THE SUITABILITY OF SOME LOCAL CLAY AS DRILLING MUD

BY

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DEPARTMENT OF PETROLEUM ENGINEERING,

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BENIN CITY,

EDO STATE, NIGERIA.

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A PROJECT REPORT SUBMITTED TO THE DEPARTMENT PETROLEUM ENGINEERING, FACULTY OF ENGINEERING, UNIVERSITY OF BENIN, BENIN CITY

IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE AWARD OF A MASTER OF ENGINEERING (M.Eng.) DEGREE IN PETROLEUM ENGINEERING

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CERTIFICATION

This is to certify that this project work was carried out by ODOGBO ANTHONY IFEDAYO with Matriculation Number PG/ENG2216119 under my supervision. It is adequate and satisfactory, both in scope and content, for the award of Master of Engineering (M.Eng) Degree in Petroleum Engineering of the University of Benin.

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APPROVAL

This project work is hereby approved in partial fulfilment of the requirements for the award of Master of Engineering (M.Eng.) Degree in Petroleum Engineering from the University of Benin.

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DR. I. OHENHEN DATE

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DEDICATION

This project is dedicated to God Almighty, my source and strength who enabled me through this programme and to my wonderful family whose love has been a source of strength.

ACKNOWLEDGEMENT

My utmost acknowledgement goes to God Almighty for giving me the strength, wisdom and direction throughout my academic journey. I would like to express my gratitude to my project supervisor Dr. I. Ohenhen for his consistent guidance towards ensuring the successful completion of this project in collaboration with Prof. O. A. Olafuyi.

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ABSTRACT

Drilling fluids play a critical role in the success of oil and gas drilling operations, yet the Nigerian petroleum industry relies heavily on imported bentonite and additives for drilling mud formulation, leading to high operational costs and foreign exchange losses. This study evaluates the suitability of selected locally sourced clays from Iyi-Ogene, Okuaghe, and Ikpoba deposits in Delta and Edo States, Nigeria, for use in water-based drilling mud formulation. Laboratory-scale drilling muds were prepared using raw and chemically activated clays, with sodium carbonate employed as the activating agent and carboxymethyl cellulose (CMC) used as a viscosifier and fluid-loss control additive. Standard American Petroleum Institute (API) procedures were adopted to determine key drilling mud properties, including density, rheological parameters (plastic viscosity, apparent viscosity, yield point, and gel strength), filtrate loss, and pH. The results show that untreated local clays exhibited poor rheological behavior and excessive fluid loss, making them unsuitable for direct drilling applications. However, significant improvements were observed after chemical activation and polymer treatment, with several formulated mud samples meeting acceptable API performance criteria. The study demonstrates that locally sourced clays, when properly activated and enhanced with suitable additives, can serve as viable alternatives to imported bentonite for water-based drilling mud formulation. The findings highlight the potential for cost reduction, improved local resource utilization, and increased sustainability in Nigeria's drilling operations.

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND OF THE STUDY

Drilling fluids (muds) play a crucial role in oil and gas well drilling. Almost every step of drilling requires an appropriate mud to carry rock cuttings to the surface, control formation pressures, lubricate the drill bit, and stabilize the wellbore. A drilling mud is a heterogeneous mixture of water, oil or chemicals, and fine solids (like clays) designed to optimize these functions. The performance of drilling operations depends heavily on mud properties (such as density, viscosity, yield point and gel strength) that must be maintained within specifications. A 2020 article by World oil stated that drilling fluid averages about 10% of total well cost, although this might seem small, it can “solve most drilling problems” if properly managed. In practice, failing to meet mud specifications can lead to issues such as; stuck pipe, loss of circulation, kicks, or even blowouts, which are very costly and dangerous.

In Nigeria, the petroleum industry traditionally relies on imported mud ingredients (especially bentonite clay and weighting materials) to formulate drilling fluids. Imported bentonite is in high demand for its swelling and viscosity−building properties, but importation costs millions of dollars and uses scarce foreign exchange (According to the World Integrated Trade Solution database, Bentonite imports into Nigeria amounted to about $1.5 million in 2023). For example, Onyejekwe *et al.* 2022 noted that oil companies in Nigeria often spend huge sums of money importing bentonite for drilling mud formulation, leading to a “huge capital flight” problem for the nation’s economy. At the same time, Nigeria has abundant local clay resources; geological surveys report proven clay reserves in the billions of tons across the country (Emofurieta, 2001). This suggests that locally sourced clays could potentially be used for drilling mud if properly formulated. However, studies of Nigerian clays show that raw local clays often have lower viscosity and higher fluid loss than commercial bentonite. These observations highlight both the opportunity and challenge of using local materials: they are plentiful and cheap, but may need treatment (e.g. chemical or particle–size modification) to meet drilling mud standards.

Given the above, there is growing research interest in formulating drilling fluids from indigenous materials. Recent studies have demonstrated that non-food additives like groundnut shells (Nzerem *et al.* 2025) or eggshells (Abdullah *et al.* 2022), when combined with local clays, can enhance mud properties and meet operational standards. Such locally–sourced formulations can perform comparably to conventional muds while promoting sustainable practices. This project continues in that line of work by investigating a water–based drilling mud formulation using locally available components from Delta State, Nigeria. In particular, this study focuses on clay from the Iyi–Ogene deposit (at Umusedelli–Ogbe, Delta State) and evaluates key mud parameters. By doing so, it addresses the need for cost–effective, locally–produced drilling fluid substitutes in the Nigerian petroleum sector.

1.2 STATEMENT OF THE PROBLEM

The Nigerian oil industry is burdened by the high cost and supply risk of imported drilling mud additives. Major components like bentonite clay and barite are often imported, draining foreign exchange and increasing operational expenses. At the same time, Nigeria’s abundant clay deposits remain underutilized for drilling purposes. Investigations of local clays have shown that many untreated deposits lack sufficient swelling and viscosity to replace imported bentonite on their own. In other words, raw indigenous clays typically produce a drilling mud with low plastic viscosity and high fluid loss, which could compromise well integrity if used without proper enhancement.

This project identifies the gap between the availability of local materials and the demands of drilling operations. Specifically, the local clay deposits in this project have not been studied for drilling mud use, it is unknown whether a mud made from these clays can meet the required rheological and filtration standards. The problem this study addresses is thus: Can a water–based drilling mud formulated primarily from Iyi–Ogene, Okuaghe and Ikpoba clay achieve satisfactory properties (e.g. density, viscosity, yield point, fluid loss, pH, gel strength) compared to those of conventional bentonitic mud? The outcome of this study could provide potential insights into the utilization of locally sourced clay as an alternative to imported bentonite, thereby reducing import dependency and overall drilling costs.

1.3 AIM AND OBJECTIVES OF THE STUDY

AIM

To evaluate the suitability of Iyi–Ogene, Okuaghe and Ikpoba clays as potential raw materials for water–based drilling mud formulation.

OBJECTIVES

The specific objectives of this project are to;

i. prepare water–based muds using local clays at different levels of activation.
ii. measure standard mud properties: density, viscosity, yield point, gel strengths (10s/10min), filtrate loss and ph.
iii. compare the measured properties of the local clay based muds with api recommended benchmarks to identify if any meet acceptable drilling mud performance criteria.

1.4 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.

1.5 SCOPE OF THE STUDY

- The investigation is limited to water–based drilling muds formulated in the laboratory. No oil–based or synthetic muds are considered.

- Tests are conducted under standard laboratory conditions. Measured parameters include mud density (via mud balance), rheological properties (plastic viscosity, apparent viscosity, yield point, gel strength using a rotational viscometer), fluid loss (using API filter press), as well as pH stripes for mud pH.

- No field drilling trials nor high temperature/pressure condition tests are performed.

- The study does not include detailed mineralogical or geochemical analysis of the clay; instead, it directly evaluates the practicality of the mud formulation.

These scope limitations clarify that the project is a laboratory–scale evaluation of specific properties of a local–material drilling mud, rather than a full-scale field study.

1.6 STUDY AREA

The drilling mud materials in this study includes clays from

The Iyi−Ogene deposit, located in Umusedilli−Ogbe community, Ndokwa West Local Government Area, Delta State, Nigeria. Delta State lies in southern Nigeria, within the oil−rich Niger Delta region. The state is underlain by sedimentary rock formations (notably parts of the Benin Formation) that are known to contain clay minerals. While detailed published information on the Iyi−Ogene deposit itself was not found, the location is in a rural part of Delta State where clay mining is feasible. The deposit name and location are provided by the project description, and no external sources were available to further characterize this specific site. In summary, the study area is in the tropical rain−belt of southern Nigeria, and the Iyi−Ogene clay represents a local raw material whose drilling mud potential is being assessed.

The Uhunmwonde deposit 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 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 EMPIRICAL REVIEW

This section reviews empirical work on formulation and evaluation of water−based drilling muds made from locally sourced materials (local clays, cassava starch, soda ash and other agro−wastes). It emphasizes Nigerian studies but includes international work where it informs methods or outcomes.

This empirical review synthesizes laboratory and field−oriented studies that have sought to (a) evaluate indigenous clays as substitutes or supplements to imported bentonite, (b) use locally available biopolymers (notably cassava starch) or agro−wastes as viscosifiers/filtrate controllers, and (c) improve local clay performance by chemical activation (commonly with soda ash / Na_2CO_3). The goal is to identify what has been tried, how it was tested, what succeeded or failed, and where the gaps lie for a focused investigation into these local clays, in freshwater drilling mud.

2.1.1 AIMS OF PREVIOUS STUDIES

Prior works on locally formulated drilling fluids have largely been driven by Nigeria's high dependence on imported bentonite and polymers. Researchers have aimed to substitute imported materials, conserve foreign exchange and support local industry by exploiting indigenous clays and agro−wastes, for example, Akinade, 2015 explicitly sought to assess whether a local Abbi clay could replace imported bentonite. Ogolo *et al.* 2023 and Aduojo *et al.* 2020 similarly emphasized converting abundant calcium or potassium rich Nigerian clays into sodium−bentonite to meet oilfield needs. Other studies aimed to enhance fluid performance using local additives: Harry *et al.* 2016 evaluated Nigerian cassava starch varieties as a low−cost viscosifier and fluid−loss control agent, while Agwu *et al.* 2019 investigated rice husk and sawdust as bio-based filtration control agents. More recent work (Eze and Chukwu, 2025) explored non−food wastes (groundnut shells, eggshells) to improve mud rheology and pH. These works share common goals: use local raw materials (e.g. bentonite, kaolinite, Ibere/Oboro clays) and locally sourced polymers or wastes (cassava starch, rice husk, groundnut shell) to formulate drilling fluids that approach or meet API performance standards, thereby reducing cost and increasing sustainability.

2.1.2 STUDIES ON LOCAL CLAYS (NIGERIA AND COMPARABLE CONTEXTS)

Several surveys/experimental papers evaluated various Nigerian clay deposits (Abbi, Ubakala, Umuna, Pindinga, Ibere, Ebonyi samples, etc.) for drilling-mud suitability. Authors typically report that:

Raw samples often show kaolinitic or mixed illite/kaolinite character rather than high-smectite (montmorillonite) content that gives bentonite its superior swelling and rheological behavior.

Consequently, un−treated local clays give low PV/YP and high fluid loss in simple mud formulations. These baseline results motivate activation/beneficiation steps used across subsequent studies.

Udoh et al. 2012 (Abak mud, Akwa Ibom state) — palm fruit pulp, locally known as “abak” was used in formulating synthetic based drilling mud to establish its suitability as a potential drilling fluid in the oil and gas industry. Beneficiation with additives such as soda ash, local starch, local charcoal and Barite resulted in an increase in rheological parameters which compared favourably with bentonite mud. This work recommends further analysis to evaluate thermal stability of the formulated mud and its filtrate loss in order to be made a possible substitute for oil and water−based drilling muds.

Godwin Nmegbu, 2014 (Emolga, Port Harcourt and Onelga clay, Rivers state) — beneficiated raw local clay samples using bentonite, sodium hydroxide (NaOH), quick Trol and carboxylmethyl cellulose (CMC) at measured concentrations to improve on the rheological properties. However, from analysis of obtained results, it proved that the local clay samples are poor potential drilling mud materials having properties far below the API standard for drilling mud formulation.

Magzoub / KFUPM thesis, 2014 (Boane/other clays) — thesis−level work examined Na_2CO_3 activation and process optimization; it reported that 2–4 wt% Na_2CO_3 with controlled aging produced marked gains in PV and filtration control. The thesis emphasizes ageing time, slurry concentration, and wash steps for reproducible activation.

Nweke Obisi Mathias, 2015 (Evaluation of Abakaliki clays for industrial application) — This work studied the characteristics and properties of local clays collected from 10 different deposits within the Abakaliki region with respect to the naturally active bentonite from Wyoming and Texas. The local clays performed poorly in areas such as plasticity, viscosity and swelling properties. The work further proposes that with additives such as sodium carbonate and Carboxymethyl cellulose, there could be remarkable improvements in the rheological properties.

Akinade, 2015 (Abbi clay, Delta State) — experimental work compared muds prepared with Abbi clay against foreign bentonite. Abbi clay required chemical treatment (potash/soda) and polymer addition to approach API specifications for PV and fluid loss; untreated Abbi performed poorly in PV and gel strength. The study highlights the need for activation and polymer augmentation when using many Nigerian clays.

Agwu et al. 2016 (Iyi, Ibiono, Ikono, Itu and Uyo clay, Akwa Ibom state) — evaluated clays from various deposits within the state for their suitability as water−based mud. Great improvement was attained upon analyzing the rheological properties of the activated local clay, where the activation resulted in a reduction in the fluid loss at about 85.73% on average of the tested clays, leading to close specifications with the API standard.

Obasi et al. 2020 (Beneficiation of Nigerian bentonite using local materials) — experimented on local Nigerian bentonite clay bought at Port Harcourt. The clay was beneficiated using locally sourced materials including; Snail shell and Mucuna solanine for which it was observe that at higher additive concentrations, there was a significant reduction in the volume of filtrate obtained. The experiment concluded that the beneficiated Nigerian bentonite at optimal additive concentrations can be a potential candidate for foreign bentonite substitution, highlighting its economic viability.

Ogolo, 2023 (Pindinga & Ubakala clays, thermochemical treatment) — Ogolo applied a thermochemical conversion (Na−activation) and characterized clays with XRD, SEM and EDX. Post−treatment clays showed an increase in swelling and viscosity appropriate for basic WBM formulations; the paper details the activation procedure and recommendations for process parameters. This work shows Na−activation can transform potassium/calcic clays toward a sodium−type behavior, beneficial for drilling muds.

Onyejekwe Ifeanyichukwu Michael, 2023 (Umuna clay, Imo state) — A study on Umuna clay evaluated its suitability for drilling mud formulation through detailed characterization. The clay's cation exchange capacity confirmed it as a calcium−based montmorillonitic clay with limited swelling ability. Although the raw clay showed weak rheological and filtration properties, beneficiation and treatment with additives such as NaOH and PacR (Polyanionic Cellulose – Regular grade) significantly improved its performance, meeting API standards for drilling muds. The findings further showed that the improved Umuna clay demonstrated high consistency index (k) and low flow behavior index (n), indicating favorable viscosity and shear-thinning properties for efficient hole cleaning.

The most common application method of the literature is chemical activation (Na-activation) using soda ash (Na_2CO_3) or NaOH to convert Ca/K–type clays to Na–type which have higher swelling and rheology.

Notes on soda ash (Na_2CO_3): numerous experimental and theoretical works explain that Na_2CO_3 facilitates cation exchange, replacing Ca^{2+}/K^+ with Na^+ which increases interlayer spacing and hydration, improving swelling. Activation is cost–effective and widely adopted in beneficiation studies. The concentration, temperature and aging time are key process variables.

2.1.3 STUDIES ON LOCAL DRILLING MUD ADDITIVES

Cassava starch as a local polymer: Nigerian researchers have extensively tested cassava (Manihot esculenta) starch as a mud additive. For example, Harry *et al*. (2016) compared starches from two Nigerian cultivars (TMS 98/0581 and TMS 96/1632) with an imported starch. They found the TMS 98/0581 starch had crystal structure and particle size very close to the imported product, and muds made with it gave almost the same viscosity and fluid–loss control. In practice, adding cassava starch (after gelatinizing it) significantly raises mud viscosity and cuts API filtrate volume. A recent work by Odeh *et al*. (2022) reported that blending cassava starch with soda ash (Na_2CO_3) and heat–treating the mix substantially improved the rheology and flow properties of mud made from local Nigerian bentonite. Unmodified cassava starch tends to break down at about 100°C to 130 °C and above, so high-temperature service may require modified starches or blends.

Other agricultural wastes (filter–cake agents): A variety of cheap agro–wastes have been tested as low–cost mud additives. For example, finely ground rice husk ash can dramatically cut fluid loss. Okon *et al*. 2014 found about 65% reduction at 20% concentration of rice husk. Similarly, groundnut (peanut) shells, eggshells and even sawdust can act as bridging solids: they help build a filter cake and lower filtrate. In lab tests, adding groundnut shell or eggshell significantly improved mud density, pH and viscosity (meeting API specifications). All these waste materials are readily available locally and are biodegradable, making them environmentally friendly alternatives to synthetic chemicals.

Plant gums and mucilage: Natural plant gums and slurries (e.g. from okra, tamarind, aloe, etc.) also show promise as drilling fluid additives. These biopolymers swell in water and increase mud viscosity. For instance, Huifeng *et al*. 2024 conducted a test using 2.5% okra mucilage in a water−based mud and found the yield point and plastic viscosity rose markedly, and the API filtrate was cut by about 40%. Such gums can also improve lubrication. The downside is that plant gums generally lose strength at high temperature (as noted, most become unstable above 120 °C), and they may require processing (grinding, sieving, etc.) in combination with bentonite and other polymers rather than as a sole substitute for a more efficient applicability.

Overall, these studies suggest that abundant local materials, from cassava starch to rice hulls or okra can greatly improve Nigerian drilling muds at low cost, so long as the right cultivar is chosen and additives are properly treated or modified.

2.1.4 COMPARATIVE SUMMARY TABLE OF SELECTED EMPIRICAL STUDIES

Below is a concise table summarizing key empirical studies useful for this project. (Note: the table gives author/year, material/additive, activation or treatment, main tests, and concise findings.)

Table 2.1: Comparative literature on local drilling mud additives

Author (year)	**Material/ Additive**	**Activation/ Treatment**	**Main tests**	**Key findings**
Magzoub (2014 thesis)	Local bentonites	Na_2CO_3 activation, aging	Rheology, filtration	Process optimization showed 2–4% Na_2CO_3 beneficial; ageing time critical.
Akinade, 2015	Abbi clay (Nigeria)	Potash/ beneficiation	Viscometer, marsh funnel, fluid-loss	Raw Abbi underperformed; required activation + polymer to approach API.
Harry et al. 2016	Cassava varieties	Starch extraction, pre−gelatinization	Rheology, filtration	Certain cassava cultivars perform comparably to imported starch at suitable dosages.
Okon, 2020	Various agro−wastes	Processing: drying, milling	Synthesis review	Rice husk, sawdust, starches have demonstrated effectiveness in many lab trials.
Odeh et al. 2021	Local bentonite + cassava starch	Cassava starch & Na_2CO_3 blends	API rheology, filter press	Cassava starch + soda ash improved viscosity and reduced filtrate vs local bentonite.
Bahranowski *et al*. 2021	Bentonite Na-activation (general)	Na_2CO_3 rehydration activation	Mineralogy, rheology	Described Na-activation mechanism & recommended 2–2.5 wt% Na_2CO_3 for rehydration routes.
Ogolo *et al.* 2023	Pindinga & Ubakala clays	Thermochemical (Na activation), XRD/SEM	XRD, SEM, rheology, filter press	Na-activation increased swelling and viscosity; recommended process parameters.

Most Nigerian clays require Na−activation or similar beneficiation to reach useful swelling/rheology levels for WBM, this is a robust finding across multiple case studies. Best rheological results are obtained on combination of different additives to produce the most consistent gains in plastic viscosity, yield point and fluid loss as single additive use seldom match API specifications. Standard API test is employed to benchmark against industry norms and expose gaps.

2.1.5 IDENTIFIED RESEARCH GAPS AND OPPORTUNITIES

Variation in sample preparation and reporting: Differences in clay drying, particle size control, additive treatment, for example, starch pre−gelatinization and activation procedures make direct comparison between studies difficult. Some studies omit key parameters (e.g., ageing time, exact Na_2CO_3 concentration), reducing reproducibility.

Insufficient thermal and HPHT testing: Many lab reports evaluate rheology at ambient conditions. Few systematically probe temperature stability (e.g. up to 150–225 °F) or high−pressure circulation performance conditions relevant to real drilling. Bench tests should be extended via HPHT filtration and to mimic downhole conditions; literature shows this is underreported locally.

Underexplored additive space: While bio−polymer like cassava starch is well studied, other biopolymers or nano-additives (e.g., cellulose nanofibers, silica nanoparticles) are rarely tested locally, presenting potential research opportunities.

Incomplete environmental or cost analysis: Few studies combine materials performance with life−cycle or cost comparisons, lab results need to be tested in pilot mixers and small−scale circulation rigs as absence of these leaves unanswered whether beneficiation + polymeration is economically competitive when upscaling.

Environmental and biodegradability assessment. We don't yet know enough about how agro–waste and starch behave or affect the environment after they're disposed of. Studying how they degrade and whether they're toxic would make the argument for using local, natural materials much stronger.

2.2 REVIEW OF METHODS OF INSTRUMENTATION

This section reviews the principal laboratory instruments and standard test procedures used to characterize drilling fluids and their components. The aim is to describe the purpose of each instrument, the underlying measurement principle, typical operating procedures, expected outputs, limitations and common sources of error. Emphasis is placed on instruments and methods that will be used in this study (density/mud balance, viscometry/rheology, API filter press, hot-roll ageing, particle size and mineralogy analyses), and on how results from these instruments inform evaluation of water-based drilling muds.

2.2.1 MUD DENSITY AND SOLID FRACTION

Purpose and significance: Mud density (mud weight) is a primary drilling fluid property because it controls hydrostatic pressure in the well. Density influences formation stability, fluid invasion, and the carrying capacity of the fluid; accurate field and laboratory measurement is therefore essential.

Instruments & principles:

Mud balance (API mud balance): A beam balance with an asymmetrical structure, it has a cup at one end for holding the mud sample and a lid with a hole in the middle allowing air escape for ensuring consistent filling. The mud weight is read directly from the graduated scale where the beam balances, according to the standards of the American Petroleum Institute (API).

Pycnometer / laboratory density bottle: A laboratory glassware method used for more precise solids and small–sample density determination when needed.

Procedure and Calibration: The mud cup must be filled completely with the drilling fluid and covered with the lid tightly and excess mud on the outside is cleaned off. The balance is placed on its base and the rider adjusted along the beam until the bubble level is centered upon which the mud weight is read off the scale. Typical measuring units include; lb/gal, lb/sq.in/1000ft, lb/ft^3 and specific gravity.

Typical sources of error: Sources of error during mud balance measurement include the presence of air bubbles in the mud sample, which lowers the apparent density; improper cleaning or residue on the cup and lid, which increases the measured weight; and incorrect leveling or reading of the beam, leading to inaccurate results. Other common errors arise from poor sealing of the lid, calibration drift, temperature variations, and vibrations or unstable surfaces during measurement. To ensure accuracy, the mud balance should be properly cleaned, leveled, calibrated, and operated on a stable surface with care taken to eliminate trapped air.

Interpretation: The measured mud density, together with the total solids data, helps confirm if the mud has the right weight to control formation pressure. It also shows whether there's too much solid material or barite settling, which can cause imbalance. If these problems occur, the mud can be corrected by dilution, removing excess solids, or adjusting its weight.

2.2.2 RHEOLOGICAL MEASUREMENTS

Purpose and significance. Rheological parameters (apparent and plastic viscosity, yield point, gel strength) describe mud flow behavior under varying shear and determine pump requirements, hole clean-up effectiveness and solids suspension when circulation stops. Standard viscometry provides the field-relevant parameters used by drilling engineers.

Instruments & principles.

Fann−type rotational viscometer (e.g., Fann Model 35): The industry standard for routine mud rheology; it measures torque at specified rotational speeds (typically 600 and 300 rpm, and other speeds where available) and allows calculation of PV, YP and AV according to API practice. The Model 35 is widely referenced in manuals and API procedures.

Laboratory rheometer (cone and plate or coaxial): Provides full shear stress–shear rate curves useful for more advanced modelling (power law, Herschel–Bulkley) when a more detailed constitutive description is required.

Key calculated parameters and formulae;

Apparent viscosity (AV): AV $= \frac{\theta 600}{2}$ (cP). (1)

Plastic viscosity (PV): PV $= \theta 600 - \theta 300$ (cP). (2)

Yield point (YP): YP $= \theta 300 - PV$ (lb/100 ft²). (3)

Gel strength:

Measured after static rest (10s and 10min) and reported in lb/100ft². These formulas and conventions are standard in API practice and instrument manuals.

Procedure and Calibration: The mud sample is poured into the mud cup up to the scribe line. The mud cup is adjusted so the rotor sleeve fits in the cup, it is adjusted so the sleeve immersion mark is at the fluid surface. The motor is initiated and dial readings at 600rpm, 300rpm and any other desired speed are taken and recorded on stabilization of the dial. Typical measuring units include; θ (dial readings), centipoise cp (PV, YP and AV) and lb/100ft².

Sources of error: Air bubbles, improper spindle selection, worn bearings and temperature variations produce measurement errors; consistent operator technique and routine calibration mitigate these problems.

Interpretation:

PV reflects the contribution of solids/coarse particles and base fluid viscosity (higher PV → higher pump losses), while YP indicates low-shear carrying capacity for cuttings. Gel strengths describe how well the mud suspends solids during static periods. These interpretations are routinely used in drilling operations and in the literature when comparing mud formulations.

2.2.3 FILTRATION AND CAKE EVALUATION

Purpose and significance: Fluid loss control is a primary mud function, excessive filtrate invasion causes formation damage and differential sticking, while the mud cake influences torque/drag and formation exposure. Standard bench tests quantify filtrate volume and cake characteristics.

Instruments & principles:

API filter press: Applies 100psi for 30 minutes to a mud sample and collects filtrate; the test gives filtrate volume (ml/30 min), spurt loss (filtrate spurt) and cake thickness per API procedure.

HPHT filter press: Extends the filtration test to elevated pressures and temperatures (HPHT conditions) to better simulate downhole conditions when required.

Procedure and Calibration: A clean dry filter paper is placed on the porous plate in the filter cell after which the stirred mud sample is poured into the filter cell. The rubber gasket and O–ring are properly seated on the top cap which is in turn secured tightly on the filter cell to prevent leakage, the graduated cylinder is then placed beneath the filter outlet. Pressure is applied from the gas source, and timer is started immediately, filtration is allowed for 30 minutes at a constant pressure, after 30 minutes the filtrate volume is measured and this is the

API fluid loss (ml/30mins). The filter cake thickness is measured (millimeters), the appearance and texture are also noted.

Sources of error: Poor sealing, inconsistent filter paper, leaks and incorrect pressure application produce invalid results. Strict adherence to API/ manufacturer instructions avoids common pitfalls.

Interpretation: Low filtrate volumes and thin, low-permeability cakes are desired. Cake composition (compact clay vs. fibrous/loose wastes) affects drill string interactions and wellbore stability.

2.2.4 HOT−ROLLING, AGING AND THERMAL STABILITY TESTS

Purpose and significance: Hot−rolling (rolling ovens) and ageing tests simulate downhole thermal and mechanical effects on mud chemistry and polymer stability; these tests are essential to evaluate whether local starches or bio-additives will resist degradation under expected temperatures.

Instruments & principles:

Roller oven: It works by placing high temperature aging cells containing fluid samples inside the oven where they are exposed to controlled heat and continuous rolling on power driven rollers, this combination evaluates mud performance under realistic operating environments. Industry glossaries and manufacturer material describe standard hot-rolling practice.

Interpretation: Substantial reductions in viscosity or increases in filtrate after hot-rolling indicate thermal degradation, guiding decisions on polymer modification or stabilizer addition.

2.2.5 SOLIDS CHARACTERISATION

Purpose and significance: Particle size distribution and specific surface area strongly influence rheology and filtration: fine, high surface area particles (e.g., montmorillonite) generate larger viscosity per unit mass and affect cake formation.

Methods & instruments.

Sieve/hydrometer and laser diffraction: Traditional sieving with hydrometer methods provides coarse/fine fractionation while laser diffraction offers high-resolution distributions across a wide size range.

BET (Brunauer, Emmett, Teller) surface area: Provides specific surface area important for predicting water adsorption and polymer adsorption behavior.

Interpretation.

High specific surface and large fine fractions typically increase PV and YP but can also increase fluid loss unless controlled with polymers and bridging solids.

2.2.6 MINERALOGICAL AND CHEMICAL ANALYSES

Purpose and significance. Mineralogy (montmorillonite versus kaolinite/illite) determines swelling and activation strategy; elemental composition (XRF) informs the expected exchangeable cations and the likely benefit from Na-activation.

Instruments & principles.

XRD: Identifies clay mineral phases and tracks interlayer changes after activation.

XRF: Quantifies bulk elemental composition (SiO_2, Al_2O_3, Fe_2O_3, CaO, Na_2O).

SEM/EDS: Visualizes particle morphology and surface features. These are standard characterization tools reported in beneficiation and activation studies.

2.2.7 OTHER USEFUL INSTRUMENTS AND TESTS

Other helpful analyses include pH meters for alkalinity control, mud retorts for solids/oil/water content (where relevant), mud centrifuge for rapid separation, TGA (Thermogravimetric analysis) for thermal decomposition of organics, and zeta-potential analyzers for colloidal stability — all used in the literature when a deeper characterization is required.

2.3 REVIEW OF SPECIALIZED TECHNICAL TERMS

A clear understanding of specialized terminology is essential to interpret test results, compose sound experimental procedures and communicate findings. Definitions below are practical and linked to measurement and engineering implications so they can be used directly in methods and results chapters.

Viscosity (η): Fluid resistance to flow; drilling muds are generally non−Newtonian, so viscosity varies with shear rate.

Plastic viscosity (PV): Fluid's resistant to flow caused by internal friction between solids and liquid. A highwr PV indicates a more mechanical resistant to pump.

Apparent viscosity (AV): Fluid's resistant to flow at a particular shear rate.

Yield point (YP): The stress that must be overcome to start flow from rest. It tells how well the fluid will lift cuttings when flow stops.

Gel strength: A measure of how much structure the fluid builds up when static. Useful for predicting how easily cuttings will re−entrain after a pause.

Rheological models (Bingham, Power-law, Herschel–Bulkley): The Bingham model is commonly used for field calculations due to simplicity while power-law/Herschel–Bulkley are applied when full rheograms are available in the laboratory.

API filtrate (ml/30 min) and **mud cake characteristics:** are defined and measured according to standard API procedures using the filter press (100 psi, 30 min). Thin, low-permeability cakes and low filtrate volumes are generally preferred to reduce formation damage.

Montmorillonite, kaolinite, illite, swelling index, Na-activation: these terms are crucial when discussing activation and beneficiation because the mineralogical type determines whether Na_2CO_3 treatment will be effective. Several experimental and review articles describe the mechanism and benefits of Na-activation (soda ash facilitating cation exchange to produce higher swelling behavior).

Viscosifiers, fluid loss additives, bridging agents, deflocculants and pH/alkalinity control — Bio−polymers and agro-wastes are widely reported in the literature as cost-effective alternatives or complements to commercial polymers for WBM when properly processed; several comparative studies show cassava starch can perform comparably to imported starch in controlled lab tests.

Hot−rolling, HPHT, degradation/hydrolysis — hot−rolling and HPHT are established methods for assessing polymer and mud stability under thermal/mechanical stress; these tests are commonly referenced in drilling-fluids method papers and manufacturer guidance.

The technical definitions above provide a consistent vocabulary and measurement basis for subsequent chapters; they ensure that rheological, filtration and activation results can be compared to standard expectations and to the studies cited in the empirical review.

CHAPTER THREE

MATERIALS AND METHODS

3.1 LIST OF MAJOR MATERIALS AND EQUIPMENT

MATERIALS

Iyi-Ogene, Okuaghe and Ikpoba clay (raw, representative samples from the deposit).

Soda ash (sodium carbonate, Na_2CO_3) — reagent grade (commercial).

Distilled/deionized water (for activation).

Carboxymethyl cellulose (CMC)

MAJOR EQUIPMENTS

Oven — For drying clay sample.

Mortar and Pestle — For crushing clay sample.

Sieve(22BSS) — For obtaining finer particles.

Sieve shaker — For faster and more efficient sieving process.

Laboratory scale — for determining weight of required clay sample and additive.

Mud mixer — for efficient dispersion of clay particles and additive.

pH test paper — for checking mud alkalinity.

API mud balance — for mud density.

Rotational viscometer (Fann model 35) — for rheology ($\theta 600/\theta 300$ and additional speeds).

API filter press (standard 100 psi, 30minute test)

Safety equipment: gloves, lab coat, nose mask.

3.2 RESEARCH DESIGN

This study is designed as a laboratory-based research work aimed at formulating, activating, and evaluating a water-based drilling mud prepared from locally sourced clay. The methodology involves the activation of raw clay with soda ash (sodium carbonate), followed by viscosity enhancement with CMC (Carboxymethyl Cellulose). Standard API (American Petroleum Institute) procedures for drilling fluid preparation and rheological testing were adopted to enable comparison with international benchmarks. The samples include;

- Sample A: The raw clay
- Sample B: Raw clay (25g) + CMC (1.25g)
- Sample C: Activated clay at 3% weight of clay + CMC (1.25g)
- Sample D: Activated clay at 5% weight of clay + CMC (1.25g)
- Sample E: API benchmark for drilling mud

  - Activation matrix: Na_2CO_3 at 3% and 5% by weight of dry clay with an aging time of 24hrs was used for the activated samples. 25g of raw clay was employed for each activation.

3.3 SAMPLE AND SAMPLING TECHNIQUES

3.3.1 CLAY SAMPLING (FIELD)

Sampling strategy: At the various clay deposits, the ground was dug in to about 3 feet upon which the sample was retrieved.

Sample size: About 5kg of bulk clay sample was collected each to ensure enough material for activation trials.

Sample handling: Samples were properly stored in a sealed plastic bag. Upon arrival at the laboratory, the samples were oven−dried and subsequently split for activation.

3.3.2 SAMPLE PREPARATION (LABORATORY)

Clay: Oven−drying of the raw samples was done at about 180°C. Dried samples were crushed and sieved (710 µm) to produce finer particles.

Soda ash: Using distilled water, required soda ash activated samples of 3% and 5% by weight of clay was prepared.

Activated samples: For each activation condition, prepared clay slurry was added designated Na_2CO_3 dose, stirred for about 15 minutes. Aging was allowed for 24 hours. Sample was then dried at about 130°C, upon drying, was crushed and sieved for uniform fine particles.

3.4 NATURE AND SOURCES OF DATA

Primary data (experimental)

Laboratory measurements from prepared muds: rheological readings (600, 300, other rpm), gel strengths (10s, 10min), API filtrate volumes, mud density, cake thickness, rheology/filtrate, pH, particle-size distributions, swelling index.

Secondary data (literature)

Published studies, theses, standards (API) and technical manuals used to set acceptance criteria and compare findings. These data support the empirical baseline and provide benchmarking values.

3.5 METHODS OF DATA COLLECTION

Before running of analysis to obtain required data, samples were prepared using a standard mud mixer to ensure efficient dispersion of solids in water.

Plate 3.1: A Hamilton Beach mixer

Viscometry: Using a Fann viscometer; dial readings at 600rpm and 300rpm were recorded. Obtained values aided in computing PV, YP, AV. Gel strengths at 10s and 10min were also recorded.

Plate 3.2: Fann Model 35 Viscometer

Density: Mud weight of the clay sample was determined with the help of an API mud balance.

Plate 3.3: API Mud balance

Filtration: An API filter press (100psi, 30min) powered by an air compressor was used to measure filtrate volume.

Plate 3.4: API Filter Press

Plate 3.5: Air compressor

Sand content: The sand content of the formulated mud was checked using the sand content kit.

Plate 3.6: Sand content kit

pH: To determine the degree of alkalinity of the clay, the pH paper strip was used.

3.6 METHODS OF DATA ANALYSIS

Direct processing/report of laboratory data

Rheology calculations: Compute

Apparent Viscosity (1)

Plastic Viscosity (2)

Yield Point (3)

Filtrate reporting: Report API filtrate (ml/30 min).

Statistical analysis

Graphical analysis: Rheograms (shear stress vs shear rate) are presented using bar charts (comparative PV/YP), and table summarizing test results.

Acceptance criteria: Results are compared to API thresholds (e.g., filtrate target, PV/YP ranges) and to values for imported bentonite or baseline commercial muds used as reference.

3.7 RELIABILITY OF INSTRUMENTS AND PROCEDURES

Calibration: All instruments must be calibrated before use or within a recent calibration period. For example, viscometer was calibrated per manufacturer instructions (use Newtonian standard fluids), mud balance was verified with distilled water.

Control samples: Control sample was periodically run during testing to confirm instrument and procedural reliability.

Safety: Chemicals (Na_2CO_3) are handled with PPE, ovens operated using heat−resistant gloves and safe containers. Laboratory safety protocols were also duly followed.

This methodology provides a reproducible, standards-based framework to characterize, activate and evaluate freshwater drilling mud formulations made primarily from Iyi−Ogene clay.

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.1 DATA PRESENTATION

A comparison of the properties of the local clays with the standard alternative, Bentonite is presented in this section. The results from the experiments will be analyzed using comparative assessments and graphical illustrations to show how the clay samples behaved and how their mud properties changed before and after chemical treatment. The table below shows results of the sample analysis with respect to some properties of sample E being the standard mud specifications to be compared with the retrieved samples. The significant difference in the rheological properties of the raw clay, represented as sample A necessitates the beneficiation of the clay to give other samples as earlier stated.

A. IYI−OGENE CLAY

Table 4.1: Examined properties of Iyi−Ogene clay samples.

Sample	$\theta 600$	$\theta 300$	AV (cp)	PV (cp)	YP (lb/100ft^2)	10s Gel strength	10min Gel strength	pH	Filtrate loss (ml)
A	5.00	2.50	2.50	2.50	0	2.50	3.00	7	312.00
B	34.50	23.00	17.25	11.50	11.50	18.50	16.00	7	8.90
C	26.00	15.50	13.00	10.50	5.00	14.00	11.00	10	7.55
D	22.50	13.50	11.25	9.50	4.00	9.00	11.00	11	7.20
E	34.00	24.00	17.00	10.00	14.00	6.00	13.00	10	8.50

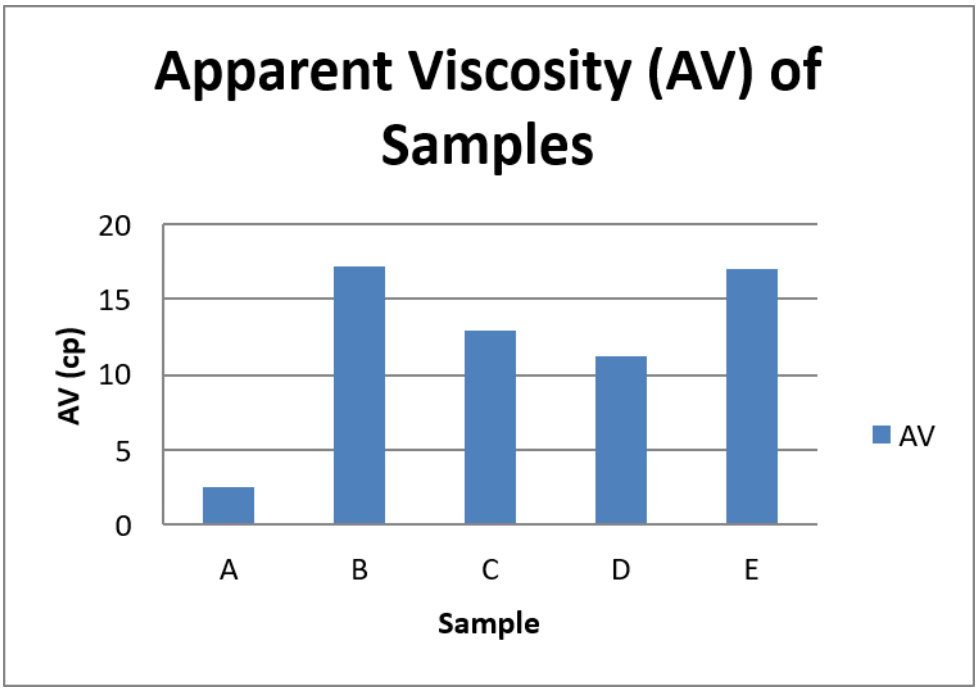

Figure 4.1: Plot of apparent viscosity of Iyi-Ogene samples

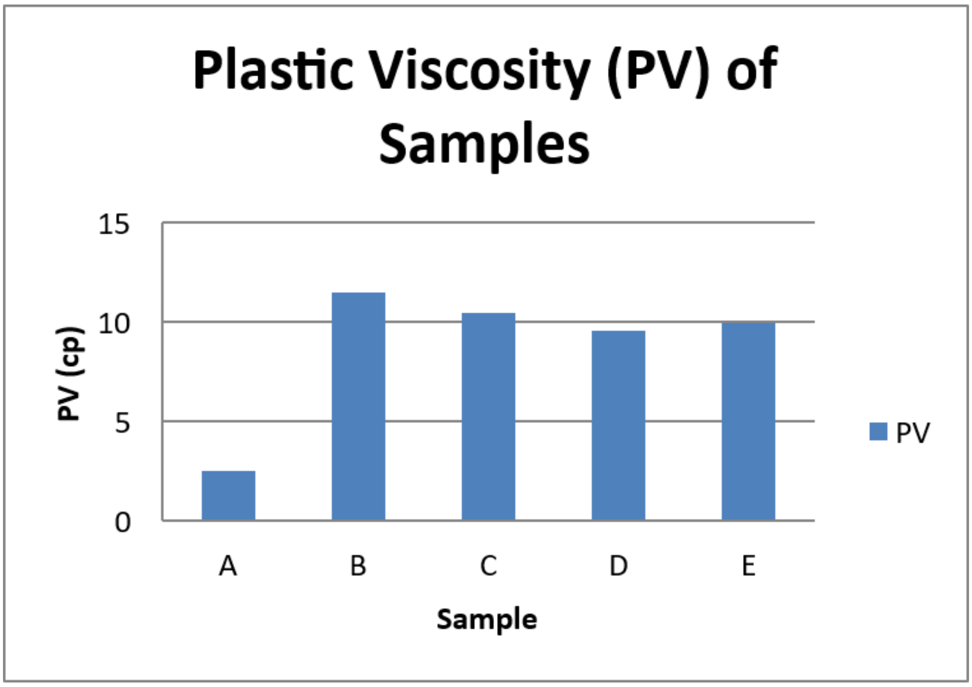

Figure 4.2: Plot of plastic viscosity of Iyi-Ogene samples

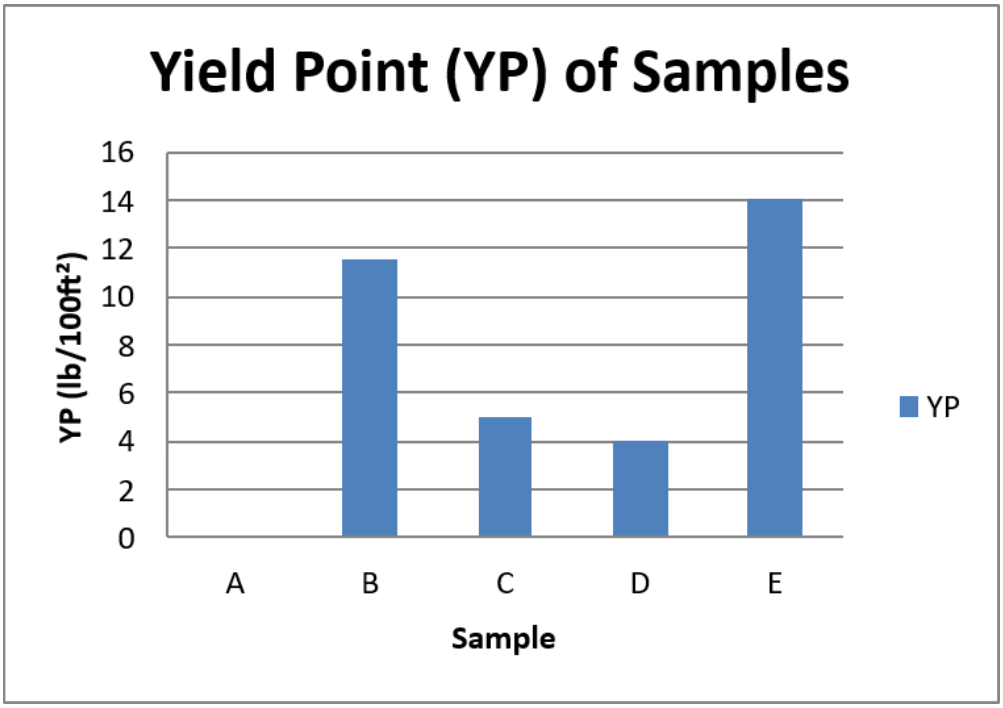

Figure 4.3: Plot of Yield point of Iyi-Ogene Samples

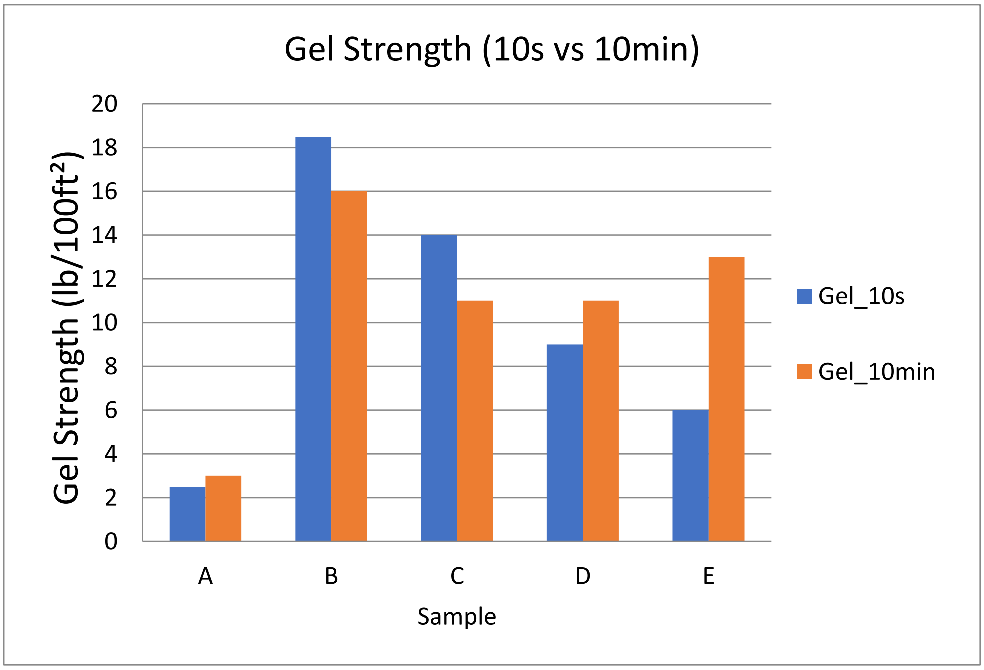

Figure 4.4: Plot of Gel strengths of Iyi-Ogene Samples

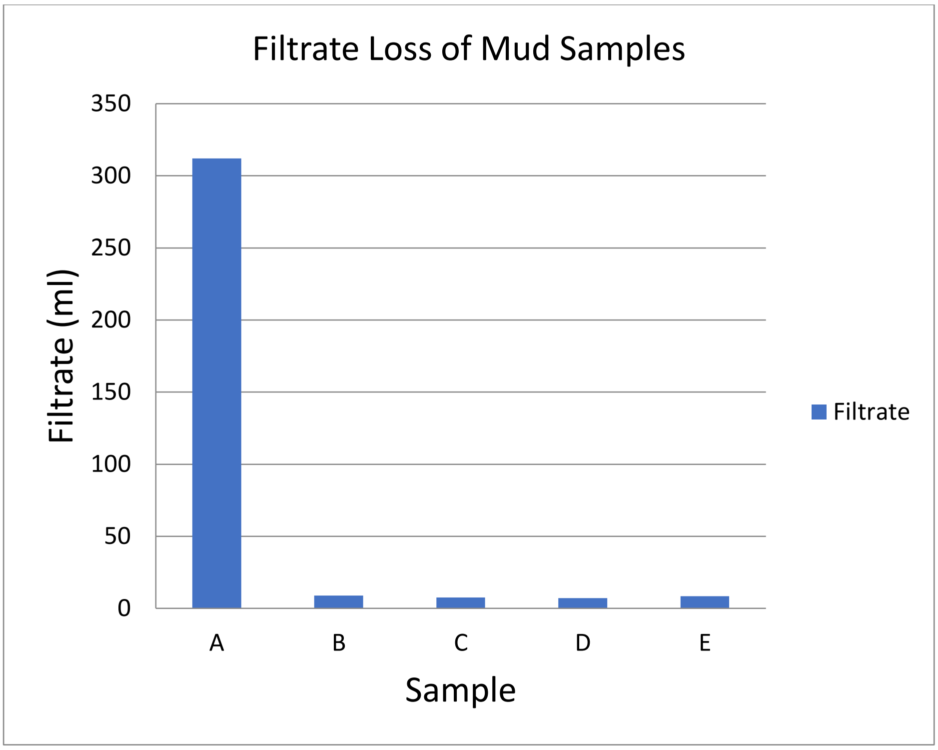

Figure 4.5: Plot of filtrate loss of Iyi-Ogene samples

B. IKPOBA CLAY

Table 4.2: Examined properties of Ikpoba clay samples.

Sample	$\theta 600$	$\theta 300$	AV (cp)	PV (cp)	YP (lb/100ft²)	10s Gel strength	10min Gel strength	pH	Filtrate loss (ml)
A	5.00	3.00	2.50	2.00	1.00	2.50	3.00	6.5	310.00
B	31.50	20.00	15.50	11.50	8.50	17.00	19.00	6.5	7.80
C	27.50	17.50	13.00	10.00	7.00	14.50	16.00	11	10.20
D	24.50	13.50	12.25	11.00	2.50	9.00	11.00	11	13.00

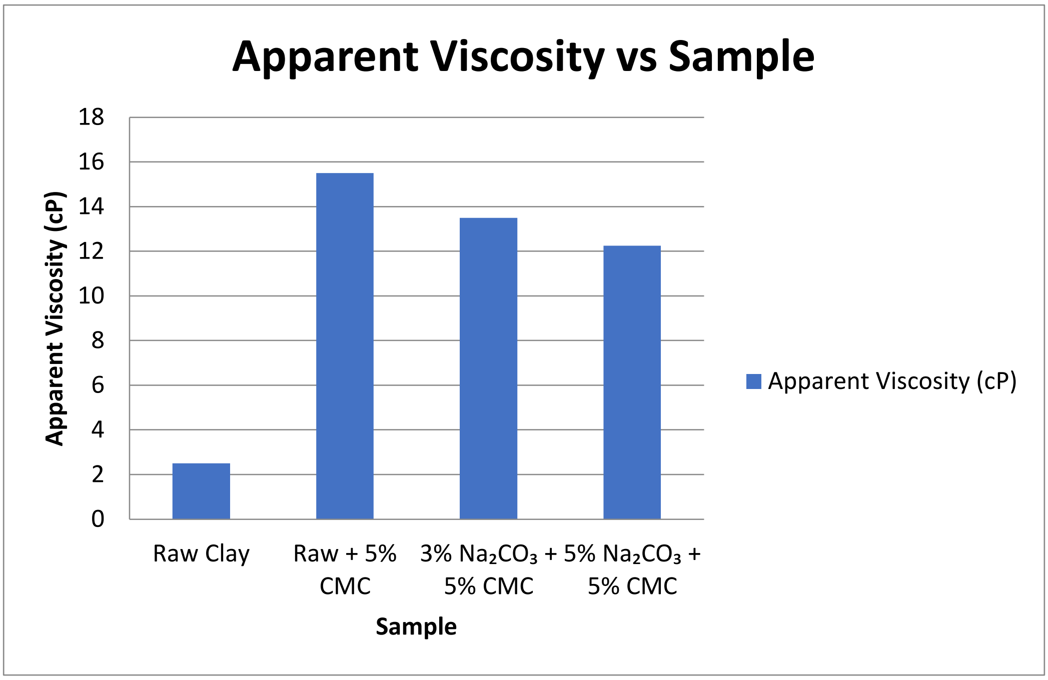

Figure 4.6: Plot of Apparent viscosity of Ikpoba clay samples

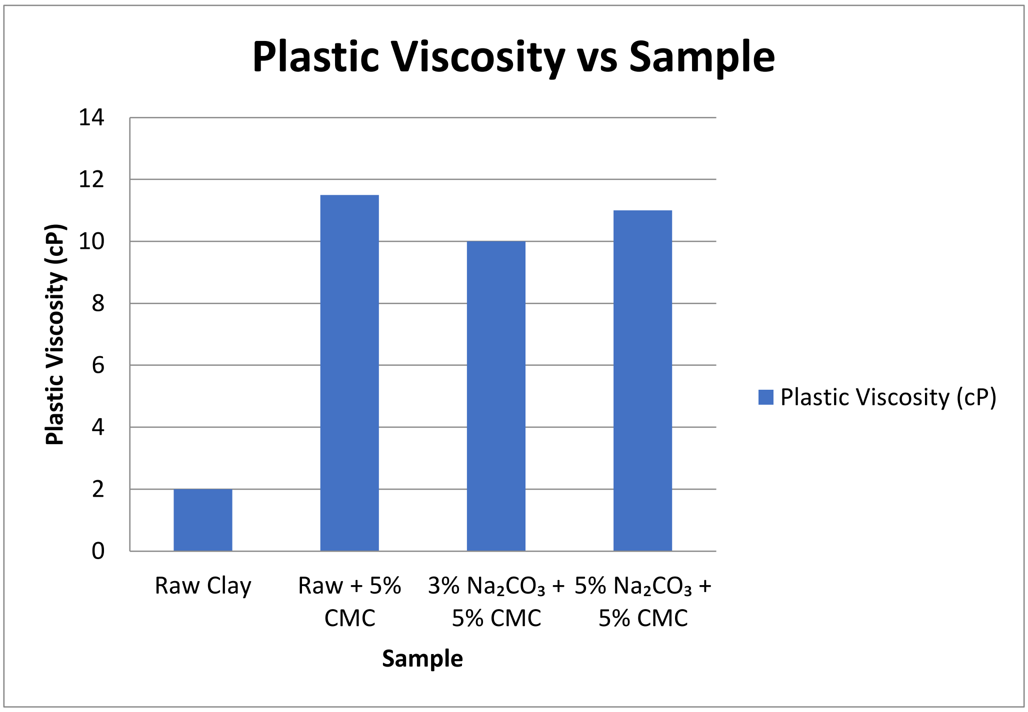

Figure 4.7: Plot of Plastic viscosity of Ikpoba clay samples

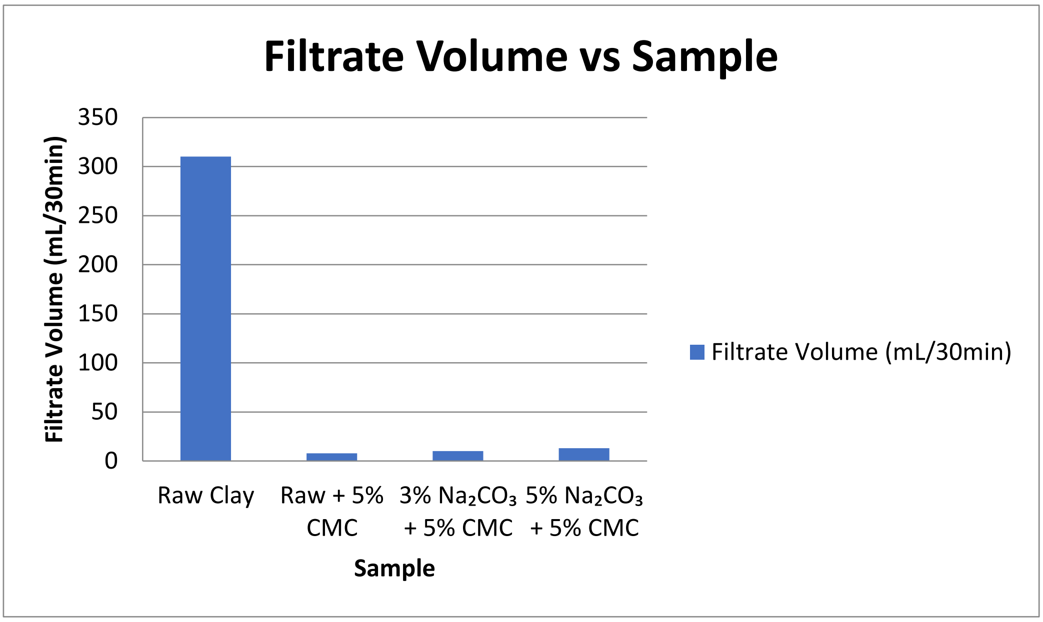

Figure 4.8: Plot of Filtrate loss of Ikpoba clay samples

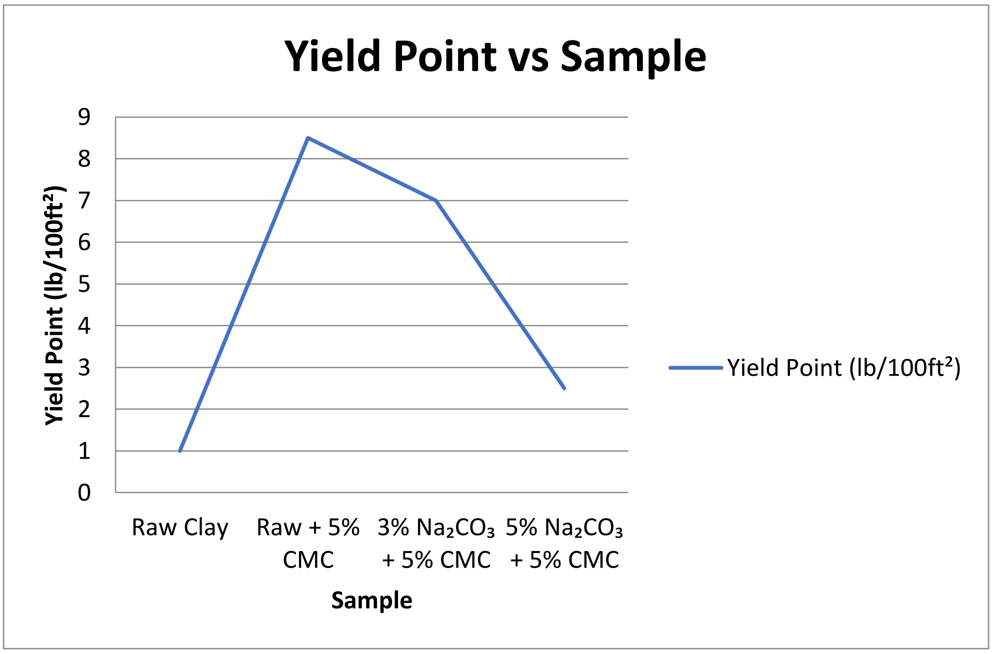

Figure 4.9: Plot of Yield point of Ikpoba clay samples

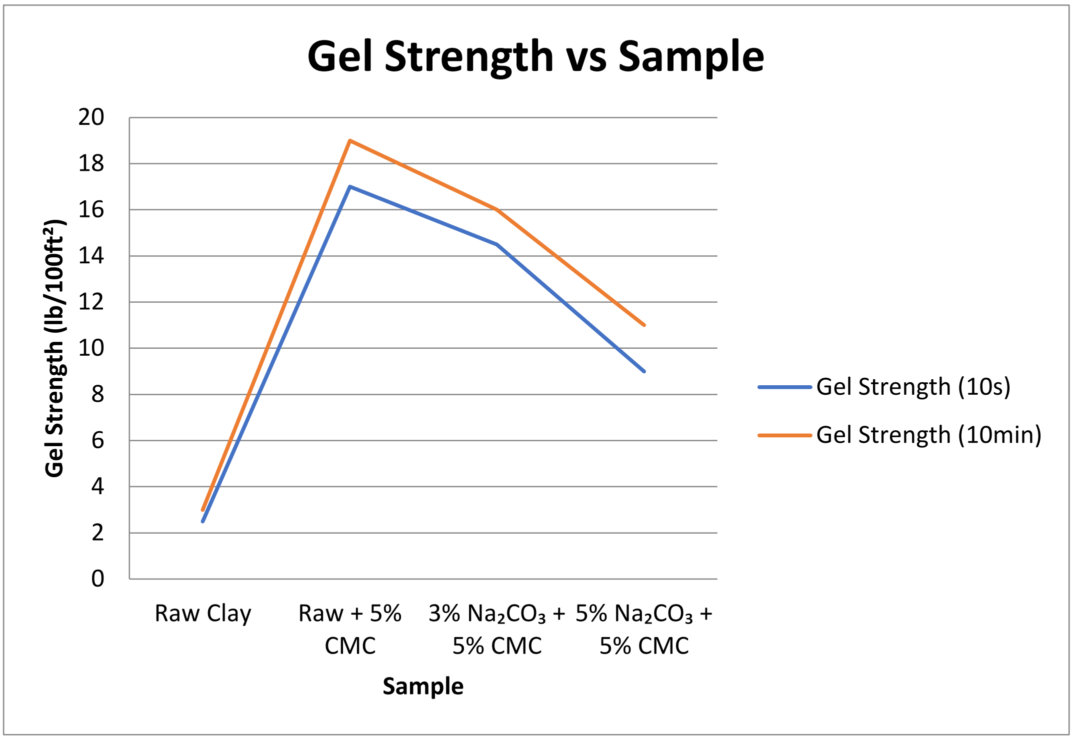

Figure 4.10: Plot of Gel strengths of Ikpoba clay samples

C. OKUAGHE CLAY

Table 2: Examined properties of Okuaghe clay samples.

Sample	$\theta 600$	$\theta 300$	AV (cp)	PV (cp)	YP (lb/100ft²)	10s Gel strength	10min Gel strength	pH	Filtrate loss (ml)
A	5.50	3.50	2.75	2.00	1.50	3.50	4.00	6.5	88.00
B	30.00	21.00	15.00	9.00	12.00	17.50	19.00	7.5	11.40
C	23.00	13.50	11.50	9.50	4.00	12.00	13.00	10.5	7.50
D	25.00	15.00	12.50	10.00	5.00	16.00	32.00	11	5.30

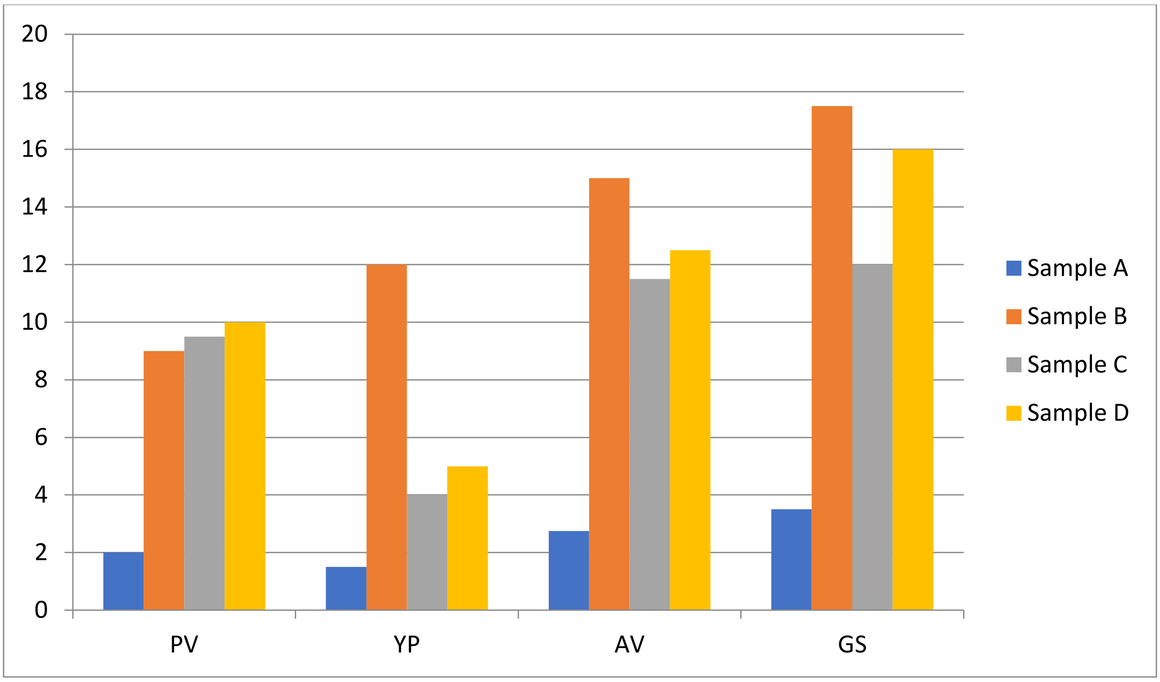

Figure 4.11: Plot of rheological properties of Okuaghe clay

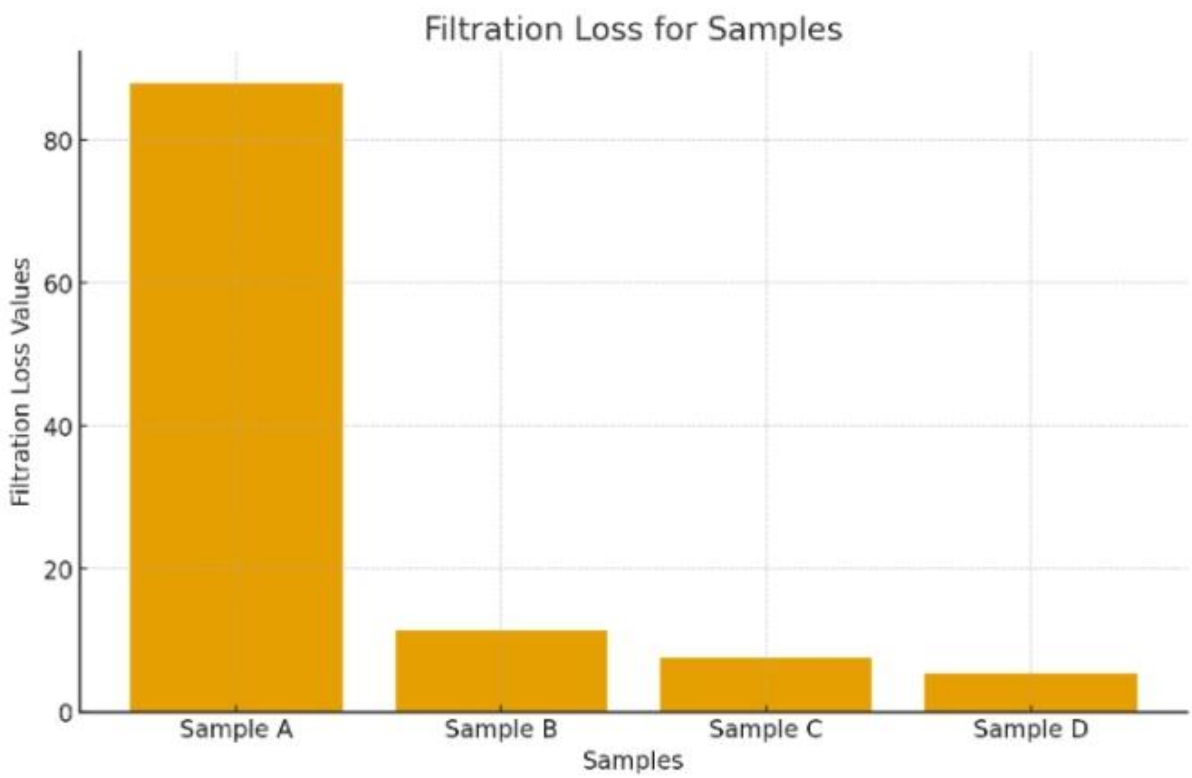

Figure 4.12: Plot of Filtrate loss of Okuaghe clay

4.2 DATA ANALYSIS

A. IYI−OGENE CLAY SAMPLES

Rheological properties

Samples B and E showed higher apparent and yield values, indicating better carrying and suspension capacity.

Sample A had the lowest values, suggesting minimal viscosity and poor gelation of the various clays in their natural form.

Gel strength

Samples B and E demonstrated stronger gel structures, implying better suspension of solids during static conditions.

Lower gel strength in sample A indicates weak structure formation.

Filtrate loss

Sample A had an extremely high filtrate loss (312ml), showing poor fluid loss control.

Other samples (B to D) maintained filtrate losses below 9ml, proving the effectiveness of CMC in reducing fluid loss.

Fluid pH

Samples C to E recorded alkaline pH values (10 to 11) desirable for clay dispersion and polymer stability.

Samples A and B remain neutral (pH 7) representing the non−activated natural clay.

Sand content

- Sand content for the formulated samples was determined to be 0.35% by volume of sand.

Mud weight

- Using the mud balance, the mud weight was measured to be 8.6 lb/gal, which falls within the acceptable API specification range for drilling mud.

The inclusion of CMC is shown to have significantly improved the rheological and filtration properties of the mud samples with sample B exhibiting the most balanced performance, showing good viscosity, gel strength and minimal filtrate loss alongside sample E, the standard specification.

B. IKPOBA CLAY SAMPLES

Fluid pH

The **pH** of the raw clay +CMC sample was initially 6.5, which is below the API standard range of 8.5-12.0, indicating an acidic environment. Upon activation with 3% and 5% soda ash, the pH increased to 11, falling within the required alkaline range for drilling fluids. This improvement shows that soda ash effectively neutralizes acidity and enhances the alkalinity necessary for clay dispersion and stability.

Apparent Viscosity

The **apparent viscosity** of the raw clay sample (15.5cp) met the API minimum requirement (≥15cp). However, a decline was observed with increasing soda ash concentration (13.5cp at 3% and 12.25cp at 5%), implying that excessive activation reduces the fluid’s viscosity.

Plastic viscosity

Similarly, the **plastic viscosity** values (11.5, 10, and 11cp) remained within / slightly above the API range (7–10cp), indicating good internal resistance to flow. The slight increase at 5% soda ash could be attributed to minor flocculation resulting from excess sodium ions.

Yield point

The **yield point** values for all samples were below the API standard range (15–20 lb/100 ft^2), indicating limited ability to lift and transport drill cuttings. The decline in yield point with higher soda ash concentration (8.5 → 2.5lb/100 ft^2) further confirms that excessive soda ash reduces the cohesive forces between clay particles.

Gel strength

The **gel strengths** (both at 10 sec and 10 min) generally showed a decreasing trend with increasing soda ash concentration. Raw clay + CMC exhibited very high gel strengths (17lb/100 ft^2 and 19lb/100 ft^2 respectively), which reduced to 9lb/100 ft^2 and 11lb/100 ft^2 at 5% activation. This reduction reflects weaker structural rebuilding at higher soda ash levels, which may affect mud suspension properties.

Filtrate loss

The **filtrate volume** values were all within the acceptable API limit (≤15 mL/30 min). However, a slight increase from 7.8 mL to 13 mL was recorded as the soda ash concentration increased, suggesting that fluid loss control slightly deteriorated with higher activation levels due to increased clay dispersion.

C. OKUAGHE CLAY SAMPLES

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.

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.

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.

FILTRATE LOSS

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.

Fluid pH

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.

4.3 DISCUSSION OF FINDINGS

The results obtained from the raw clay samples showed significant deviation from the API standards. The mud exhibited high fluid loss and very low viscosity, which are clear indicators of weak gel strength and poor fluid loss control, this implies that the raw clays in their natural form lacks the necessary colloidal properties to provide effective drilling fluid performance.

To address these shortcomings, Carboxymethyl Cellulose (CMC) was incorporated as an additive. CMC serves as both a viscosifier and a fluid loss control agent; it helps improve the carrying capacity of the mud, enhance its stability, and minimizes fluid invasion into the formation by forming a thin, consistent filter cake, by so doing, brings the performance of the drilling mud closer to the API standards.

Following the improvement observed after incorporating CMC, further tests were carried out by activating the raw clay with sodium carbonate at 3% and 5% by weight of clay. Sodium carbonate acts as an activating agent by converting calcium−based clay to its sodium form, thereby improving its plasticity, yield and overall responsiveness to additives like CMC. These additional tests aimed at determining the extent to which chemical activation, in combination with polymer treatment, could improve the rheological and filtration properties of the locally sourced clay to meet API specifications.

The results obtained upon activating the raw clay with sodium carbonate and testing with CMC shows a decreasing trend in viscosity and gel strength as the level of activation increases. While sodium carbonate is generally used to enhance swelling and dispersion of calcium−based clays, this project shows that excessive quantities can weaken the structural network responsible for viscosity and gel strength development, in addition, high sodium ion can reduce the interaction between the clay particles and the polymer (CMC).

As a result, instead of improved rheology, the mud exhibits lower viscosity and gel strength with increasing sodium carbonate content. This suggests there is an optimum activation level beyond which the beneficial effects of sodium carbonate are reversed.

CHAPTER FIVE

CONCLUSION 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:

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.

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

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

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.

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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