DEVELOPMENT AND CHARACTERIZATION OF POLYMER DRILING FLUID

BY

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A RESEARCH PROJECT SUBMITTED TO THE DEPARTMENT OF CHEMICAL ENGINEERING, SCHOOL OF ENGINEERING AND ENGINEERING TECHNOLOGY, FEDERAL UNIVERSITY OF TECHNOLOGY MINNA, NIGER STATE.

IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE AWARD OF BARCHELOR OF ENGINEERING (B. ENG.) DEGREE IN CHEMICAL ENGINEERING.

DECEMBER, 2009.

DECLARATION

I hereby declare that this project work was carried out by me under the supervision of Engr. Dim Paul, and therefore, information hereby obtained from published and unpublished work of others have been duly referenced and acknowledged.

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11-03-2010
DATE

CERTIFICATION

is is to certify that this research work titled "Development and characterization of polymer lling fluid/mud" was carried out by Salihu Warah Suleiman under the supervision f Engr. Dim ul and submitted to the Department of Chemical Engineering, Federal University of chnology Minna, in partial fulfillment of the requirement for the award of Bachelor of gineering (B.Eng) degree in Chemical Engineering.

.... 11-03-10 ....

NGR. DIM P. E. **DATE**

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NGR. J. O. OKAFOR **DATE**
IEAD OF DEPARMTNET)

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XTERNAL SUPERVISOR **DATE**

DEDICATION

This work is indeed dedicated to my omnipotent creator (ALLAH) the almighty and my role model, admiring, Islamic icon and noble prophet (MUHAMMAD) Peace Be Upon Him as well as my parent (Alh. Salihu Utono and Hajiya Zainab Salihu) and siblings.

ACKNOWLEDGEMENT

All praises and thanks belong to omnipresent deity (ALLAH) the almighty, the most gracious and most compassionate who have created, protected, guided and led me to a clear and illuminative way of life (i.e. Islam). I wish to express my extreme appreciation to my ideal, unique, superior, pioneer and noble prophet (i.e. MUHAMMAD) Peace Be Upon Him (Amen) whose way of life transmits ALLAH'S guidance to humanity in general.

My sincere appreciation goes to my supervisor Engr. Dim Paul for his guidance and encouragement in the course of this project work. I also wish to express my profound appreciation, indebtion and prayers to my great father and mother equally "Alhaji Salihu Utono and Hajiya Zainab Salihu" who had given me the financial and moral support for the successful completion of this project work.

Moreover, my tremendous gratitude and endless thanks goes to my beloved cousin "Ismail Bako" brothers "Sunusi Isah and Kabiru Isah" and friends "Ismail Abdullahi, Aliyu Aminu" who have contributed a lot for this work to be accomplished.

ABSTRACT

he production and characterization of water based drilling mud by comparing the properties of ıspected bentonite clay deposited at Okada Local Government Area of Edo State with imported entonite and blends at various ratio of 50%:50% and 75%:25% of local plus imported clay. The roperties tested include mud density, mud p^H, plastic viscosity, apparent viscosity, yield point, ltrate volume and %sand content before and after the addition of chemical additives formulation /upgrading). The results obtained for the local bentonite clay sample before and fter the formulation were: (8.50, 9.00) lb/gal as mud density, (7.00, 11.00) as mud p^H, (18.00, 0.00, 30.00, 22.00) as viscometer reading at 600rpm and 300rpm, (10.00 .00) as filtrate volume and traces as %sand content before and after upgrading. The results vere also consistent with API specification.

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CHAPTER ONE

1.0 INTRODUCTION

In geotechnical engineering "drilling fluid/mud" means a fluid used to drill boreholes into the earth. Often used while drilling oil wells, natural gas wells and as well on the exploration (drilling rigs). Drilling fluids are also used for much simpler boreholes such as water wells. Generally drilling fluid is a fluid used in a drilling operation circulated through the wellbore during drilling. The mud is a chemical component comprising of barite and bentonite clay, water and lignite used in the production of hydrocarbon to ensure well control, stabilization and protection against contamination. The proportions of the additives that makes up the drilling mud determines the treatment strategy, efficiency of the mud handling equipment and as a consequence affects the materials needed to build up density and viscosity. The drilling fluid is generally a mixture of a dispersed gel forming phase such as colloidal solid or emulsifying liquid which furnishes the desired viscosity, thixotropy and well cake cum other inert dispersed materials/solids such as weighting materials and cuttings. It also has various chemicals necessary to control its properties with desired limits. The most important non-metallic mud ingredients/materials which occur in nature are bentonite and barite. They are the principal weighting agents to almost if not all the drilling fluids. The drilling fluid is a mixture of montmorillonite clays, water, barite and few additives. In 1973, Afuze (a town in Okada local government, Edo state) clay was used during drilling operation for coal by the defunct Nigerian steel development authority. The development and exploration of abundant clay in Nigeria awaits private investment. This is what has been the motivation for this research work. This research work will focus on developing and characterizing a polymer drilling fluid using imported and local bentonite clay as well as their blends at different ratios. This can be done by analyzing both clays and their blend and as well by adding the appropriate chemicals in order to make it polymeric. This is ultimately expected to obtain a polymer drilling fluid with a result that is in consistence with American Petroleum Institute (API) standard.

1.1 aims and objectives

The aim of this project work is to develop and characterize a polymer drilling fluid using imported and local bentonite clay as well as their blends. The objective of this work is to produce a polymer drilling fluid from imported and local bentonite clays and their blends at ratio 50%:50%, 75%:25% of local and imported clays.

1.2 Approach

In order to achieve the above stated objectives the following steps were followed:

I. collection of bentonite clays
II. characterization of bentonite clay samples
III. formulation of drilling mud/fluid
IV. characterization of drilling fluid

1.3 scope of work

This project work will focus on the comparative study of the imported and local bentonite clays and of different blends. It will also be limited to water-based drilling mud prepared from existing clay deposit obtained from Afuze town, in Okada local government area of Edo state.

1.4 Justification

The technology is aimed at developing a drilling mud/fluid using local bentonite clay in order to provide an alternative to using imported bentonite clay thereby reducing the expenditure. The proper development and exploitation of our local would also go along way in aiding the industrial development in Nigeria and provides numerous employment opportunities for her citizens.

1.5 Study constraints

The constraints to this project work study are lack of adequate equipments and proper funding in carrying out the analysis.

CHAPTER TWO

2 LITERATURE REVIEW

2.1 Drilling mud technology

The transition from experimentation on individual wells to the application of scientific principles to the design and control of drilling fluid is pointed chronogically to the year 1930, which is said to be the year of drilling fluid awareness because important event relating to the sudden surface of interest in drilling fluid took place that year. The dynamic development of drilling fluid technology that began earlier 1930 has been going on ever since. Technology is the application of both scientific knowledge and engineering principles to a specific industrial development. Drilling fluid technology involves the sciences such as chemistry, physics, geology and application of engineering. The technology is not aimed only at the designing and maintenance of an "ideal" drilling fluid but at the achievement of a "real" end product e.g. the successful completion of borehole with minimum overall expenditure.

2.2 Drilling mud

The term drilling mud/fluid is a fluid (which could be either liquid or gas) circulated through the wellbore during operations. They are classified on the basis of their principal component which could be water, oil or gas. Hence different types of drilling fluid exist, but no two drilling fluid types are the same even they are alike initially. This is because the effects of formulated substances and surface handling equipment introduced differences. The most appropriate drilling fluid is one that is most economical in the total perspective of safety, cost and eventual production. Typically, the liquid in a drilling mud is water, oil or a stable mixture of both. An emulsion is a mixture in which one liquid is suspended in minute globules (droplets) in another (Moore, 1974).

2.30 Classification of drilling mud

The three categories of drilling fluids are water-based mud (which can be dispersed and non-dispersed), non aqueous mud usually called oil-based mud and synthetic-based mud.

2.3.1 Water-based mud (WBM)

Generally water-based mud system begins with water, then clays and other chemicals are incorporated into the water to create a homogenous blend resembling between chocolate milk and malt (depending on viscosity). The clay (called "shale" in its rock form) is usually a combination of native clays that are dissolved into the liquid while drilling, or specific type of clay that are processed and sold as additives for the water-based mud system. The most common of this type is bentonite, frequently referred to as "gel" in the oil field (Grey, 1987). Gel likely makes reference to the fact that while the fluid is being pumped, it can be very thin and free-flowing (like chocolate milk), though when pumping is stopped, the static fluid builds "gel" structure that resist flow. When an adequate pumping force is applied to "break the gel", flow resumes and the fluid returns to its previous free-flowing state. Many other chemicals (e.g. potassium formate) are added to a water-based mud system to achieve a various effects including: viscosity control, shale stability, enhances drilling rate of penetration, cooling and lubricating of equipment. Generally, "gel strength" is one of the properties of drilling mud that described the attractive forces of mud when it is in a static state condition.

2.3.2 Oil-based mud (OBM)

This can be a mud where the base fluid is a petroleum product such as diesel fuel. Oil-based muds are used for many reasons, some being increasing lubricity, enhanced shale inhibition and greater cleaning abilities with less viscosity. Oil-based mud also withstands greater heat without breaking down. The oil frequently selected is diesel oil and must contain emulsifying agents. If water is added, the oil mud is called an invert emulsion mud. Various thickening and suspending agents are added as well as barite. The use of oil-based mud has special consideration which includes cost and environmental consideration. The emulsified water may contain alkalis and salts (Narrisa, 1999).

2.3.3 Synthetic-based mud (SBM)

This is a mud where the base fluid is synthetic oil. This is most often used on offshore rigs because it has the properties of an oil-based mud, but the toxicity of the fluid fumes are much less than that of an oil-based fluid. This is important when work with the fluid in an enclosed space such as an offshore drilling rig.

2.4.0 Composition of drilling mud

2.4.1 Water-based mud (WBM)

This consists of a mixture of solids, liquids and chemicals. Some solids (clay reacts with water and chemical in the mud) are called "active solids". The activity of these solids must be controlled in order to allow the mud to function properly. The solid which do not react within the mud are called "inactive or inert solids" (e.g. barite). Fresh water is used as the base for most of these muds, but in offshore drilling, salt water is more readily available. Figure 1.0 shows the typical composition for a water-based mud.

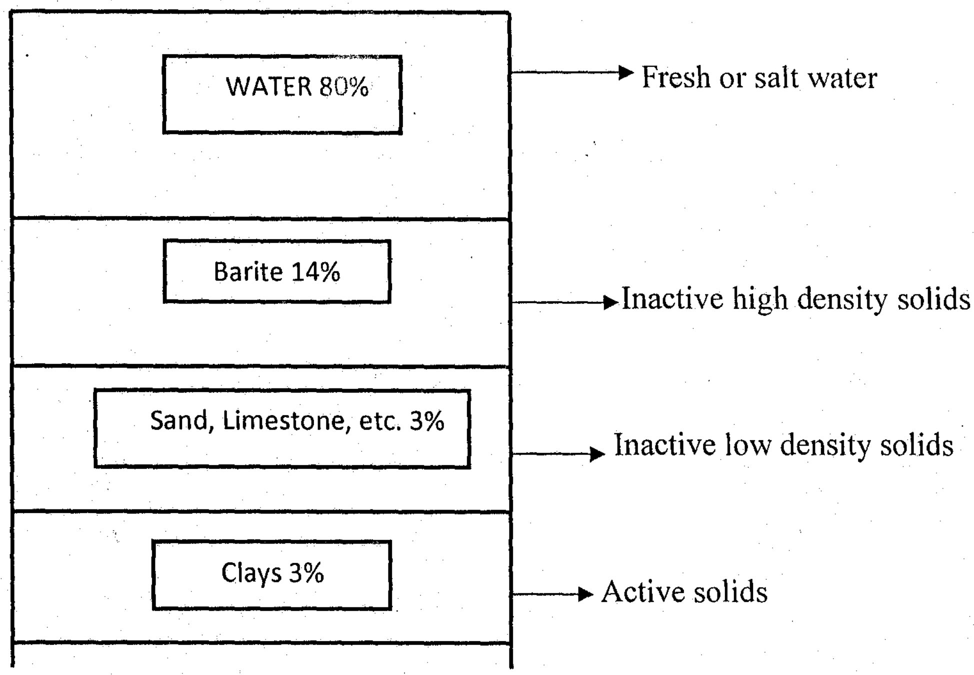

Figure 1.0 Composition of Typical Water-based Mud

2.4.2 Oil-based mud (OBM)

This is similar in composition to water-based mud with the exception that the continuous phase is oil. In invert emulsion mud, water may make up percentage of the volume, but is still continuous phase. The water is dispersed through out the system as droplets. Figure 2.0 shows the typical composition for oil-based mud.

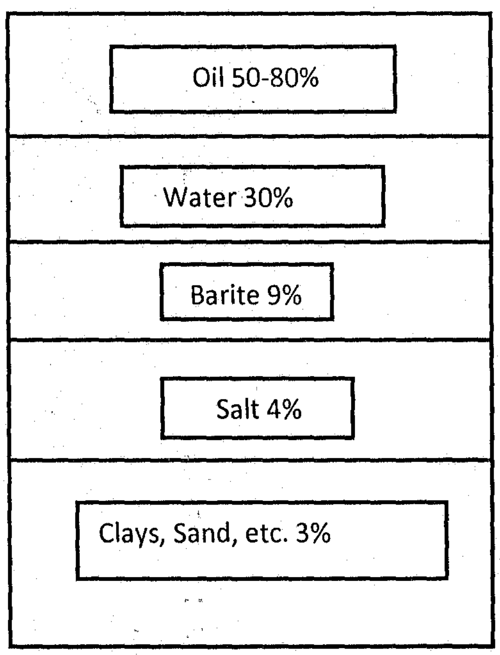

Figure 2.0 Composition of Typical Oil-based Mud.

2.5.0 Functions of Drilling Mud

Drilling mud/fluid is a vital component in the rotary drilling process. Most of the problems encountered during the drilling of a well can be directly or indirectly contributed to the mud. Due to the complexities of treating, monitoring and conditioning the mud, an operating company will usually hire a servicing company to provide a drilling fluid specialist (mud engineer) on the rig. The cost of mud, chemical additives may fairly be high (around 10% of the total well cost). Although this may seems expensive, the consequences of not maintaining good and properties may prove much more expensive in terms of drilling problems. The main functions of drilling mud/fluid are as follows:

2.5.1 Removal of Drill cuttings

As bit penetrates the formation, the rock cuttings drilled must be removed; otherwise the drilling efficiency will decrease. In removing the drill cuttings there are three (3) separate operations that take place which are:

I. Lifting the cuttings to the surface while circulating
II. Suspension of cuttings while not circulating and
III. Dropping out of cuttings on surface.

The mud properties must be properly engineered to fulfill these requirements. The lifting capacity of depends on the annular velocity, density and viscosity. Suspension depends on gelling thixotropic effect, which develops after circulation is stopped. Mechanical devices such as shale shakers, de-sanders and de-silters can be used to achieve the removal of solid materials from the mud at the surface. It is not economically feasible to remove all solids before re-circulating the mud. The more the solids removal the lesser chemical treatment and dilution is frequently required.

2.5.2 Controlling of formation pressure

The hydrostatic mud pressure must be sufficient to prevent an influx of formation fluids into the wellbore; the density is the controlling factor. By increasing the mud weight however, the risk of formation break down and loss circulation increases and the rate of penetration decreases. The mud must be very carefully selected to meet specific requirements. Barite is added as a weighting material/agent due to its high specific gravity (SG= 4.2). If formation pressure increases, mud density should also be increased, often with (barite) or other weighting materials to balance the pressure and keep the wellbore stable. Unbalanced formation pressure will cause a blowout oil/blowout from pressured formation fluids. Hydrostatic pressure depends on mud weight and true vertical depth. If hydrostatic pressure is greater than or equal to formation pressure, the formation fluid will not flow into the wellbore.

2.5.3 Maintaining of wellbore stability

The drilling fluid should deposits a filter cake on the wall of the borehole to consolidate the formation and to prevent formation damage. The filter cake is formed by the hydrostatic pressure forcing the liquid part of the filtrate into the formation, leaving some solid material s on the side of the borehole. A good filter cake must be thin, slick and impermeable. In a permeable zone (e.g. sand), the fluid loss must be controlled otherwise:

I. The filter cake will be become so thick which may cause stuck pipe.
II. Filtrate entering productive zone may cause damage which will reduce formation's productivity.

Chemical composition and mud properties must combine to provide a stable wellbore.

2.5.4 Cooling and lubricating of the bit

The combine effect of weight and speed of rotation generate at the bit. Unless the bit is cooled it will overheat and quickly wear out. If the mud contains lubricants such as oil the friction of the bearings will be produced. This will also reduce the friction between the drill string and the borehole as the hole is drilled. Not only will this prolong the service life of the down hole equipment but it will also help to prevent drilling problems such as torque, drag and differential sticking.

2.5.5 Transmitting hydraulic horsepower to bit

For efficient drilling, most of the power delivered by the pumps should be used at the bit. The hydraulic horsepower is transmitted by the drilling fluid and so mud properties such as plastic viscosity, yield point and weight are important. The velocity created by pumping mud through the bit nozzle provides the turbulence to the bottom of the hole.

2.5.6 Supporting the walls of a well

A drilling fluid with proper characteristics can support a formation that might otherwise cave into well. This type of drilling mud or fluid plasters the wall of a well like a mortar, in order to prevent entry of formation fluid into the well, also to prevent loss of drilling fluid into the porous zones by its formation of filter cake or mud cake.

2.5.7 Prevents caving of formation

Caving of formation results from factors other than hydration of susceptible shale by water overhangs, ledges, vertical bedded formation etc. may tends to break off and fall into the hole if a high pressure or density differential exist between the formation and the mud/fluid. The mud weight and the gel strength will be increased to provide a plastering effect to the formation and then since slight hydration effect may be experienced, the fluid loss may have to be lowered.

2.6.0 Properties of Drilling Mud

Different kinds of drilling mud with different properties are needed for various formation and drilling conditions. This is to ensure effective performance of the drilling function. However, the following physical and chemical properties needed to permit its function effectively.

A. Physical properties

I. Mud density
II. Viscosity (apparent and plastic viscosity)
III. Gel strength
IV. Yield point
V. Filtration

B. Chemical properties

I. Mud p^H
II. Alkalinity of the mud
III. Calcium content
IV. Salt content

2.6.1 Mud density

Density can simply be defined as mass (weight) per unit volume. Inert solids such as barite are used to increase the weight or density of drilling mud. Other inert solids in suspension may be drilled solids that are chemically inactive, limestone, dolomite or sand. Commercial and natural clays also increase the density of drilling mud, but as much as barite. Barite has specific gravity of 4.2 and 4.35, and most frequently used in preparing mud that weighs more than 10ppg. Muds that do not have barite added to them are called "un-weighted mud". They normally have a density of less than 10ppg. These muds often contain drilled solids as well as solid particles from commercial clays.

2.6.2 Viscosity

Viscosity can be defined as the resistance of drilling fluid to flow. Higher viscosity mud can carry more cuttings and inert solids to the surface that can lower viscosity mud. Drilling fluids must be mixed thick (viscous) enough to bring soil cuttings up from the bottom of the hole to the surface, yet not so viscous so as to prevent their settling out in the mud pits. However, the ability of a fluid to lift cuttings increases rapidly as viscosity and up-hole velocity are increased. Viscosity can therefore be divided into two namely:

I. Apparent viscosity and
II. Plastic viscosity

2.6.3 Apparent viscosity

Apparent viscosity can be defined as the measurement of viscosity as a timed rate of flow through a funnel called the marshal funnel. In the field, the Derickman determines how long it takes a certain amount of mud to flow through the marsh funnel. It is used to determine the flow rate of fluid under pressure in a given time usually in seconds/quart. A quart is usually equal to 946ml or cc/cm^3. A scribe line crossing the diameter of the marsh cup each has a measurement that equals 946ml.

2.6.4 Plastic viscosity

Plastic viscosity is that part of flow resistance in mud caused by mechanical friction. This mechanical friction is as a result of the friction between the solids in the mud, the friction in liquid itself and the friction between the solid and the liquid around them. Plastic viscosity depends on the concentration, size and shape of the solid present in the mud.

2.6.5 Gel strength

Gel strength can be described as the attractive forces of mud when it is in a static condition. It can be thought of as the stress required to getting the mud moving. The gel strength can be measured using viscometer. Gel strength increases when the mud is at rest. Generally, yield point and gel strength are directly related, i.e. as yield point increases the gel strength also usually increases.

2.6.6 Yield point

Yield point is that component of resistance caused by electrochemical attraction within the mud while it is flowing. This force of attraction exists between the solid particles and is as a result of positive or negative electrical charges located on or near the surface of each clay particles. In drilling mud the solid particles tends to arrange themselves so that attractive (unlike charges) and repulsive (like charges) forces are satisfied when the fluid is at rest. The yield point of drilling mud can be altered or controlled by chemical treatment that changes the strength or amount of the positive or negative forces active in the mud. Lowering the yield point also lowers the apparent viscosity.

2.6.7 Filtration rate

Filtration can be defined as the rate at which fluid from a mud sample is forced through a filter cake under a specified temperature and pressure. Mud solids are deposited on the wall of the wellbore (filter cake), while filtrate invade the formation. The wall cake formed the further loss of water into the formation. Poor filtration may be due to poor particle size distribution, i.e. not having the right size or type of solid in the fluid. Addition of bentonite clay or organic filtration control agents caused the cakes quality and composition by plugging tiny holes in the poorly formed wall cake. A good wall cake should:

I. Minimizes formation damage
II. Improves hole stability
III. Reduces the loss of liquid phase to formation.

2.6.8 Mud p^{H} and alkalinity

Mud p^H can be defined as the degree of acidity or alkalinity of mud. The p^H of the drilling mud has to be determined in order to know whether or not it is good enough for a particular formation at a given time. The p^H of mud for drilling operation is maintained at a p^H range of 9.5 to 11.5 and 8.5 to 12.5 in order to avoid corrosion and detection of any possible contamination of the spud mud. The mud p^H simply gives us information about the acidity and alkalinity of that used in a particular formation; most water-based muds are alkaline. However, caustic soda is added to some fresh water and salt water muds with low p^H level in order to raise the p^H and thereby maintaining the correct alkalinity.

2.6.9 Calcium content

Drilling mud containing anhydrite or gyps contamination, cement contamination or any other form of calcium may likely lead to filtrate increase. Versenate test shows increase in ppm calcium filter cake thickening and spongy appearance, flow back when making connection. In other words, soda ash or bicarbonate of soda is employed to treat out calcium to enable it perform its optimum function.

2.6.10 Salt content

Salt content muds are desirable in some drilling situation, such as the attalpulgite salt (i.e. sodium chloride) can act as contaminant in others for example, that acquired in drilling through a bed salt. In this case, the mud must be chemically treated to maintain the correct body and filtration.

Table 1.0 p^H of common drilling fluids/muds (Onize, 2003)

Mud Types	P^H Values
Low solids salt	6.5
Phosphate	7.5-9.5
Organic-dispersant	7.5-12
Gypsum	8.0-10
Calcium chloride	10plus
Lime treated mud	11.5plus

Table 2.0 p^H of common drilling mud treating agents (Onize, 2003)

Treating agents	P^H Values
Barium carbonate, $BaCO_3$	10.0
Sodium bi-carbonate, $NaHCO_3$	8.3
Calcium sulphate $CaSO_4.0.5H_2O$	6.0
Chrome lignosulphate	3.4-4.0
Sodium carbonate, $NaCO_3$	11.0
Calcium hydroxides, $Ca(OH)_2$	12.0
Sodium hydroxide, NaOH	13.0
Calcium lignosulphate	7.0

Table 3.0 Bentonite specifications for industries (Onize, 2003)

Sodium-based bentonite	%
SiO_2	74.64
Al_2O_3	12.96
Fe_2O_3	1.16
CaO	Traces
MgO	2.77
Na_2O	1.91
K_2O and others	0.57

Table 4.0 Calcium-based bentonite (Onize, 2004)

Calcium-based bentonite	%
SiO_3	69.0
AlO_3	13.33
FeO_3	2.09
CaO	2.83
MgO	3.38
Na_2O	1.93

Table 5.0 Barite specifications for oil industries (Onize, 2003)

Barite	%
$BaSO_4$	27.93
Al_2O_3	0.1
Specific gravity	4.2
Soluble alkaline earth	250ppm

2.7.0 Drilling mud ingredients

The drilling mud ingredients include the following:

2.7.1 Clay

Clay which is bentonite is used to provide viscosity and filter cake on the borehole wall to control fluid loss. The constituents of clay are called minerals, which can be divided into two broad groups:

I. Expandable (hydrophilic) clays- these will readily absorb water (e.g. montmorillonite)
II. Non-expandable (hydrophobic) clays- these will not readily absorb water (e.g. illite)

2.7.2 Water

This is the largest component of water-based muds (WBM). It may be used directly in the natural state or salt may be added to change filtrate reactivity with the formation. Water hardness is often eliminated through treatment hence alkalinity is often controlled.

2.7.3 Polymer

This is a substance made up of a great many simpler units, identical to each other or at least chemically similar, joined together in a regular way. These simpler units materials are known as the "monomers". All polymers are macromolecules but not all macromolecules are polymers. These are used to reduce filtrate, stabilize clays, flocculate drilled solids and increase cuttings-carrying capacity. Cellulosic, polyacrylic and natural gum polymers are used in low solid muds to help maintain hole stability and minimize dispersion of drill cuttings. Long chain polymers are absorbed unto the cuttings thereby preventing disintegration and dispersion (Kirk and Omar, 1987).

2.7.4 Thinners

Thinners are added to the mud in order to reduce resistance to flow and to stifle gel development. They are typically plant tanning, polyphosphate, lignite materials, lingosulphate or synthetic polymers.

2.7.5 Inorganic chemicals

A wide variety of inorganic chemicals are added to the mud to carry out several functions. For example, calcium hydroxide is used in lime mud and calcium chloride in oil-based muds. Sodium hydroxide and potassium are used to increase mud p^H and solublize sodium carbonate to remove hardness, sodium chloride for inhibition. Other functions of sodium chloride include increasing salinity, density, preventing hydrate formation and providing inhibition (Onize, 2003).

2.7.6 Bridging materials

Calcium carbonate, cellulose, fibers, asphalt and gilsonite are added to build up filter cake on the fractured hole and help prevent filtrate loss.

2.7.7 Weighting agents

These serve as emulsifiers, foamers, defoamers, detergents, lubricants and corrosion inhibitors. Examples are barite, potassium hydroxide, etc.

2.8.0 Clay chemistry

Clay plays an important part in water-based muds and understanding of some clay is necessary. The constituents of clay called minerals, which can be divided into expandable (hydrophilic) clays, which will readily absorb water (e.g. montmorillonite) and non-expandable (hydrophobic) clay which will not readily absorb water (e.g. illite). Clay minerals are complex aluminum silicates composed of two basic units: silica tetrahedron and aluminum octahedron. Clay minerals have sandwich like structure usually consisting of three layers, the alternate layers are of silica and alumina. A clay particle usually consists of several sandwiches stacked together like a card of composition cards. The chemical composition of montmorillonite differs from that of illite, which accounts for the difference in water absorption. All clay minerals contains 140 tetrahedral sheet similar to micas tend to occur in minute flaky crystals. Clay minerals include kaolinite, illite, montmorillonite, vermiculate, seprolite and allophone. Montmorillonite bentonite has the molecular formula ($Al_4(Si_{16}Al_2O_{20})(OH_4)^2H_2O$) (Moore, 1987). Aluminum can be replaced by iron and magnesium, potassium, sodium, or calcium ions may partially fill the inter layer sites. The positive cations are exchangeable bases and their presence account for high base exchange capacity of the minerals. An overall residual negative charge often remains in deep marine muds.

2.8.1 Barite

Barite is a naturally occurring mineral containing barium sulphate ($BaSO_4$) used in the production of drilling mud particularly in the petroleum industry. This is used to increase the density of the drilling fluid for the control of the formation processes. Barite has a specific gravity of about 4.2 which is relatively high. The specific gravity of barite combine with its low water solubility of about 0.3ppm in sea water, low Moh's hardness of between 2.5 and 3.4, and chemical inertness are properties which makes it suitable for drilling fluids. The availability of commercial deposit provides a low cost product and combined with its desirable properties makes barite the most useful mineral as a weighting material. Areas of significant occurrence of barite within the country are in Aara, Akari, Ibi, and Iloshi of Plateau and Benue state as well as Tungel in Taraba state. The Nigerian mining corporation has confirmed a reserve of 730,000 tones of barite in five veins out of the eighteen located in Azara areas in Benue state. The major impurities of barite are quartz and iron oxides especially the geotite. These impurities tend to reduce the specific gravity of unprocessed barite, which ranges from 3.6 to 4.9. These impurities can be removed by gravity and magnetic separation respectively. Pure barite contains 65.7% barium oxide BaO, and 34.33% sulphate SO_3 (Narrisa, 1999).

2.8.2 Bentonite

Bentonite is an important ingredient in the production of drilling mud. It belongs to the group of non-metals whose properties are controlled by the proportion of montmorillonite. Bentonite exists in the northeast quadrant of Nigeria where a probable of more than 700 million tones has been indicated. Similarly, over 90 million tones have been in Abia, Anambra and Imo state. (Michael, 2004).

2.8.2.1 Processing of bentonite

Sodium has been proven in Nigeria. However, in the occurrence of calcium montmorillonite, it has been reported in places mentioned above. Processed calcium bentonite can be used in viscosity control. Processing of bentonite consists of three major steps namely:

I. Removal of undesirable impurities that decrease the relative content of montmorillonite in the natural state and reduce its quality.
II. Physiochemical benefaction
III. Chemical-mechanical activation.

2.8.2.2 Physical and chemical properties of bentonite

Bentonite used in the production of drilling mud must consist the following properties:

I. It has density between 2.0 and 2.7 which decreases with increasing ions.
II. It has color ranges from white to grey, yellow, green and brown.
III. It should have high dispersion properties with large surface area particles and high ability to bind or hold i.e. absorbs water when swelling.

2.8.3 Carboxyl-methyl cellulose (CMC)

Sodium carboxyl-methyl cellulose (CMC) and Hydroxyl-ethyl cellulose (HEC) are the cellulosic most widely used in drilling fluids. CMC is manufactured by carboxyl-methylation of cellulose which changes the water-insoluble cellulose into the water-soluble CMC, hydroxyl-ethyl cellulose and carboxyl-methyl hydroxyl-ethyl cellulose (CMHEC) are made by the named process. The viscosity grade of the material is determined by the degree of substitution and the molecular weight of the finished product. Sodium carboxyl-methyl cellulose is an ionic polymer and its effectiveness as a viscosity builder decreases with increasing electrolyte concentration. It can be precipitated with calcium and magnesium by raising the p^H of the mud. Poly-anionic cellulose was introduced to over come some of these limitations. The main application of CMC is to control the filtrate rates (Grey, 1978).

CHAPTER THREE

3.0 METHODOLOGY

3.1 Materials and equipments

The materials and equipments used in carrying out the experiment are listed in the table below:

Table 6.0: List of materials used for the experiment

Materials	Chemical Formula
Local bentonite clay	$(Al_4(Si_{16}Al_2O_{20})(OH_4)^2H_2O)$
Imported bentonite clay (aqua gel)	$(Al_4(Si_{16}Al_2O_{20})(OH_4)^2H_2O)$
Barium sulphate	$BaSO_4$
Sodium hydroxide	$NaOH$
Carboxyl-methyl cellulose (CMC)	

Table 7.0: List of the equipments used for the experiment

Equipments	Research Functions
Multi-mixer cup	Mixing of the base fluid and chemicals
Mud balance	Measuring mud weight or density
Standard filter press	Measuring fluid loss/ filtrate volume
Direct indicating viscometer	Measuring viscosity, Gel strength
Standard API sieve	Measuring sand content
Stop watch	Measuring time
Thermometer	Measuring sample temperature

3.2.0 Experimental procedure

This section consists of two stages, these are:

Stage 1

I. Preparation of the clay samples (local and imported clays)
II. Confirmatory test of the clay samples
III. Weighing and blending of the clay samples
IV. Mixing (clay samples + 200ml of distilled water)
V. Characterizing/testing the properties of the samples before upgrading

Stage 2

I. Upgrading/formulating the clay samples

II. Characterizing/testing the properties of the upgraded clay samples

STAGE 1

3.2.1 Preparation of the clay samples

This section explains how the clay samples (local and imported) were prepared. Although the imported clay obtained from the petroleum training institute (PTI) laboratory Warri, was processed already. The local clay which was obtained from a clay deposit in Afuze (a town in Okada Local Government Area of Edo State) was prepared by grinding it using a jaw crusher. After grinding the local clay, then the clay was sieved using a 200 mesh sieve which is in consistent with the American Petroleum Institute (API) standard.

3.2.2 Confirmatory test of the clay samples

After getting the samples prepared, a confirmatory test was carried out on the samples in order to have a certainty that the samples used were bentonite clays. In line with American Petroleum Institute (API), standard bentonite clay must posses the following properties;

Its density should be between (2.0-2.7) lb/gal and its colour ranges from white to grey, yellow, green and brown. Considering the conditions mentioned above, mud balance was used initially to measure the densities of the samples which were found to be (2.5 and 2.8) lb/gal for local and imported bentonite respectively. Physically, the local clay gave a grey colour while the imported clay gave a brownish colour. These showed that the samples used were bentonite clays.

3.2.3 Weighing and blending of the clay samples

After confirming the clay samples, the samples were weighed and blended at different ratio of 50%:50% and 75%:25% of local and imported bentonites. A standard weighing balance was used to weighing 23.0g of both local and imported clays for 100%, 11.5g of both samples for the 50%:50% blend, and 17.5g and 5.75g of local plus imported clays for the other.

3.2.4 Mixing (clay samples +200ml of distilled water)

Using a graduated cylinder, 200ml of distilled water was measured into the blender, 23.0g of local bentonite was poured gently into the blender, and mixed thoroughly with a mixer for 15 minutes. The above mentioned process was repeated for imported clay sample, 50%:50% and

75%:25% blends of local plus imported clays. After mixing has taken place the samples were kept for a period of 24 hours (aging) before carrying out any test of the clay properties, this was done in order to allow the samples to absorb the water in it.

3.2.4 Characterizing/testing the properties of the samples before upgrading

In order to determine the physical and chemical properties of the drilling fluid after mixing, certain tests must be carried out to ensure that it fulfils its functions. By carrying out these tests at regular intervals, any deterioration in mud quality can be identified before it causes any problem down hole. It is essential to characterize/test the mud/fluid so that it could meet the standard of a particular specification of the mud properties. Among the test carried out on the mud are as follows:

- **I.** Mud weight (density) test
- **II.** Rheological properties (plastic and apparent viscosities) test
- **III.** Mud P^H test
- **IV.** Filtrate volume test
- **V.** Sand content test

3.2.4.1 Mud weight (density) test

Density is defined as the weight per unit volume of drilling fluid. It is commonly reported as kilograms per cubic meter (kg/m^3) as well as pounds per gallons (lb/gal). The desired density for drilling situation is usually less than 1080kg/m^3 (i.e. 9.0lb/gal)

The procedure for measuring the density of the mud

After aging, the local clay sample was again poured into the blender and mixed for 10 minutes. After that, a cleaned, dried cup attached to a mud balance was filled with the fresh screened mud that has just been mixed. The lid was placed on the cup and rotated until when it was firmly settled. It was ensured that some fluids were squeezed out of the hole; the excess mud from the exterior of the balance was also wiped. After the exterior surface of the balance has been dried, the balance with its knife edge was placed on the ground and leveled by adjusting the rider. The mud density was read from the edge of the rider and the value was recorded. The cup was washed immediately after used and the balance was kept cleaned for accuracy and consistency of the result being obtained. The process was repeated for imported clay sample and 50%:50%, 75%:25% blends of local plus imported clays.

3.2.4.2 Determination of rheological properties (plastic and apparent viscosities)

The procedure used in calibrating direct indicating viscometer.

After mixing the aged clay samples again for 10 minutes as stated in the above procedure, a sample of local clay was poured in a mud cup, and the rotor sleeve was immersed exactly to the scribe line. The crank was rotated at 600rpm; the dial reading was allowed to reach the steady value. The dial reading for 600rpm was recorded. It was shifted to 300rpm and as well the crank was rotated, the dial reading was recorded. This process was repeated for imported clay sample and 50%:50%, 75%:25% blends of local plus imported clays and the corresponding readings were recorded.

3.2.4.3 Mud p^H test

The p^H test is a measure of the concentration of hydrogen ions in aqueous solution. This can be achieved either by phydrion paper or by a special p^H meter.

The procedure used for mud p^H determination

With the p^H meter containing a probe device, the probe used was washed. The probe was simply placed in the mud sample and allowed to stay until the needle contained in the probe stabilized. The mud p^H was read and recorded directly from the meter. This procedure was repeated for all the clay samples.

3.2.4.4 Filtrate volume test

The procedure used for filtrate volume test

The instrument used consists of a mud cell, pressure assembly and filtering device. The test was carried out at room temperature. After aging, the clay sample was again poured into blender where it was mixed again for 10 minutes. After that, the clay sample was poured to about half inch on top of the cell; the cell was closed at the bottom by a lid which is fitted with a screen. A filter paper was placed on top of the screen which was pressed up against an o-ring seal. A graduated cylinder was placed under the screen to collect the filtrate. The pressure of 100psi was applied for a period of 30 minutes. When the pressure was bled-off, the cell was then opened and the filter paper was examined where the volume of the filtrate was measured in (cm^3) and recorded. The procedure was repeated for all the clay samples.

3.2.4.5 Sand content test

The percentage of sand in the mud was measured by using a standard 200 mesh sieve and a graduated glass tube.

The procedure used for determining sand content in the mud

The glass measuring tube was filled with mud sample up to the scribe line. The fluid was mixed again by shaking for about 1 minute and then poured through the sieve; the sand retained on the sieve was washed thoroughly in order to remove the remaining mud. A funnel was fitted to the top of the sieve and the sand was washed into the glass tube by a fine spray of water. After allowing the sand to settle, the sand content was read off directly as a percentage and recorded. The procedure was repeated for all the clay samples.

Stage 2

3.2.5 Upgrading the clay samples

The section explains how chemical additives were added to the clay samples in order to upgrade the clay properties (such as density, viscosity, filtrate volume, p^H) so that the formulated drilling mud/fluid could meet up with the American Petroleum Institute (API) standard/specification. The additives added were:

- Sodium-carboxyl-methylcellulose (CMC) which was used to build up the viscosity and to control the filtration rate of the drilling fluid.
- Barium sulphate ($BaSO_4$) used to increase the density of the fluid.
- Sodium hydroxide (NaOH) used to increase the p^H of the fluid.

3.2.5.1 Mixing/upgrading (clay samples + additives)

The aged local clay sample which was just mixed again was poured into the blender and mixed thoroughly for another 10 minutes. It was followed by the addition of 0.25g of sodium-carboxyl-methylcellulose (CMC) and stirred for 10 minutes. 1.2g of barite was added to it and stirred for another 10 minutes. Moreover, this was followed by the addition of 0.4ml of sodium hydroxide and it was stirred for 20 minutes. With the exception of 100% imported clay sample, the above described process was carried out for all the clay samples.

3.2.6 Characterization of the upgraded clay samples

After upgrading the clay samples as described above, the formulated/upgraded clay samples were also characterized. The characterization procedures follow the same way as conducted in stage 1 when the samples were not upgraded. But after adding 0.4ml of sodium hydroxide into the local clay sample during the upgrading, its p^H value was still found to be below the range (i.e.7.90) consequently, 0.2ml of NaOH was added into it and mixed again where the value raised to 11.0. The changes in the clay properties (density, p^H, viscosity, filtrate volume etc.) caused as a result of the additives added were observed, measured and recorded consistently.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Experimental results

The experiment was carried out in Baroid laboratory of petroleum training institute (PTI) Warri, Delta state of Nigeria. The results obtained from the analysis are presented in the tables given below. Designating the following letters to the clay samples i.e. A, B, C and D for local, imported, 50%:50% and 75%:25% of local plus imported clays respectively.

Table 8.0: physical properties of the clay samples

Properties	A	B
Colour	grey	brownish
Odour	odourless	odourless
Texture	powdery after sieving	powdery

Table 9.0: Results for 100% samples A and B before upgrading/formulation

Properties Tested	A	B	Specifications
Density (lb/gal)	8.50	7.90	8.50-9.50
Mud p^H	7.00	11.50	9.50-12.0
Viscometer reading			
Rheometer at 600rpm	18.00	25.0	30maximum
Rheometer at 300rpm	10.00	16.00	20maximum
Plastic viscosity (cp)	8.00	9.00	8-10
Apparent viscosity (cp)	9.00	12.50	30maximum
Yield point lb/100ft^2	2.00	1.00	30maximum
Filtrate volume (cm^3)	10.00	12.50	15maximum
% sand content	traces	traces	traces
Temperature (^{o}C)	25.00	24.5	25.00

Table 10.0: Results for samples C and D before upgrading/formulation

Properties Tested	C	D	Specifications
Density (lb/gal)	8.65	8.60	8.50-9.50
Mud p^H	7.20	8.20	9.50-12.0
Viscometer reading			
Rheometer at 600rpm	25.00	20.00	30cp
Rheometer at 300rpm	15	12.00	20cp
Plastic viscosity	10.00	8.00	8-10
Apparent viscosity	12.50	10.00	30maximum
Yield point lb/100ft^2	5.00	4.00	30maximum
Filtrate volume (cm^3)	12.00	14.00	15maximum
% sand content	traces	traces	traces
Temperature (^{o}C)	24.50	25.50	25.00

Table 11.0: Results for A, C and D samples after upgrading/formulation

Properties Tested	A	C	D	Specifications
Density (lb/gal)	9.00	8.90	9.20	8.50-9.50
Mud p^H	11.00	12.50	13.00	9.5-12.0
Viscometer reading				
Rheometer at 600rpm	30.00	55.00	75.00	30cp
Rheometer at 300rpm	22.00	40.00	63.00	20cp
Plastic viscosity	8.00	15.00	12.00	8-10
Apparent viscosity	15.00	27.00	37.5	30maximum
Yield point lb/100ft^2	14.00	25.00	51.00	30maximum
Filtrate volume (cm^3)	7.00	10.00	12.50	15maximum

% sand content	traces	traces	traces	traces
Temperature (^oC)	26.00	26.50	27.8	25.00

4.2 Discussion of results

The table above shows the results obtained from the analysis carried out, and the results are discussed below.

Considering the mud weight (density) values of local clay and the blends at 50%:50% and 75%:25% of local plus imported clays in tables 9.0 and 10.0 were obtained initially before upgrading as (8.50, 8.65 and 8.60) lb/gal respectively, which were within the range of API specification, but for the imported clay, its value was found to be 7.90 which was slightly below the specification. However, adding 1.2g of barium sulphate ($BaSO_4$) into the samples (excluding imported clay sample) during upgrading changed the density values to (9.0, 8.9 and 9.2) lb/gal which were still within the range. With the exception of the imported clay whose p^H value was 11.50, all the clay samples were initially found to have a p^H value below the range (i.e.7.0, 7.2 and 8.2), but when 0.4ml of sodium hydroxide (NaOH) was added to the samples B and C while upgrading, the p^H values were raised to (12.5 and 13) of the blends at 50%:50% and 75%:25% of local plus imported clays respectively but for local clay, after adding 0.4ml of NaOH its value was (7.90), which was below the range. Consequently, 0.2ml was added again and mixed where the value raised to (11.0). The rheometer reading at 600rpm for local, imported clay and blends at 50%:50% and 75%:25% of local plus imported clays were (18, 25, 25 and 20) cp respectively. The values for all the clay samples were below the specification before upgrading. During upgrading 0.25g of sodium carboxyl-methyl-cellulose (CMC) was added to each sample, consequently, the values raised to (30, 55 and 75) cp of local clay and the blends. This indicates that the values for both blends were above the range while that of local clay is within the specification. To control the viscosities, certain thinners (like lingo-sulphate, polyphosphate etc.) need to be added. However, the initial rheometer reading at 300rpm for the clay samples were (10, 16, 15 and 12) cp respectively. Similarly, the values for all the clay samples were below the range. But when CMC was added to the samples, the values raised to (22, 40 and 63) cp, here it was only the local clay had a value slightly above the specification but for the blends the values were highly above the specification. Thinners as well need to be added to other samples (i.e., the blends) so that the viscosities could be controlled / reduced in order to meet up the specification.

The plastic viscosities of the clay samples were obtained using the relationship given below;

i.e. PV= (600rpm reading-300rpm reading).. (1.0)

Similarly, apparent viscosities of the clay samples were calculated using the formula given below;

i.e. AV= rheometer reading at 600rpm/2.. (2.0)

And as well the yield points for the clay samples were obtained using the relationship given below;

i.e. YP= rheometer reading at 300rpm-pv.. (3.0)

Moreover, the filtrate volume values for all the samples were initially found to be within the specification with the exception of sample A whose value was 10.00 which is below the specification. After adding the sodium CMC, the values changed to (7.0, 10.0 and 12.5), this indicated that the filtrate volumes of the samples were controlled/reduced as a result of adding the CMC into the samples. For the %sand content, it was recorded as traces for all the samples. The temperature variation of the samples is due to the effect of the chemicals added into the samples and the mixing period.

CHAPTER FIVE

0 CONCLUSION AND RECOMMENDATION

.1 CONCLUSION

From the analysis carried out and the results obtained, it was concluded that the aims and objectives of this project work were achieved by producing a polymer drilling fluid/mud whose tested properties were determined to be within the range of American petroleum institute (API) specification.

5.2 RECOMMENDATIONS

In the course of carrying out this project work, various challenges were encountered; consequently some recommendations were made below i.e.

I. I absolutely recommended that the departmental laboratory should be upgraded thereby providing ample and standard equipments for student to carry out such project work within their academic institution in order to alleviating the expenditure.

II. I also recommended that the institution should employ more proficient, talented and experienced laboratory technicians in order to raising the standard of the institution.

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