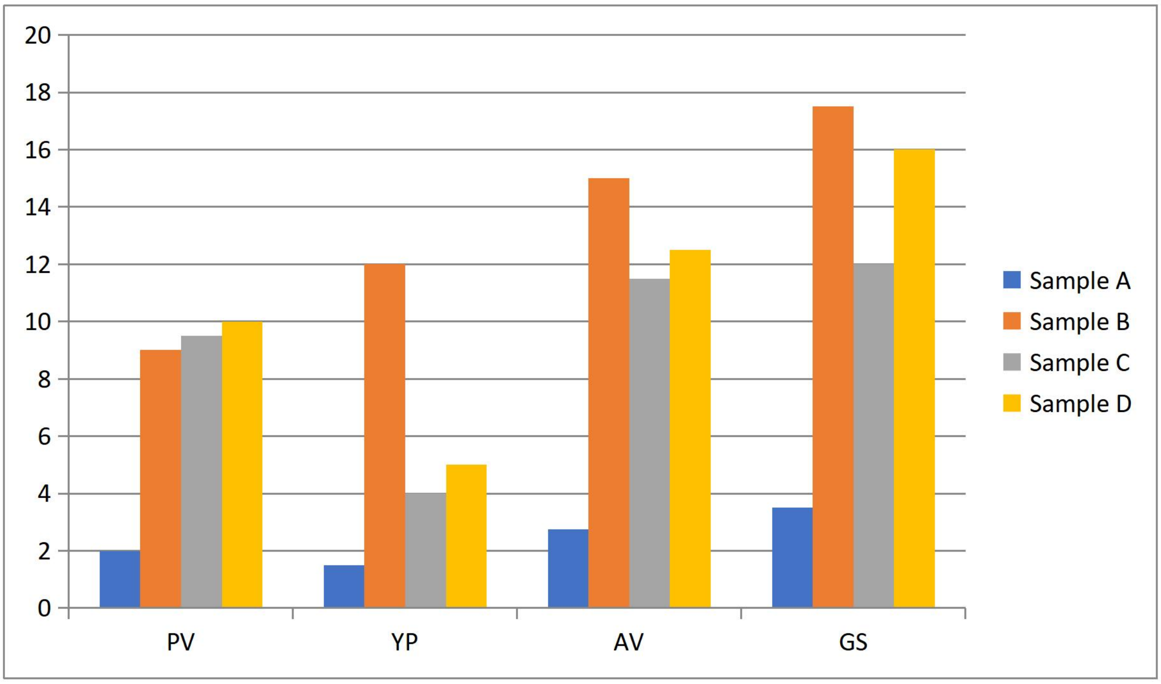

Figure4.1: Bar graph representation of rheological properties

4.1.4 Filtration Properties

Filtration tests were carried out using a standard API Filter press for 30minutes. The results obtained are shown below;

TABLE 4.4: Filtration Test Results

Parameter	Sample A	Sample B	Sample C	Sample D
Filtrate Loss(ml)	88	11.4	7.5	5.3

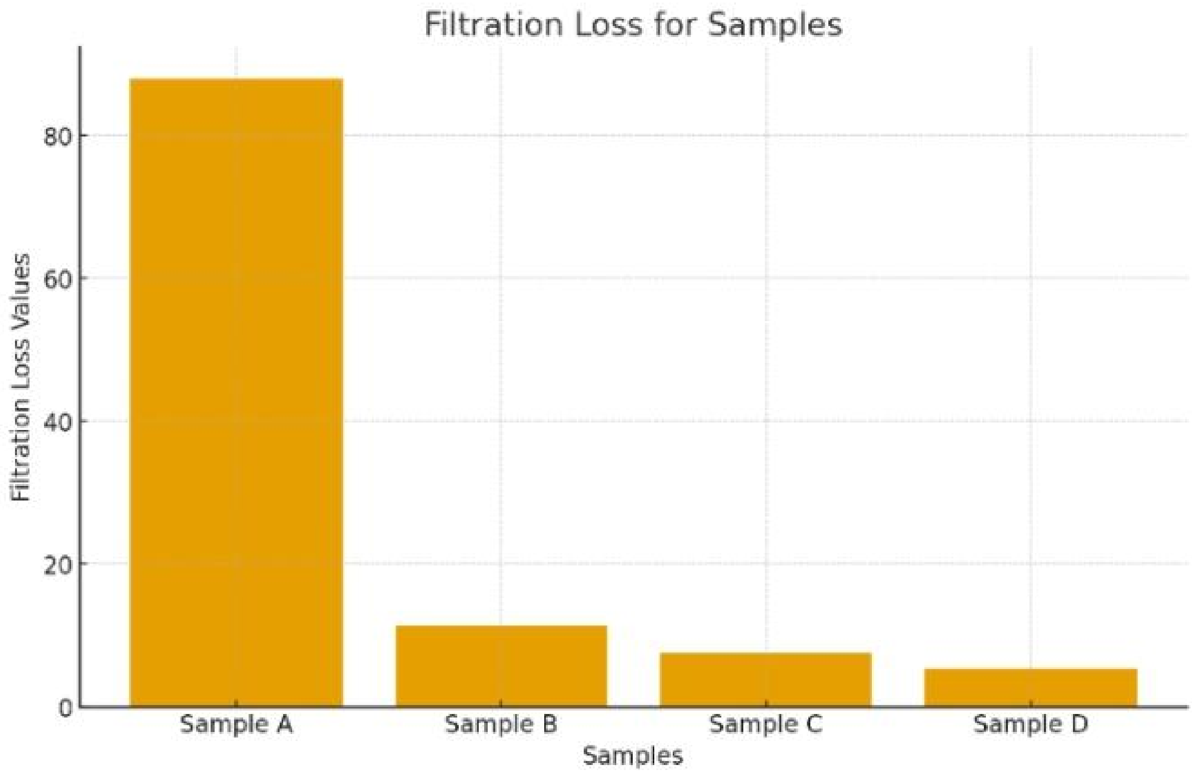

*Figure4.2***:** *Bar graph Representation of Filtrate Loss Analysis Values*

The results show that Sample D has the least filtraGte loss, suggesting better fluid loss control.

4.1.5 pH Evaluation

The pH of the formulated mud samples was measured using a pH strip.

TABLE 4.5: pH of mud samples

Sample	**pH Value**
A	6.5
B	7.5
C	10.5
D	11

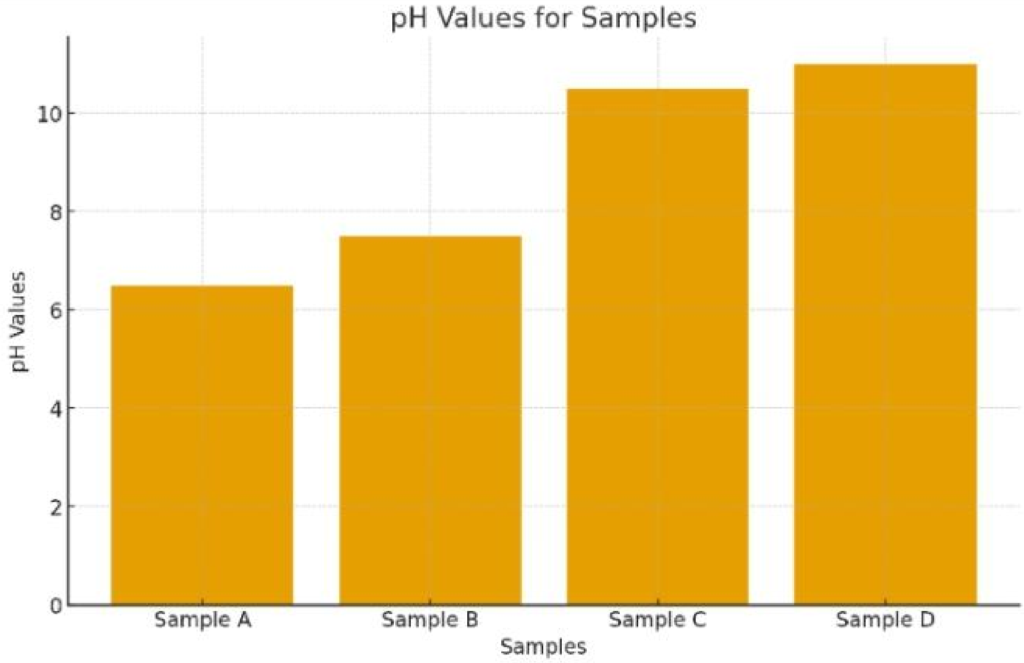

Figure4.3: Bar graph representation of pH values

The alkaline nature of samples C and D shows and confirms that the activation of the local clay with sodium carbonate effectively adjusted the pH to the desirable range for water-based drilling MUDS.

4.1.6 Sand Content

When carrying out the test in the laboratory, the sand content of the local clay was determined using a sand content kit. The **sand content** was determined to be **1.**

From the Presented data;

It was shown that the addition of CMC to the clay effectively reduced the fluid loss and also the addition of sodium carbonate to the clay also effectively reduced the loss.

And also sodium carbonate also helped in the increment of the pH value of the different samples, increasing the alkalinity of the samples to the desirable range of the water-based drilling mud.

4.2 DATA ANALYSIS

4.2.1 MUD DENSITY

The measured density of the four mud samples ranged from 8.7lb/gal to 8.9lb/gal. The increase in density with clay concentration is expected because the addition of sodium carbonate to the clay enhances the overall mud weight of the local clay.

An ideal drilling mud density should provide sufficient hydrostatic pressure to prevent formation fluid influx (kick) while avoiding excessive formation damage. The obtained densities fall within the acceptable range (8.65-9.60lb/gal) for water based mud systems. Hence, the locally formulated muds are suitable in terms of density control.

4.2.2 ANALYSIS OF RHEOLOGICAL PROPERTIES

4.2.2.1 PLASTIC VISCOSITY

The plastic viscosity increased from 2cp (Sample A) to 10cP (Sample D).

This trend indicates that increasing clay concentration enhances both internal resistance to flow and the carrying capacity of the mud.

Excessively high plastic viscosity values can increase pump pressure requirements. Which means the plastic viscosity of my samples provides an optimum balance between viscosity and pumpability especially Sample D.

4.2.2.2 GEL STRENGTH

Due to the wavering in the values of Gel strength readings and since there is no gradual and consistent increase in the gel strength values. This implies that sodium carbonate plays a major role in this behavior due to the high concentration of sodium ions which can disrupt the gel structure, leading to a decrease in strength. This means that the mud cannot suspend cuttings effectively during drilling pauses. And this can be rectified by the addition of polymers.

4.2.3 ANALYSIS OF FILTRATION PROPERTIES

The filtrate volume (fluid loss volume) decreased from 88ml (sample A) to 5.3ml (sample D). This shows that higher CMC content improved the mud's filtration control. CMC acts as a fluid loss additive by forming a thin, impermeable film on the wellbore wall, minimizing water invasion into the formation. The results are consistent with API standards, which recommend filtrate loss below 15ml for water-based muds.

Therefore, sample B, sample C, and sample D all exhibit acceptable filtration characteristics, with sample D performing best.

4.2.4 pH EVALUATION

The pH of the formulated muds ranged between 6.5 and 11. With the addition of sodium carbonate to the sample, the pH ranged from 10.5-11. The alkaline environment helps prevent corrosion of drilling equipment and stabilizes the clay.

A pH range of 9-11 is recommended for water-based drilling muds. Hence the locally formulated muds satisfy this criterion.

4.2.5 SAND CONTENT ANALYSIS

The sand content of the mud was determined to be 1. This implies that the mud sample is in the range of the API standard range of sand content which ranges from 1 – 2.

4.2.6 COMPARATIVE EVALUATION WITH STANDARD MUD

When compared with standard commercial water-based mud sample, the locally formulated muds demonstrated comparable rheological and filtration characteristics. While some differences do exist, the result shows that local clay, sodium carbonate (soda ash), and CMC can effectively replace imported materials for drilling fluid preparation.

4.3 DISCUSSION OF FINDINGS

From the analysis of the results:

Sodium carbonate (soda ash) maintains pH in the alkaline range suitable for drilling operations. Most of the performances of the formulated muds meet API requirements for water-based drilling fluids.

CMC effectively reduces filtrate loss.

4.3.1 IMPLICATIONS OF THE FINDINGS

- ECONOMIC BENEFITS: Reduced dependence on imported additives lowers drilling costs.
- INDUSTRIAL POTENTIAL: Encourages local production of drilling fluid materials, supporting indigenous technology development.
- ENVIRONMENTAL BENEFIT: Local clays can be processed and disposed of more safely, reducing the environmental footprint associated with bentonite mining and transportation.
- PERFORMANCE OPTIMIZATION: The study shows that local clays can achieve API-complaint performance when appropriately conditioned with additives such as CMC.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSION

Based on the results obtained and their analysis, it can be concluded that:

- Water-based drilling muds to can be successfully formulated using local clay, CMC and soda ash (sodium carbonate) with the addition of some polymers for further enhance its rheological properties.
- The formulated muds exhibited adequate filtration, and chemical properties for drilling operations.
- Locally sourced materials can significantly reduce drilling costs and encourage industrial self-reliance, particularly in oil-producing developing nations like Nigeria.
- Local clay possesses physicochemical characteristics suitable for drilling mud formulation and falls within API standards for drilling mud materials.
- The addition of CMC as a viscosifier significantly enhanced the filtration properties of the local clay based mud.
- The formulated mud maintained acceptable density and pH values, ensuring stable drilling performance.

Therefore, this study demonstrates that the local materials investigated are viable alternatives for drilling fluid formulation in petroleum industry.

5.2 RECOMMENDATIONS

In light of the findings from this research, the following recommendations are made:

1.) **Industrial Application:** Oil and gas companies should consider adopting locally formulated water-based muds in their drilling operations to reduce cost and dependence on imported additives.

2.) **Material Improvement:** Further beneficiation and purification of local clay can be carried out to improve its rheological properties and performance consistency.

3.) **Research Extension:** Future studies should explore the use of other local products as drilling fluid additives.

4.) **Government Support:** Government agencies and research institutes should support local production and standardization of drilling mud additives through funding and technical collaboration. Government agencies and research institutions should also support further exploration and development of local clay resources for industrial applications.

5.) **Environmental Considerations:** The environmental impact of large-scale use and disposal of local clay-based mud should be assessed to ensure compliance with environmental safety standards.

5.3 CONTRIBUTION TO KNOWLEDGE

This study contributes to knowledge by:

- Demonstrating the technical feasibility of formulating standard water-based drilling muds using locally available materials.
- Providing quantitative data on the rheological and filtration behavior of muds formulated from Nigerian clay and other materials.
- Highlighting the economic and environmental benefits of utilizing local resources for drilling operation.

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