International Journal of Oil, Gas and Coal Engineering
2023; 11(2): 28-36
http://www.sciencepublishinggroup.com/j/ogce
doi: 10.11648/j.ogce.20231102.11
ISSN: 2376-7669 (Print); ISSN: 2376-7677 (Online)

Improvement of Local (Umuna) Clay for the Production of Drilling Mud

Onyejekwe Ifeanyichukwu Michael

Department of Petroleum Engineering, Federal University of Technology, Owerri, Nigeria

Email address:
oronst@yahoo.com

To cite this article:
Onyejekwe Ifeanyichukwu Michael. Improvement of Local (Umuna) Clay for the Production of Drilling Mud. *International Journal of Oil, Gas and Coal Engineering*. Vol. 11, No. 2, 2023, pp. 28-36. doi: 10.11648/j.ogce.20231102.11

Received: January 13, 2023; **Accepted**: February 14, 2023; **Published**: April 24, 2023

Abstract: The continuous importation of foreign bentonite in the presence of proved and potential clay deposits spread across states in the country is not consistent with the government desire and commitment for the development of local content. This research explores the possibility of improving the Umuna local clay samples for the production of drilling mud. The clay samples were experimentally analysed in accordance with API standard of measurement. The obtained results show a marked trend as most of the considered rheological parameters such as yp, PV, gel strength, yp/PV, viscosity @600rpm and fluid loss were far away from satisfying the minimum required API standard specification for drilling mud. While parameters such as mud density, n-factor, K-factor, specific gravity and filter cake all satisfy the minimum required API standard specification for drilling mud production. The rheological properties of the local clays were significantly improved after beneficiation with 2g PAC-R. These obtained result after beneficiation now equated to that of the imported bentonite and also satisfy the required minimum API standard specification. The local clay fell under the inactive soil type based on its average activity value of 0.52. The presence of oxide compositions and cation exchange capacity (CEC) range of 70 – 150 Meq/100g suggests and confirms that the analyzed clay is of the montmorillonite family, with traces of illite which is good for drilling mud production. The obtained average thinner cake value (0.35) for the local clay is more desirable in drilling operations for reducing the risk of pipe sticking. This property with the combination of high value (29.39av) of consistency factor (k) and low value (0.28av) of the power law flow behavior index (n) portrays the clay sample been very much adequate for effective hole cleaning due to its high viscosity resulting from high consistency factor (k) and enough shear thinning property derived from the low power law flow behavior index (n).

Keywords: Filtration Loss, Bentonite, Local Clay, Rheological Properties, Improvement

1. Introduction

Drilling of an oil well demands the use of a greater quantity of drilling fluid in achieving functions such as proper hole cleaning, lubrication of drill string, and prevention of loss circulation etc. A particular fluid that is now used in the drilling industry is the drilling mud which is a group of complex mixtures of clays. Specifically, bentonites are major determinant of drilling mud due to their unique properties such as viscosity that enables the drilling mud to suspend drill cuttings and weighting materials. Drilling fluid was first introduced to rotary drilling between 1887 and 1907 [1] and has been generally described as the blood and most important element in any drilling operation [2]. Bentonite is the widely used and the best drilling clay to be employed in drilling mud production. It is currently being imported from the United States of America (USA). The continual importation of bentonite is a major drain to foreign earnings [3] that should be used in other sector of the economy. This trend is expected to continue as drilling activities increases. The continuous importation of bentonite is also not consistent with the government's desire and commitment to the development of local content, which covers self-sufficiency of the oil industry, and the maximization of our natural resources. Following the ban on the importation of foreign bentonite since 9th June, 2003 [4] by the government as a strong move to support its desire and stand on local content, the need for locally sourced option arose and consequently there has been sustained interest among researchers [5-9] and related institutions to provide replacement for the imported bentonite, though it is still being imported into the country till date.

The need for this study arises as the recent economic crises in the world continues and so many companies and countries are running on borrowed or shaking economy. Continuous importation of foreign bentonite in the presence of proved and potential clay deposits distributed across states in the country [5, 10] amounts to a wastage of scarce resources that could have served alternative ends. There is therefore need to ensure the proper utilization and maximization of these resources. Hence, the government outright ban or severe minimization of bentonite importation while the local clays are used will reduce the price of drilling mud production, the cost of drilling and generally the price of the refined products, thereby given optimum credence to the locally sourced bentonite or other suitable clays.

It is with this in mind that this study is been carried out. Bearing in mind that this study is an effort to evaluate the possibility of improving the local clay for drilling mud production, there is need to look at previous studies done by researchers.

1.1. Literature Review

Adeleye et al. [11] in their study on analysis of rheological properties of treated Nigerian clay using factorial analysis stated that the increase in clay concentration alone or with addition of gum Arabic could not improve the rheological properties of this particular clay, but with the enhancement using sodium carbonate (soda ash), flow properties were influenced. Ali and Fatima [12] carried out a study on the potential use of local bentonite as drilling fluid. After comparing the physical and chemical compositions of the locally sourced clay to that of API standard specification for drilling mud, they concluded that the characteristic of the local clay (bentonite) makes it likely to be use for drilling fluid formulation when beneficiated.

Studies [9, 11, 13-14] have shown that most of the locally sourced bentonite in Nigeria is rheologically deficient in properties when compared to required minimum API standard specification for drilling mud. Oyeneyin and Rai [15] carried out a laboratory analysis study to ascertain the possibility of using Nigeria clay as a drilling mud material for the oil industry. Their obtained result indicated that mud prepared from local clay in their natural status without the addition of extenders fail to satisfy the minimum required API standard specification for drilling mud. They concluded that this clays lack the required amount of chemical cations for plasticity, thereby could not be used without beneficiation for drilling mud production. James et al [16] in their study on beneficiation and characterization of a bentonite from North East Nigeria, beneficiated the local Yola clay using dry and wet methods and sodium treatment. Their obtained result indicated that though sodium treatment improves the rheological properties of the clay suspension, but still fell far below the minimum required API standard specification. They concluded that the Yola bentonite clay is a low grade calcium montmorillonite, making it unsuitable for drilling fluid applications. Onwuachu [17] in his study on investigation into the use of local clays in drilling operations stated that the obtained result from swelling index analysis indicates that the local clays have acceptable swell index factors. This he said is however, suggestive that the indigenous clays when collected from a suitable depth can be used in drilling operations.

Formulation of drilling mud using available local materials as additives have been studied by researchers [18, 19, 20]. Ikechi and Bright [21] carried out an experimental assessment on the suitability of using periwinkle shell ash (PSA) as filtration loss control in water-based drilling mud. The obtained ash from the periwinkle was used in the formulation of the mud samples. The filtration control property of the mud that was analysed under strict adherence to API filter press and in accordance to API recommended practice were the filtrate volume and thickness and consistency of the deposited filter cake. The obtained results indicate that the filter cake for the mud sample with higher gram of PSA were thinner and more consistent than others. Result further indicates that addition of PSA to the various mud samples improved the filtration characteristics of the formulated water base mud.

1.2. Summary of Reviewed Literature

Drilling fluid has been generally described as the blood and most important element in any drilling operation, and this they submit that it will be difficult or almost impossible to drill for oil and gas without it and its additives. Reviewed literature shows that the continuous importation of bentonite that are major determinant of drilling mud in the existence of proved and potential clay deposits spreads across states in the country connotes wastage of limited resources that could have served alternative ends. Results from reviewed literature suggests that drilling mud prepared from local clay in their natural states without beneficiation is rheologically deficient in properties when matched with the required standard API specification for drilling mud, but that this property are improved after beneficiation thereby making it probably to be used in drilling fluid formulation.

The general conclusion from studies submits that the rheological properties of the local clays can truly be improve after beneficiation and then be a worthy substitute for the foreign bentonite. This will assist in minimizing the loss of capital flight associated with the importation of foreign bentonite, generate the much needed employment opportunities for both skilled and unskilled Nigerians on the long run, improves the country's economy by bringing in external investments.

2. Materials and Methods

First, comprehensive lists of all the experiments, apparatus and the corresponding procedures employed for this research were defined. The clay samples for this research were collected from various vertical profiles from Umuna, Onuimo Local Government Area of Imo State, South East Nigeria.

Measurements and experimentations were meticulously carried out on the collected sample after they were oven-dried and milled. The samples were analysed physically, chemically and rheologically for untreated and treated mud. All the experiment for this research were carried out in the Erosion laboratory, Federal University of Technology, Petroleum Engineering laboratory, Federal University of Technology Owerri, South East Nigeria and Best Land & Sea Oil services laboratory, Port Harcourt, Rivers State, South-South, Nigeria.

2.1. Physical Analysis of Raw Clay

The under listed tests were meticulously carried out on the collected clay sample within the API standard specifications.

2.1.1. Grain Size Analysis

The aim of this experimental test is to obtain the appropriate grain size distribution for the locally sourced clay samples with the aid of oven, stop watch, weighing balance, sieve of different mesh sizes as the apparatus. The weight of sieve No. $0.4\mu m$ was measured and recorded and 60g of the samples dried in an oven at a temperature of about 23.0°C were weighed using a weighing balance. The samples were introduced on the nest sieve No. 0.4mm on a sieve shaker and switched on for 20 minutes after which it was disconnected. The sieve with its content were weighed and recorded.

2.1.2. Specific Gravity

The aim of this experiment is to obtain the ratio of a given volume to the weight of equal volume of distilled water. In achieving this, weight of a specific gravity bottle was taken and 1000ml distilled water pressured out and poured into the distilled gravity bottle and weighed. 20g of the local clay samples was measured in the weighing balance and poured into the bottle after which weight of both the samples and the bottle were recorded. Distilled water was poured inside to fill the bottle containing the local clay sample to make up 1000ml, and weight of the content taken.

2.1.3. Moisture Content Test

The aim of the experiment is to determine the amount of water content present in the clay samples. 50g of samples was measured in a weighing balance and poured in a crucible, dried in an oven at constant temperature of 105°C for 4 hours. The weight of the dried samples was then measured in a weighing balance.

2.1.4. P^H Test

The aim of this experiment is to determine the acidity or alkalinity of the mud sample. P^H paper strip was dip into the mud sample while observing the colour changes. The paper strip changed to greenish blue colour, corresponding to a P^H value of 7-8 and value recorded.

2.1.5. Plastic Limit Test

The aim of this experiment is to determine the water content where clay starts to exhibit plastic behaviour. To enhance the consistency of this experiment, a 3mm diameter rod was used to guage the thickness of the thread while conducting the experiment. In this experiment, water was added drop by drop to 10g of the clay and the sample then rolled to 3mm diameter rod. The water content at which the clay just begins to crumble was identified and recorded.

2.1.6. Liquid Limit Test

The aim of this experiment is to determine the amount of water content where the clay sample changes from plastic to liquid. Using the casagrande method, 10g of clay was placed into the metal cup portion of the device and groove was made down its centre with a standardized tool. The cup is repeatedly dropped 10mm onto a hard rubber base during which the groove closes up gradually as a result of the impact. The number of blows for the groove to close for 13mm (1/2 inch) was noted and recorded. Note that the moisture content at which it takes 25 drops of the cup to cause the groove to close is defined as the liquid limit.

2.2. Chemical Analysis of Sampled Clay

Two locally sourced clay sample were subjected to the following chemical analysis.

2.2.1. Percentage Oxide Content

The aim of this experiment is to identify the ions of some elements in the clay samples using them in identifying the clay. UNICAM 969 atomic absorption spectrometer electric sand bath, electric weighing machine, volumetric flasks, digestion tube and filter paper were the apparatus used for this experiment. The required reagents for this test are wet digestion solution containing 650ml of Nitric acid(NHO_3), perchloric acid $(HCLO_4)$ and sulphuric acid (H_2SO_4) with addition of distilled water to the mixture. 20ml of wet digested solution was added to 1gram of sieve sample of clay and the mixture placed on the electric sand bath, and then the temperature of the sand bag was steadily regulated from 50°C to 235°C at which the digestion of the clay was expected to be completed. The solution was left to stand until the silica content has settled down. It is then filtered and dried. The elements suspected in the stabilizer were determined using UNICAM 969 atomic absorption spectrometer.

2.2.2. Cation Exchange Capacity

The aim of this experiment is to determine the amount of active bentonitic clay and cation exchange capacity of a given clay sample using baroid methylene test kit as the equipment. 1ml of mud was added to 10ml of distilled water in the Erlenmeyer flask. 15ml of 3% hydroxide peroxide and 0.5ml of distilled water was added and the content boiled for 10 minutes and 50ml of distilled water was used for its dilution. Methylene blue solution was then added to the dropper. A drop of the content (dye) was placed on the filter paper to check the end point of the filtration and the dye spread as a greenish blue or tint around the spot of dyed solids. The flask was shaken for 2 minutes when the blue ring or tint was detected around the spot. Another drop was placed on filter paper and the end point was reached when the blue appeared.

2.3. Untreated Mud Analysis

The aim of this experiment is to determine the ability of the locally prepared mud to satisfy American Petroleum Institute (API) standard specification for drilling mud prepared with bentonite. The mud for various sample was prepared by pouring 20.0g of the local clay into 350ml of distilled water, stirred for 25 minutes and allowed to stand for 16 hours. This is the required measurement for a standard raw mud preparation.

2.3.1. Mud Density Determination

The mud density experiment is to determine the weight of the mud per unit volume using baroid mud balance. Density of mud must be great enough to afford adequate hydrostatic head to prevent influx of formation fluid, but not so great to cause loss circulation, damage to the drilled formation, or decrease the rate of penetration (ROP). The instrument base for this test was set up until it is level and a clean dry cup was filled with the mud to be weighed. The lid was placed on the cup, and seated firmly but slowly with a twisting motion allowing some mud to escape through the hole in the cup. The excess mud was wiped from the outside of the cup and arm, knife set on the fulcrum and the sliding weight was moved along the graduated arm until the cup and arm are balanced. The density of the mud was then read at the left hand edge of the sliding weight and reported to the nearest scale division in Ib/gal.

2.3.2. Viscosity and Yield Point Determination

The aim of this test is to determine the plastic viscosity and yield point of the local clay samples using baroid viscometer. The viscosity of a fluid is simply the fluid resistance to flow, and for a particular drilling operation, the desired viscosity is influenced by several factors such as temperature, shear rate, pressure of the system etc. The yield point on the other hand is simply the resistance of the fluid to initial flow or the stress required to start fluid movement. The yield point is calculated in $Ib/100ft^2$ by subtracting the calculated plastic viscosity of the prepared mud sample in centipoise from the 300rpm reading. In this experiment, a recently agitated sample is placed in a thermos-cup and mud surface adjusted to scribed line on the rotor sleeve. The motor was started by placing the switch in the high speed position with the gear shift all the way down and waited for a steady indicator dial value for the 600RPM and 300RPM reading to be recorded. The same procedure was repeated for the same samples, treated with 2g PAC-R and 2g soda ash (Na_2CO_3).

2.3.3. Gel Strength Determination

The aim of this experiment is to determine the ability of the mud to suspend cuttings at static conditions and be able to release them at the surface. The sample was stirred at 600RPM for appropriately 15seconds and the gear assembly was slowly lifted to the neutral position and the motor shut off for 10seconds. The knob was flip switch to 3RPM and maximum deflection units in $^{ib}/_{100ft^2}$ were recorded as initial gel. This was repeated while allowing 10minutes, then the knob was slowly turned to 3RPM and the maximum deflection unit was read as the 10minutes gel.

2.3.4. Filtrate Loss Determination

The aim of this test is to measure the fluid loss and filter cake characteristics of the drilling mud prepared using local clay with baroid standard filter press. The cell was filled with mud samples to within ¼ inch of the top and the clip checked to make sure the gasket was in place. The top cap was placed on the cell and the unit was secured with T-screw. A dried graduated cylinder was place on the filter tube. The regular T-screw in its maximum outward position was used to open the valve of the cell. A pressure of about 100psi was applied to the filter cell rapidly screwing the regulator. Timing of the test was started immediately. The volume of the filtrate collected from the graduated cylinder was read after 5, 10, 15, 20, 25 and 30 minutes. The valve to the cell was closed at the end of 30 minutes and the safety blender valve opened. The cake thickness on the filter paper was measured using a ruler.

3. Results Discussion

The results and discussion on the laboratory investigation on the improvement of local (UMUNA) clay samples to ascertain if they are able to compete with the imported bentonite and measure up to the standard API specification for drilling mud production is presented.

Table 1. *API Bentonite Specification 13A Section9.*

Drilling Fluid Properties	Numerical Value Requirement
Moisture content	10% Max
Cation Exchange Capacity Range	70 - 130 Meq/ 100g Min
Screen analysis	4% max
Viscometer dial reading at 600rpm	30 cp
Mud Density range (Ib/gal)	8.65 – 9.60
Plastic Viscosity (cp)	8-10
Yield point ($Ib/100ft^2$)	3 ×Plastic viscosity
YP/PV ratio	3.0 Max
Fluid Loss (H_2O)	15.0 ml Max
N-Factor (Power law index)	1 Max
Filtrate	$13.5cm^3$ max, $<15cm^3$
Ph	9.5 Min – 12.5 Max
Montmorillonite	Ion capacity 70-130
Kaolite	3 – 15
Illite	10 – 40
Chlorite	Ion capacity 10 – 40
Attapulgite	Ion capacity 10 – 35

3.1. Grain Size Analysis

The results on the analysis carried out on particle size for the local clay samples to find out its ability to suspend solids are presented on Table 2. The results indicate that the clay percentage in the local mud for sample (X1) and (X2) is 40% and 55% respectively as against 85% for the imported bentonite. This is a far cry from that of the imported bentonite. The low clay content for the local mud samples may be indicative of the presence of quartz in the source location while the high clay content for the imported bentonite may be attributed to pre-importation treatment ensuing the removal of unwanted portion. Consequently, the UMUNA local clay should be mined properly before use. The obtained results for silt and gravel composition as represented on Table 2 indicates samples (X1) and (X2) having 45% silt, 40% silt and 3%, 1.50% gravel respectively as against 10% and 0% for the imported bentonite. This results suggests the presence of quartz which will affect the suspension capability of the clay. Study [7] has reveal that the poor physio-chemical performance of clays can be attributed to the presence of quartz which acts as abrasive. The sand content examination from Table 2 shows 12% and13.5% for samples (X1) and (X2) respectively. These obtained result fell short of the API numerical value standard specification that specifies 0.3% - 1.0% range. The sand content of the imported bentonite is 5%. This high sand content for UMUNA local clay samples is detrimental to efficient and effective drilling operation as sand particles can be highly abrasive with the resultant extreme wear of drill bits, pump parts and pipe connections. The presence of high sand content in a drilling mud could also result in thick filter cake been deposited on the walls of the hole thereby meddling with the smooth operation of the drilling tools.

Table 2. *Physical properties.*

Samples	Clay (%)	Sand (%)	Silt (%)	Gravel (%)	Moisture content (%)	Specific gravity	P^H	Plastic limit	Liquid Limit	Plasticity PI	Activity
S_1	40	12	45	3	13.20	2.98	7.80	61.60	82.00	20.40	0.51
S_2	55	13.5	40	1.50	14.60	3.19	7.60	64.10	93.00	28.90	0.52
BENTONITE	85	05	10	00	12.40	2.00	8.00	31.00	70.00	39.00	0.46

3.1.1. Moisture Contents

The results on the analysis carried out on moisture content, specific gravity and P^H for the UMUNA local clay samples are as represented on Table 2. The obtained result from Table 2 indicates that the UMUNA local clay sample (X1) and (X2) has moisture content of 13.2% and 14.6% respectively. These result indicates that the sampled muds were higher in moisture content and hence fell short of required API standard specification for drilling mud (i.e. 10% max). The moisture content value of the imported bentonite clay is 12.4% which also did not satisfy the required API standard specification for drilling mud. The activity values as represented on Table 2 shows that the sampled clay is of the inactive soil type and also a pure clay.

3.1.2. P^H Analysis

P^H value analysis help in defining the need for chemical control of the mud, and shows the presence of contaminants such as cement and gypsium. Its analysis is also imperative because its affects the solubility and dispersion of clays present in the mud. From Table 2, the UMUNA local clay samples (X1) and (X2) has P^H values of 7.80 and 7.60 respectively. The result indicates that the local clays was a little acidic, that is having the presence of acidic mineral in the clay samples, and hence fell short of API minimum numerical value standard (i.e. 9.5) specification for drilling mud. Consequently, there is need for the UMUNA local clay samples to be treated with basis additives such as lime, sodium hydroxide or any other additive that is capable of reducing the acidic content of the local UMUNA clay in order to satisfy the required API standard specification for drilling fluid. The P^H value of the imported bentonite mud sample was found to be 8.00 which also did not satisfy the required API standard specification for drilling fluid.

3.1.3. Specific Gravity

The specific gravity describes the density in air of a given fluid component compared to the density of equivalent volume of water at a definite temperature. The specific gravity result as obtained from Table 2 suggests that the UMUNA local clays generally have a high specific values (average of 3.09) which compares to that of Texas bentonitic clay [22] which has specific gravity value range of 2.50 to 2.80 and that as obtained from studies by Abdullahi et al., and Kearey with specific gravity values of 2.87 and 2.74 respectively [23-24]. The specific gravity result of the imported bentonite was found to be 2.00 which is suggestive of a low specific value. Clays used as drilling mud needs higher density in order to have control over pressure [25].

3.2. Chemical Analysis

The results on the chemical analysis carried out on the given clay sample to determine their percentage oxide and cation exchange capacity are shown on Table 3. The result from Table 3 shows the presence of silicate and aluminates which is primary evident for the composition of all clay types. The composition of oxide from the result of Table 3 is indicative that the clay samples are very similar to the general montmorillonite percentage oxide fraction. The presence of some percentage magnesium oxide also suggests that the clay samples belongs to the family of montmorillonite. The presence of traces of potassium oxide indicates the presence of traces of illites while that of ion oxide suggest the presence of feldspar and quartz which is not desirable for the plasticity of the clay. The Cation Exchange Capacity (CEC) result from Table 3 for the clay samples fell within the 70 – 150Meq/100g as also shown on Table 1. This result further suggests that the analysed clay samples are of the montmorillonite family, with traces of illite which is good for drilling mud production.

Table 3. *Chemical properties.*

Samples	Oxide (%)							Cation		
	S_1O_2	AL_2O_3	FE_2O_3	NA_2O	K_2O	CaO	MgO	Bentonite Equivalentb (Ib/bbl)	CEC (Meq/100g)	CEC Activity
S_1	84.80	10.83	0.26	0.16	0.04	0.12	0.20	7.5	75	1.88
S_2	90.20	5.86	0.20	0.28	0.04	0.57	0.34	8	80	1.45
BENTONITE	49.37	18.82	3.72	0.81	0.88	6.41	8.50	8.5	85	1.00

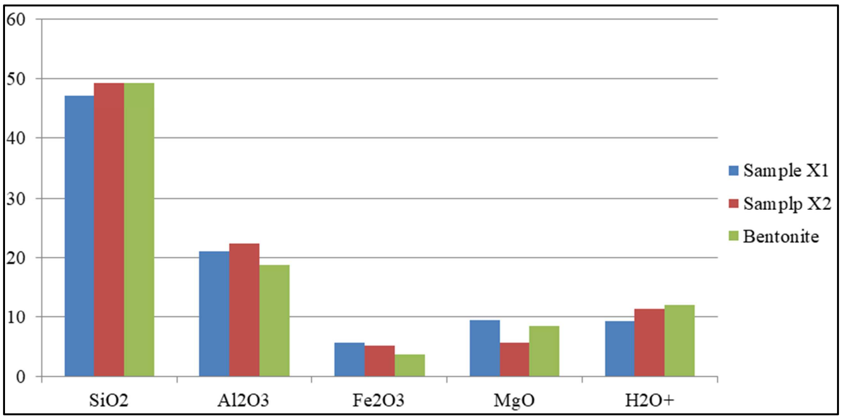

Figure 1. *Bar chart of the Percentage Oxide Content of Macro Clay Content.*

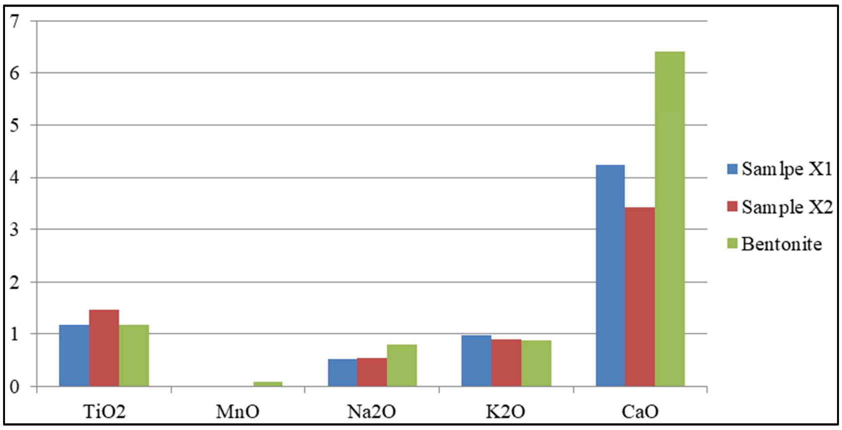

Figure 2. *Bar chart of Percentage Oxide Content of Micro Clay Mineral.*

3.3. Rheological Properties for the Untreated Clay Samples

The result on the analysis carried out on the local clay to determine its rheological properties are presented below.

3.3.1. Mud Density

The results on the investigation carried out on the clay sample to determine its mud density are shown on Table 4. The mud density for the local clays (X1 & X2;) shows that they compare with that of the imported bentonite and also averagely satisfy the minimum (8.65 – 9.60) AP1 standard specification as represented on Table 1.

Table 4. *Mud density.*

Samples	Weight (Ib/gal)
S_1	8.70
S_2	8.60
Bentonite	8.60

3.3.2. Filtration Properties of Untreated Clay Samples

The results on the analysis carried out on the given local clay samples to measure their gel strength, plastic viscosity (PV), yield point (yp), fluid loss, viscosity reading @ 600rpm and filter cake are shown on Table 5 and 6 respectively. The results from Table 5 shows that the obtained values for PV, yp, viscometer reading @ 600rpm and $^{yp}/_{pv}$ for samples (X1) and (X2) were generally far from comparing to API standard specification according to Table 1, consequently the need for improvement to meet the minimum required API standard specification for drilling mud. The obtained values also for the imported bentonite fail to meet the API standard specification. The obtained low values (7.9844) for the consistency index factor (k) is not desirable. This is because the consistency index factor (k) is synonymous to the true viscosity of Newtonian fluid. The result as obtained on Table 6 for fluid loss indicates that the local clay samples 90.20 (X1) and 100.00 (X2) were generally far from the standard set by American Petroleum Institute and is highly incomparable with 15.0 ml max API standard specification according to Table 1. This behaviour of the local clay samples leads to its improvement with a polymer and filtrate loss agent PAC-R. This additive was chosen because of its significant effect on the rheology and filtration properties. The obtained filter cake results as presented on Table 6 shows that the filter cake thickness for the local clay samples (X1) and (X2) approximates to that of the imported bentonite and the obtained lower values (a thinner cake) as against the 0.44 inches for the imported bentonite is more desirable thinner in drilling operation. This is because a thinner cake reduces the risk of pipe sticking hazard.

Table 5. *Gel strength, PV, YP, n-factor and K-factor for the untreated clay samples.*

RPM	600	300	200	100	6	3	10secs	10mins	PV (cp)	YP (Ib/100ft^2)	n-factor	k-factor
S_1	5	4	3	3	3	2	2	3	1	3	0.1505	7.9844
S_2	6	4	4	3	3	2	2	2	2	2	0.1505	7.9844
Bentonite	25	19	17	15	10	10	4	5	6	13	0.1394	40.6234

Table 6. *Fluid loss and Filter cake.*

Time (min)	0	5	10	15	20	25	30	Thickness (inches)
S_1	0.00	38.50	52.00	64.00	73.00	82.50	90.20	0.31
S_2	0.00	45.00	60.00	74.00	87.00	95.00	100.00	0.38
Bentonite	0.00	40.00	58.00	72.00	80.00	88.00	96.40	0.44

3.3.3. Improving the Rheology of the Local Clay Samples

The results obtained for PV, YP, $^{yp}/_{PV}$ and viscometer reading @ 600rpm from the addition of 2g of PAC-R to the prepared local clay samples (X1) and (X2) on Table 7 significantly improves their values to approximates to that according to Table 1, such that PV changing from approximately average of 2cp to 9cp, yp from 3Ibs/100ft^2 to 24Ibs/100ft^2, gel strength @ 10sec from 2Ibs/100ft^2 to 6 Ibs/100ft^2, gel strength @ 10mins from 3 Ibs/100ft^2 to 7 Ibs/100ft^2, $^{yp}/_{PV}$ from 2 to 3, n-factor from 0.1505 to 0.28, k-factor from 7.9844 to 29 and viscometer reading @ 600rpm from 6cp to 41cp thereby satisfying the required minimum API standard specification for drilling mud according to Table 1. Figure 3 shows the rheology of untreated mud sample and the imported bentonite while Figure 4 shows the rheology of the treated mud sample and the imported bentonite. The obtained result from the addition of 2g of PacR to the prepared local clay sample on Table 7 shows a great improvement on the PV, YP, YP/PV and viscometer reading @ 600rpm to compare to the required values according to Table 1 thereby satisfying the required API standard specification for drilling mud. Figure 4 shows the rheology of the treated mud sample and imported bentonite which clearly indicates significant improvement on the rheological properties of the locally sourced mud with reference to the base case according to Figure 3.

Table 7. *Gel strength, PV, YP, N-factor and K-factor for the beneficiated clay samples.*

RPM	600	300	200	100	6	3	10secs	10mins	PV (cp)	YP (Ib/100ft^2)	n-factor	k-factor
2gPacR+X1	38	30	25	16	13	9	6	7	8	22	0.2614	30.0588
2gPacR+X2	43	34	29	20	15	9	5	6	9	25	0.2886	28.7173

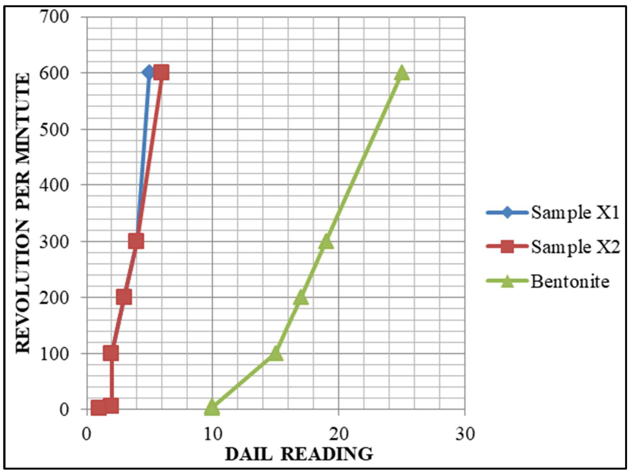

Figure 3. *Rheology of Untreated Mud Sample and Bentonite.*

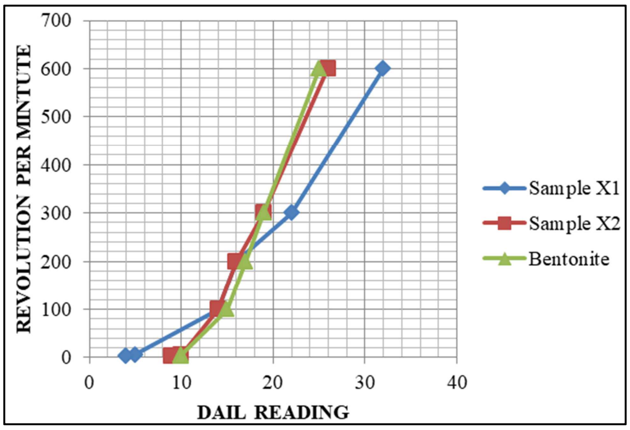

Figure 4. *Rheology of Treated Mud Sample and Imported Bentonite.*

4. Conclusion and Recommendation

4.1. Conclusion

With reference to experimental result obtained and discussed in this study, it was obvious that some of the examined parameters for the local Umuna clay samples such as mud density, power law flow behaviour index (n-factor), consistency factor (k), filter cake, specific gravity, Activity (A) and cation exchange capacity activity (CECA) all met the minimum API standard specification for drilling mud. While rheological parameters such as yield point (yp), plastic viscosity (PV), gel strength, viscometer reading @ 600rpm (Apparent Viscosity), $^{yp}/_{PV}$ and P^H fell short of meeting the minimum API standard specification for drilling mud and therefore needed improvement with an additives for favourable comparison with the imported bentonite and also to satisfy the required API standard specification for drilling mud. The presence of silt and gravel at a higher concentration is suggestive of the presence of quartz that affects the suspension capability of the clay while the high sand content will lead to deposition of thick filter cake on the walls of the hole that will impede smooth operation of the drilling tools.

The presence of silicate, aluminates, oxide compositions, magnesium and potassium as obtained from the chemical analysis result are primary evident that the Umuna local clay is good for drilling mud production. Similarly, the obtained activity average value of 0.51result suggests that the Umuna soil fell under the inactive soil type. The result obtained from cation exchange capacity (CEC) shows that the Umuna local clay deposit belongs to the montmorillonite clay family and has the propensity for slightly swelling due to its calcium content. More so, the analysed clay in its raw state cannot perform well as a drilling mud without beneficiation because of its relatively weak rheological and filtration properties. The general result obtained from physical analysis of the Umuna local clay samples shows that they compare fairly well with the imported bentonite on the moisture content, specific gravity and P^H values. The clay content of 45% for sample (X1) and 55.5%for sample (X2) as against the 85% for the imported bentonite is suggestive that the high clay content of the imported bentonite is due to pre-importation treatment resulting in the removal of all unwanted portion. The P^H of 7.80 for sample (X1) and 7.60 for sample (X2) as against the 8.00 for the imported bentonite, suggest that the local clay sample is slightly acidic and should be treated with basic additives such as NaoH that is capable of reducing the acidic content. From the result obtained in this study, it is concluded that with greater improvement through the addition of PacR, the rheological properties of the local clay were significantly improved to equate to that of the imported bentonite and satisfy the required minimum API standard specification for drilling mud production. Also agreed is that the Umuna local clay samples is very much adequate for effective hole cleaning. This is confirmed from the combination of high value of consistency index factor (k) and low value of the power law flow behaviour index factor (n) obtained. High values of consistency index factor (k) is suggestive of a high viscosity and fluids with such viscosity under near zero shear rate conditions offer significant improvement in hole cleaning efficiency. Similarly, the lower "n" value, the more non-Newtonian the mud, showing the property of shear thinning for drilling bits and nozzle cleaning.

4.2. Recommendation

Based on the reviewed literatures and results obtained from this study, the Nigerian government is encouraged to maintain its ban on importation of bentonite, while local production of additives that has similar characteristics like polyanionic cellulose must be encouraged. Also efforts should be directed towards exportation of local clay to boast our foreign earnings. This shall in the long run provide the much needed job opportunities for both the skilled and unskilled Nigerians.

References

[1] G. V. Chilingarian., P. Vorabutr., & D. Acosta. "Drilling and drilling fluid" Amsterdam, New York Elsevier Scientific Pub, New York, 767P, 1981.

[2] C. W. Davies."The swelling of bentonite and its control."Ind Eng. Chem., vol. 19, pp. 1350-1352, 1927.

[3] I. M. Onyejekwe., U. I. Duru., U. J. Obibuike., J. E. Odo., & N. Okoli "Characterization of local clay for drilling mud production" International Journal of Oil, Gas and Coal Engineering, vol. 10 (1), pp. 42-49, 2022.

[4] A. B. Oriji., F. S. Lawal., &Z. Bala. "Evaluating the efficiency of Nigerian local bentonite as an extender in oil well cementation" Chemical and Process Engineering Research, vol. 28 pp. 78-88, 2014.

[5] R. O. Afolabi., O. D. Orodu., & V. E. Efeovbokhan. "Applied clay science properties and application of Nigerian bentonite clay deposits for drilling mud formulation: recent advances and future prospects." Appl Clay Sci., vol. 143, pp. 39-49, 2017.

[6] O. A. Falode., O. A. Ehinola., & P. C. Nebeife. "Evaluation of local clay as oil well drilling fluids in Nigeria." Appl Clay Sci., vol. 39, pp. 19-27, 2007.

[7] T. U. Apugo-Nwosu., I. A. Mohammed-Dabo., A. S. Ahmed., G. Abubakar., A. S. Alkali., & S. I. Ayilara."Studies on the suitability of ubakala bentonite clay for oil well drilling mud formulation."Br J Appl Sci Technol, vol. 1 (4), pp. 152-171, 2011.

[8] O. Omole., J. O. Adeleye., O. Falode., S. Malomo., & O. A. Oyedeji. "Investigation into the rheological and filtration properties of drilling mud formulated with clays from Northern Nigeria." J Petrol Gas Eng., vol. 4 (1), pp. 1-13, 2013.

[9] O. E. Agwu., A. N. Okon., & F. D. Udoh. "A review of Nigerian bentonitic clays as drilling mud." In: SPE presented at SPE annual technical conference and exhibition, Nigeria, 2015.

[10] O. E. Akhirevbulu., C. V. O. Amadasun., M. I. Ogunbajo., & O. Ujuanbi. "The geology and mineralogy of clay occurrences around kutigi central bida basin, Nigeria." Ethiopian Journal of Environmental Studies and Management, vol. 3 (3), pp. 49-56, 2010.

[11] J. O. Adeleye., K. K. Salam., & I. A. Adetunde. "Analysis of rheological properties of treated Nigerian clay using factorial design." European Journal of Scientific Research, vol. 37 (3), pp. 426-438, 2009.

[12] A. A. Rabah & F. E. Abdelrahman. "Potential use of local bentonite as drilling fluid." International Conference on Chemical, Civil and Environment Engineering (ICCEE), Dubai, pp. 290-292, 2012.

[13] B. B. Dewu., S. A. Arabi., M. O. Oladipo., I. I. Funta., I. A. Mohammed-Dabo., & A. M. Muhammad. "Improvement of rheological properties of bentonitic clays using sodium carbonate and a synthetic viscosifier." Int. Arch. Appl Sci Technol, vol. 2 (2), pp. 43-52, 2011.

[14] A. S. Arabi. B. B. M. Dewu., M. O. A. Oladipo., & I. I. Funtua. "Mineralogy and rheology of raw activated turonian toconiacian clays from Benue trough, northern Nigeria." Egyptian Journal of Petroleum, vol. 27 (1), pp. 1-14, 2017.

[15] M. B. Oyeneyin & B, M. Rai. "Laboratory analysis of Nigerian clay for possible use as a drilling mud for the oil industry." 1982.

[16] O. O. James. "Beneficiation and characterization of a bentonite from North-Eastern Nigeria." Journal of the North Carolina Academy of Science, vol. 124 (4), pp. 154-158, 2008.

[17] P. N. Onwuachi. "Investigation into the use of local clays in drilling operations" Journal of Engineering and Applied Sciences, vol. 4 pp. 51-53, 2012.

[18] M. Omotoma., P. C. N. Ejikeme., & J. I. Ume. "Improving the rheological properties of water based mud with the addition of cassava starch." IOSR Journal of Applied Chemistry (IOSR-JAC), vol. 8 (8), pp. 70-73, 2015.

[19] O. Omole., S. Malomo., & S. Akande. "The suitability of Nigeria black soil clays as drilling mud clays." J. Appl Clay Sci, vol. 4, 357-372, 1989.

[20] A. O. Olatunde., M. A. Usman., O. A. Olafadehan., T. A. Adeosun., & O. E. Ufot. "Improving the rheological properties of drilling fluid using locally based materials." Petroleum & Coal, 54 (1), 65-75, 2012.

[21] I. Ikechi & B. K. Bright. "The use of periwinkle shell ash as filtration loss control agent in water-based drilling mud" International Journal of Engineering Research and General Science, vol. 3 (6), 375-381, 2015.

[22] O. M. Nweke., E. O. Igwe., & P. N. Nnabo. "Comparative evaluation of clays from Abakaliki formation with commercial bentonite clays for use as drilling mud." Afr. J. Environ. Sci. Technol, vol. 9 (6), pp. 508-518, 2015.

[23] A. S. Abdullahi., A. A. Ibrahim., M. A. Muhammad., M. Y. Kwaya., & Mustapha. "Comparative evaluation of rheological properties of standard commercial bentonite and locally beneficiated bentonitic clay from marine deposit in upper Benue basin, Nigeria." British J. Appl. Sci. Technol, vol. 1 (4), pp. 211-221, 2011.

[24] P. Kearey. "The new penguin dictionary of geology." 2nd Edition Penguin Books, London. 327pp.

[25] P. L. Hall. "Mechanism of over pressuring: an overview In: manning, D. A. C, Hall, P. L. Hughes, C. R., (Eds), Geochemistry of clay-pore fluid interactions. Chapman and Hall, London. pp. 265-309, 1993.