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Suitability Of Nigerian (Warsale) Bentonitic Clay For Oil Well Drilling Mud Formulation

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Abstract

Nigerian oil and gas drilling operations are highly depended on the imported bentonite for use as drilling fluid. The importation drains the nation's foreign reserve despite the fact that the country is equally blessed with huge deposit of this natural resource even though of inferior quality. This research characterized the Warsale montmorillonite clay from Dikwa formation. The clay was beneficiated (wet and dry) using Na_2CO_3 and the beneficiated drilling muds formulated. Drilling fluids formulated from the beneficiated clay did not possess the minimum rheological properties for use in oil and gas drilling operations. However, an improvement in rheological and filtration properties was observed when beneficiated with Na_2CO_3 and treated with CMC. The optimum values for plastic viscosity and gel strength were obtained at 6-10%wt Na_2CO_3 concentrations. The fluid loss of muds from Warsale bentonite was improved by about 50% when treated with Carboxy-Methyl-Cellulose (CMC) and meets the API requirements. The pH and sand content of the muds also fall within the API standards. The rheological and filtration properties of the local clay were found to be inferior to the reference Wyoming bentonite due to low concentrations of smectites and high levels of contaminants in the compositions of the local clays. However, this study shows that given the proper conditioning, beneficiated Warsale clay will give a good promise for drilling purposes at optimum sodium carbonate and additives concentrations.

Keywords: Drilling fluid, Warsale clay, Dikwa formation, Bentonite, Oil well

INTRODUCTION

The economy of Nigeria is highly dependent on the petroleum sector. Contribution of petroleum to the national revenue is about 70 percent, with more than 90 percent of foreign exchange earnings coming from oil exports. The petroleum industry is dominated by multinationals, with little participation by indigenous companies. In order to address this problem, the local content policy of the Federal government was initiated through N.N.P.C. Government has set a minimum target of 70 percent by 2010 (Ogbeide & Audu, 2006). Even though, the set target was not achieved but significant improvement was made in that respect. Drilling is the major activity in the upstream sector and the major component in the success of a drilling operation is the performance of a drilling fluid. The importance of clay and clay minerals in drilling industry is evident from the fact that clays are added to drilling fluids to build viscosity, thixotropy, and contribute wall building properties. The most commonly used clay in drilling fluid formulation is Bentonite. Bentonite having sodium (Na^+) as either the dominant or as an abundant exchangeable ion typically has very high swelling capacities and forms a gel-like mass when added to water. Bentonite in which exchangeable calcium (Ca^{++}) is more abundant than other ions has much lower swelling capacities than sodium varieties. Most of the marine shale found in Nigeria are enriched in calcium and mixed bentonite (RMRDC, 2010). Bentonitic clays exist in the north-east quadrant of Nigeria (Borno, Yobe, Gombe, Taraba, and Adamawa) where a probable reserve of more than 700 million tonnes has been estimated. The purpose of this research is to improve the calcium based Warsale bentonitic clay through chemical activation and investigate its rheological and filtration properties as a constituent of oil well drilling fluids. The present level of bentonite consumption for oil drilling was put at about 60,000 MT (RMRDC, 2010). There is an anticipated increase in consumption due to exploration works especially in Benue trough, Sokoto and Chad basin.

In a quest to provide substitute for the imported bentonite (mostly Wyoming) as component of the drilling fluid in the oil and gas industry in Nigeria, many researchers have investigated clays from various deposits across the nation. Folade et al (2007) evaluated Pindiga clay and improved its rheological properties obtaining a high 600rpm rheometer reading. (Okogbue, 2008) examined the geochemical characteristics of bentonitic clays from the South-eastern part of the nation and established their potential for use in drilling mud formulation. Yola (Adamawa State) montmorillonite clay was characterized and beneficiated. The results obtained revealed that the clay was Ca-based montmorillonite. Treatment improved its rheological behaviour but fell below the required standard for use in drilling mud formulation (James et al. 2008). Adeleye et al. (2009) treated locally sourced betonitic clay from the North-west of the country with locally sourced gum Arabic and sodium carbonate and analysed its rheological properties using factorial design. The work gave an express method of determining the required treatment of the local clay. Ubakala clay from Abia State was evaluated for its potential as drilling fluid component. Its beneficiation with Na_2CO_3 and improvement with CMC enhanced its plastic viscosity by up to about 1207% (Apugo-Nwosu et al. 2011). Extensive characterization, beneficiation and property improvement works were carried out on clays from Pindiga and Fika formations in the North-eastern part of the country (Dewu et al. 2011a; Dewu et al. 2011b; Arabi et al. 2011; Dewu et al. 2012). Local raw materials were employed to modify the pH of the mud by Okorie (2009).Water- and synthetic-based drilling muds were formulated using raw materials. The low value pH muds were improved to the required standard of between 9.5 and 12.5 (Ajugwe et al. 2012; Udoh & Itah, 2012). Unprocessed Ota (Ogun State) Kaolin was employed as a weighting additive in drilling fluid formulation (Adebayo & Ajayi, 2011). Recently, Bilal used many analytical techniques to characterize some local Bentonitic clays from Chad Basin and Benue Trough. Analytical methods such as Fourier transform infrared spectroscopy (FTIR) and scanning electron microscopy (SEM) were utilized (Bilal, 2015; Bilal et al. 2016; Bilal et al. 2017). This work seeks to increase the number of candidate Nigerian bentonitic clays that can be considered for oil and gas drilling fluid formulation.

MATERIALS AND METHODS

Sample Collection and Preparation

The raw clay sample was collected from a pit dug to a depth of about 3ft at Warsale village of Dikwa province of Borno State of Nigeria. Dikwa is situated 86km from the Borno State capital, Maiduguri and located at latitude 12.035 degrees north and longitude 13.92 degrees east. The Warsale village is located 30km eastwards of Dikwa town. About 30kg of the sample was crushed to finer particles and sun dried for three days to ease pulverising and sieving. The sample was then ground to powder with the aid of a jaw crusher and ball mill machine. It was then shaken with test sieve shaker to obtain 63µm particle size to suit API specifications for bentonite

Sample Characterization

Determination of Chemical and Mineralogical Composition

Chemical and mineralogical compositions of the raw Warsale clay sample was determined using X-ray fluorescence, XRF (model Pan analytic B.V PW4030/45B) and X-ray Diffractometer (model Schmadzu 6000) respectively. Wyoming bentonitic clay was used as the standard (control) hence it was equally characterized for the chemical and mineralogical composition. The hydrometer method was used for *particle size distribution analysis* of the clay samples whereas, the Bentonite Laboratory Manual of the British Geological survey agency (Inglethorpe, 1993) was used for cation exchange capacity (*CEC)* determination.

Chemical Beneficiation (Activation)

Chemical activation was carried out on the 63µm fraction obtained above and the predominant calcium bentonite was converted to sodium bentonite through ion exchange using sodium carbonate as the activating agent. Two modes (wet and dry) of beneficiation were applied for comparison purpose. In the wet technology, 2 to 14%wt. of Na_2CO_3 were added to the bentonite powder suspension in water at intervals of 2%. The suspension was stirred vigorously and allowed to stand for 2 hours in order to ensure that proper ion exchange had taken place. The beneficiated samples were oven dried to reduce moisture content and ground to powder using ball mill. The ground sample was sieved again to obtain 63µm fraction.

The dry technology was carried out by dry blending the sodium carbonate with the raw bentonitic clay sample powder using the above concentrations. It is usually considered that ion exchange takes place during clay hydration in water after formulation of the mud.

Drilling Mud Formulation

In order to formulate the sample mud, 24.5g of the beneficiated bentonitic clay at the various concentration of the sodium carbonate was weighed with the aid of an electric weighing balance. The samples were poured into the mixer cups containing 350ml of water, thoroughly mixed and then agitated vigorously with the aid of Hamilton Beach Mixer for 10 minutes to obtain a homogeneous mixture and improve hydration of the clay.

In order to further improve the rheological and filtration properties of the formulated sample muds, 1g of carboxymethyl cellulose (CMC) was separately added to the mud samples with a view to ascertain their effectiveness on the mud samples. The mixture of clay, water and the additive was thoroughly mixed and the homogeneous mixture allowed to age for 24 hours. The control mud was formulated using Wyoming bentonite as above. Filtration and rheological tests were carried out on the aged muds.

Drilling Mud Testing Procedures

Plastic Viscosity, Apparent Viscosity, Yield Point and Gel Strength Determination

Ofite 900 model viscometer was used for these measurements. The procedure provided by the manufacturer was followed. The sample mud was poured in to the sample cell and the rotor sleeve of the viscometer was immersed in the mud exactly to the scribed line. The mud was allowed to stabilize for ten seconds before the dial reading at 600rpm (θ_{600}) was taken and recorded from the screen. After additional ten seconds the dial reading at 300rpm (θ_{300}) was displayed by the viscometer on the screen; it was also taken and recorded. The viscosity values obtained from these measurements are in centipoises (cP). After additional ten minutes and ten seconds, the instrument displayed plastic viscosity (PV), yield point (YP), next ten seconds gel strength and next ten minutes gel strength. All the values were recorded. The plastic viscosity is in cP, the gel strength and yield point in pounds per hundred feet square (lb/100ft^2). The apparent viscosity is the dial reading at 600rpm divide by 2 and it is expressed in cP.

Fluid Loss Determination

Low temperature API filter press was used for fluid loss or water loss measurement. The sample mud was poured in to the API filter press cell (not more than ¾ cup). The filter cell was then placed in the frame. The top cap was placed to ensure that the gasket was firmly secured in place. The top cap was held tight with the screw and a graduated cylinder placed under the drain tube to collect the filtrate. Having ensured that the unit was tight, 100psi (690kpa) pressure from the mini carbon dioxide cartridge was applied to the filter cell through a regulator (in about 30 seconds). A stop watch was set for 30 minutes. The test period begins at the time of pressure application. The volume of the filtrate or fluid loss was then read off from the graduated cylinder and recorded in millilitres (ml). After making sure that all the pressure has been relieved, the cell was removed from the frame, disassembled and the mud discarded. The filter paper was then replaced.

Sand Content Determination

Sand content of the mud samples were estimated by the use of Baroid sand screen set. The set consisted of a 200-mesh sieve 2.5in.(63.5mm) in diameter, a funnel to fit the screen and a glass measuring tube. The glass measuring tube was filled with the sample mud to the indicated mark. Water was added to the next mark and the mouth of the tube closed and shaken vigorously. The mixture of mud and water was poured out through the screen, and the liquid passing through the screen was discarded. More water was added to the tube, shaken, and again

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poured on to the screen. This was repeated until the water passing through the screen was clear. The sand retained on the screen was washed to free it of any remaining mud. The quantity of sand that settled in the calibrated tube was then read and recorded as the sand content of the mud in percentage by volume of the mud.

RESULTS AND DISCUSSION

Bentonitic Clay Samples Characterization

Chemical Analysis

Table 1 presents the chemical composition of the raw Warsale bentonitic clay and Wyoming bentonite as obtained using an XRF analysis. It can be observed from the table that the Al_2O_3/SiO_2 was approximately 1/3 in Wyoming bentonite as expected of smectites, which is the main component of bentonites. This ratio was higher in Warsale bentonitic clay. The obtained value is in agreement with the results reported by Falode et al (2007), Deer et al (1992) and Kirk-Othmer (1980). It can also be noticed that the Wyoming bentonite has higher percentage of Na_2O (3.22%) than the Warsale bentonitic clay (0.10%) which is an indication that the Wyoming bentonite consist of sodium montmorillonite. Warsale bentonitic clay however has higher percentage of CaO (2.02%) when compared with Na_2O present (0.10%) which indicates the presence of calcium montmorillonite as expected of Nigerian bentonitic clays (Falode et al. 2007). The Warsale bentonitic clay sample showed high presence of K_2O than the Wyoming bentonite. This causes less hydration of clay particles in water. The potassium cation is thought to prevent hydration of clays due mainly to its size. The potassium cation hydrates very little and is almost the same diameter as the spacing between the oxygen in the outer silica tetrahedrons of the clays (Darley & Gray, 1988). It was also observed that the Wyoming bentonite is richer in MgO, which is commonly used to enhance gel strength as explained by Falode et al (2007). The Wyoming bentonite also shows high percentage of BaO, an indication of the presence of Barite ($BaSO_4$), a non clay mineral.

Table 1: Chemical Composition of the Bentonitic Clay Samples

Chemical compound	Wyoming (%)	Warsale (%)
Al_2O_3	14.2	19.20
SiO_2	43.6	48.09
Na_2O	3.22	0.10
K_2O	0.93	1.81
CaO	7.05	2.02
TiO_2	1.30	2.07
MnO	0.11	0.11
Fe_2O_3	14.50	18.18
NiO	0.02	0.02
CuO	0.14	0.07
MgO	2.40	1.24
BaO	11.0	ND
PbO	0.06	ND
RuO	0.56	ND
ZnO	ND	0.04
SrO	ND	0.05
ZrO_2	ND	0.11
Cr_2O_3	ND	0.07
Others	ND	6.82
TOTAL	100.00	100.00

Mineralogical Analysis

X-ray diffraction (XRD) analysis was carried out on the clay samples in order to ascertain their mineralogical composition. This is usually the most common analysis carried out to determine the type of minerals in clay deposits. The Wyoming bentonite sample composed mainly of smectite (montmorillonite), sanderite, barite, morimotoinite and muscovite (Table 2). Other minerals detected in trace amounts are zinc arsenate, behierite and ammonium chlorate. The smectite dominates the Wyoming bentonite (about 50%) as expected. The smectite clay mineral is responsible for the swelling and high rheological and filtration properties of the drilling fluids. The Wyoming bentonite also shows high amount of barite (about 20%), a non clay mineral used in drilling fluid as a weighting agent to increase the density of the drilling fluids. This could indicate that the Wyoming bentonite might have been treated with barite. It was also observed that the local bentonitic clay sample composed mainly of

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smectite, quartz, kaolinites, gismondine and serpentine.

Minerals like berlinite, marshite and bariandite were detected in small amounts. Unlike Wyoming bentonite, where the dominant mineral is smectite, in the Warsale clay sample, smectite and gismondine were found to be the dominant minerals. This might be responsible for the inferior performance of this local clay when compared to Wyoming in terms of drilling application. Gismondine, a non-clay mineral, which belongs to the zeolite group is the dominant mineral in the composition of the local bentonitic clay.

Table 2: Summary of Mineral Composition of the Clay Samples

***WYOMING* BENTONITE**		***WARSALE* CLAY**	
Mineral	**Composition (%)**	**Mineral**	**Composition (%)**
Smectite	50	Smectite	33.26
Barite	19.4	Quartz	9.43
Sanderite	10	Kaolinite	5.35
Morimotoinite	7.9	Gismondine	35.31
Muscovite	6.9	Serpentine	6.09
Others	5.8	Others	10.56

Particle Size Distribution

Basic particle size distribution analysis was conducted in order to ascertain the percentage of particle size that constitute the clay sample (sand, silt and clay). Table 3 presents the particle size distribution of the Wyoming and Warsale bentonitic clay samples. From the table it can be observed that, the percentage composition of clay, silt and sand in the Wyoming and Warsale samples are 47, 33 and 20 and 65, 16 and 19 respectively.

Table 3: Particle Size Distribution of the Clay Samples

Sample	**40 seconds reading**	**2hours reading**	**% Clay** (<0.002mm)	**% Silt** (0.002-0.05mm)	**% Sand** (0.05-2mm)
Warsale	40	32	65	16	19
Wyoming	33	23	47	33	20

The percentage clay of the Wyoming sample is less when compared with the local clay samples, this may not be unconnected with the presence of high amounts of non-clay minerals like barite in the composition of the Wyoming clay as shown by the result of the mineralogical analysis. The sand content of all the muds was found out to be less than 0.8% which is below the maximum of 2% based on API standard

Cation Exchange Capacity

The CEC is the total amount of cations adsorbed expressed in milliequivalents per 100g of dry clay. High CEC will have a positive impact to the hydration and swelling capability of the clay suspensions. Table 4 shows the CEC values of the investigated samples. The CEC of the Wyoming bentonite was found to be 86meq/100g which falls within the general range of (80-100) meq/100g (Table 4). This agrees with the values reported by Falode et al (2007). It can be seen from the table that, the untreated local bentonitic clay sample has low CEC, but when treated with 6% Na_2CO_3 about 50% increase in CECs was observed. This is still much less than the CEC value of Wyoming bentonite. The CEC of clay and the species of cations in the exchange positions are a good indication of the colloidal activity of the clay. Clay such as smectite that has high CEC swells greatly and forms viscous suspensions at low concentrations of clay particularly when sodium is in the exchange positions.

Table 4: Cation Exchange Capacities of the Clay Samples

Parameter	Untreated Warsale	Treated Warsale with 6% Na_2CO_3	Wyoming
CEC, meq/100g	33	50	86

Rheological Properties of the Sample Muds

Variation of Na_2CO_3 Concentration in the Mud with the Dial Reading at 600rpm (θ_{600})

The θ_{600} measurements on the sample muds beneficiated with Na_2CO_3 showed increase in the dial reading at 600rpm as concentration of Na_2CO_3 increased from 2% to 8% for the clay sample muds. The highest value recorded was 7.8 at 8% Na_2CO_3 concentration. This is the optimal value for the clay sample muds without treatment. Fig.1 represents the plot of θ_{600} against the Na_2CO_3 concentration for the clay sample muds.

When the sample muds were treated with 1g of sodium carboxymethylcellulose (CMC) the values increased to the maximum of 18.1 at 8% Na_2CO_3 concentration for Warsale sample muds as shown in Fig. 2. This indicates that the sodium carboxymethyl cellulose improved on the dial reading at 600rpm (θ_{600}).

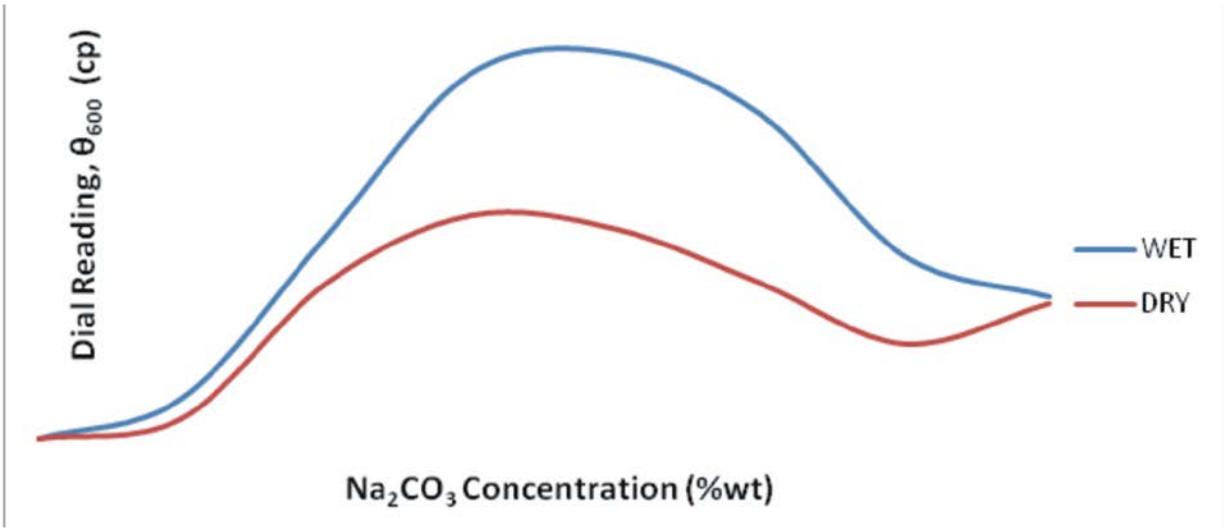

Fig. 1: Variation of Na_2CO_3 Concentration with Dial Reading for Warsale Muds without Treatment

The CMC polymer chain does the work of binding the flocculating particles in the mud together and the presence of Na_2CO_3 aided the process. The wet method of beneficiation proved better than the dry technology method, as can be seen from the result.

Effect of Na_2CO_3 Concentration on Plastic Viscosity

The commonly used direct indicating viscometer was specifically designed to facilitate the use of the Bingham plastic model. The PV is the slope of the Bingham plastic line. Plastic viscosity is used as an indicator of the size, shape, distribution and quantity of solids, and the viscosity of the liquid phase. The effect of Na_2CO_3 indicates an upward trend in plastic viscosity as the concentration of Na_2CO_3 present in the mud increased from 2% to 8%. The highest plastic viscosity was observed at 6%-8% Na_2CO_3 for the untreated sample muds and treated with CMC. Figs 3 & 4 show this trend. This shows that beneficiation improved the rheological properties of calcium based clays as demonstrated by Falode et al (2007) and Song et al (2005). The PV depends largely on the bulk volume of solids in the mud and on the viscosity of suspending liquid. The Na_2CO_3 converts the

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calcium bentonite to sodium bentonite and hence causes dispersion of clay. The dispersion is commonly used to describe subdivision of particle aggregates in a suspension and subdivision of clay platelet stacks as a result of electrochemical effect. The dispersion increased the PV of the sample muds until an equilibrium is reached where the PV is at its maximum value i.e. at optimum concentration of Na_2CO_3.

Since the dial reading at 600rpm is analogous to shear stress and the relationship between shear stress and plastic viscosity is proportional, increase in θ_{600} results to increase in PV. The wet method also, proved more effective than the dry technology in terms of PV improvement.

Effect of Na_2CO_3 Concentration on Gel Strength

Gel strengths indicate the gelation or thixotropic properties of a drilling fluid and are the measurements of attractive forces under static conditions in relationship to time. Yield point, conversely, is a dynamic property. However, gel strength and yield point have a proportional relationship. Increase in one may results in increase in the other and vice versa. Figs 5 and 6 represent variation of Na_2CO_3 Concentration with gel strength of the muds treated with CMC and untreated muds for the sample clay. An increase in gel strength and yield point was observed when the Na_2CO_3 concentration in the mud increased from 4% to 8% for the sample muds

Further reduction in gel strength and yield point was observed from the 8% to 14% Na_2CO_3 concentration for the sample muds. The same trend was observed for muds treated with 1g CMC. Gel strength and yield point depend on the presence of colloidal clays, and contamination by inorganic salts.

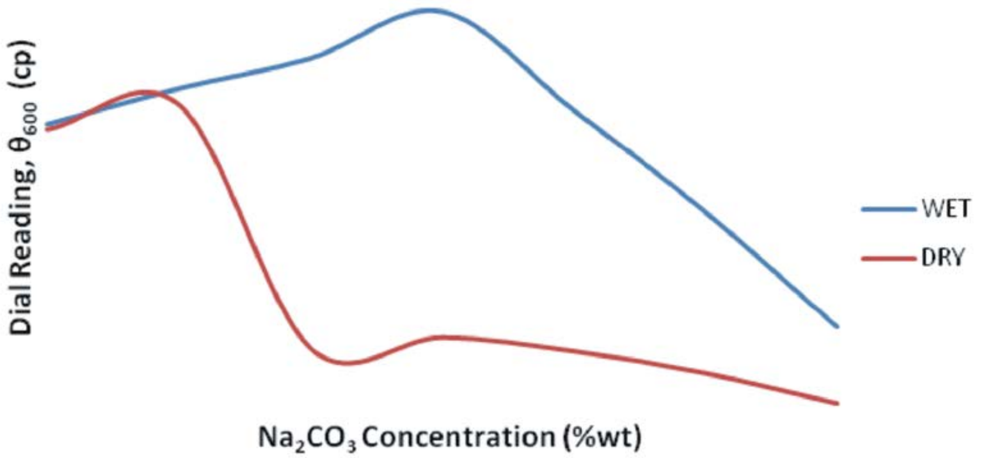

Fig. 2: Variation of Na_2CO_3 Concentration with Dial Reading a 600rpm For Warsale Muds Treated with 1g of CMC

Gel strength is due to flocculation and aggregation of clay platelets. Flocculation is limited to lose association of clay platelets which forms flocs or gel structures, while aggregation refers to the collapse of the diffuse double layers and the formation of aggregates of parallel platelets. Where flocculation causes an increase in gel strength, aggregation causes a decrease because it reduces the number of units available to build gel structures and the surface area available for particle interaction. When the Na_2CO_3 concentration was increased from 2% to 10% gel strength continues to rise because of flocculation, but the particles reach equilibrium positions slowly (at 10%). Evidently, the attractive and repulsive forces are nearly in balance. Further increase in Na_2CO_3 concentration led to decrease in gel strength which can be attributed to the formation of aggregates of parallel platelets as explained by Darley and Gray (1988). Ideally, the gel strength should just be high enough to suspend barite and drill cuttings when circulation is stopped. Additionally, initial gel strength in a weighted mud system must be sufficient to prevent settling of weight materials.

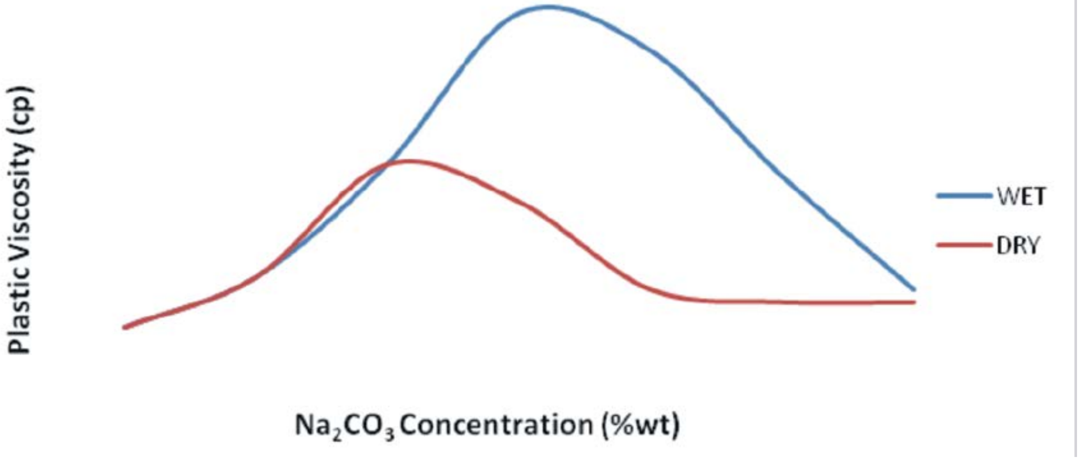

Fig. 3: Variation of Na_2CO_3 Concentration with Plastic Viscosity for Warsale Muds without Treatment

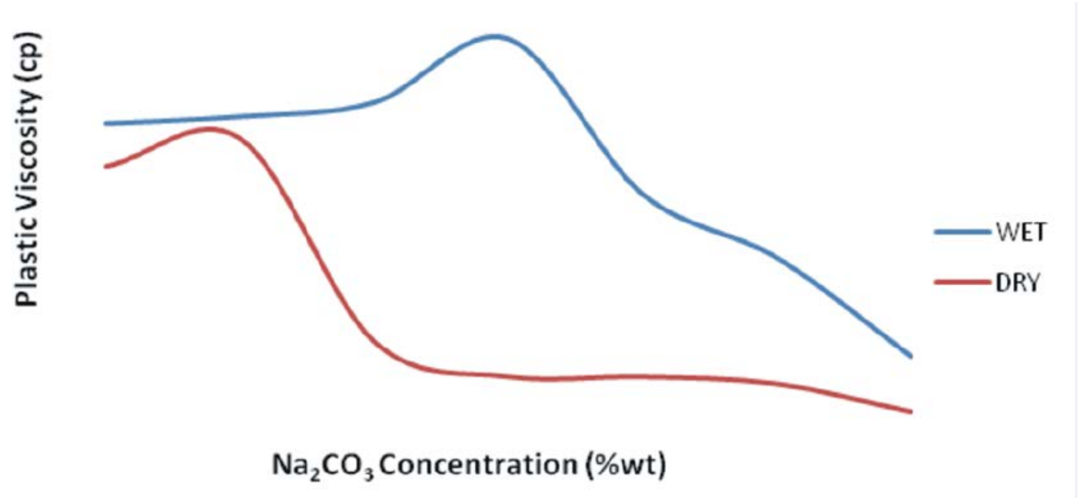

Fig. 4: Variation of Na_2CO_3 Concentration with Plastic Viscosity for Warsale Muds Treated with 1g of CMC

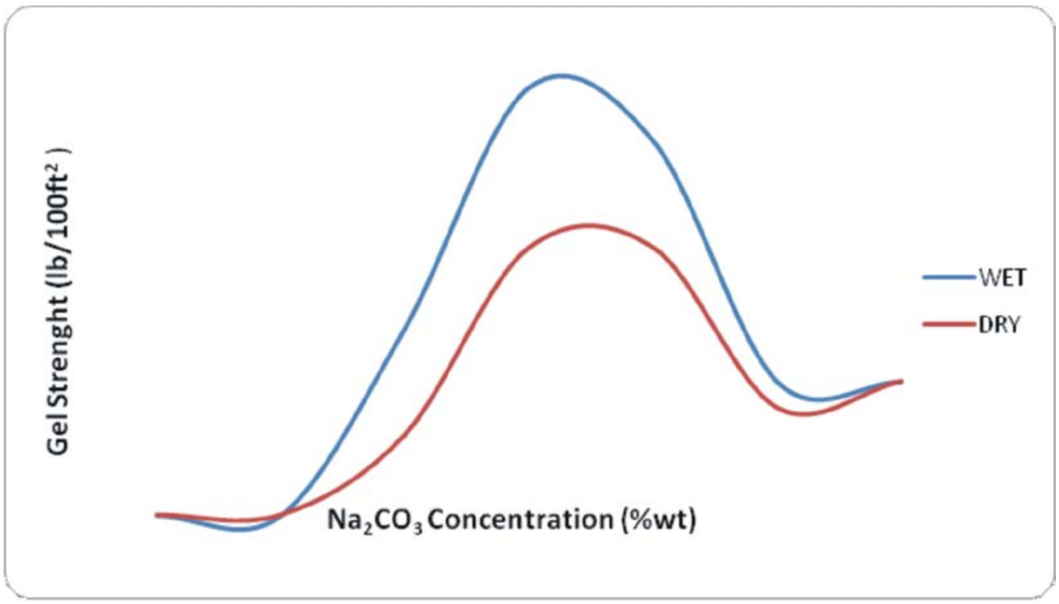

Fig. 5: Variation of Na_2CO_3 Concentration with Gel Strength for Warsale Muds without Treatment

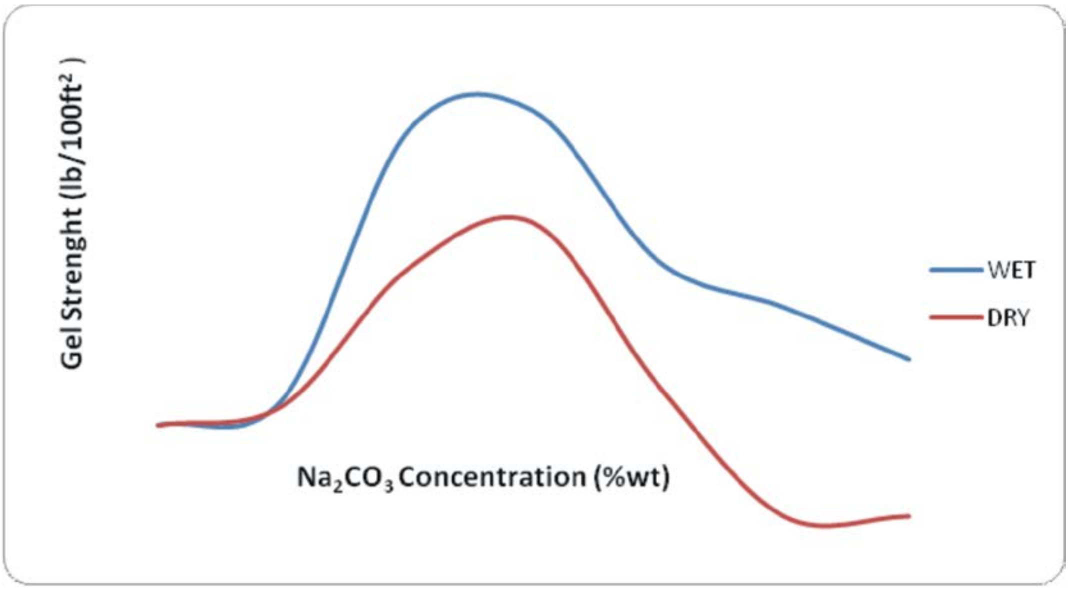

Fig. 6: Variation of Na_2CO_3 Concentration with Gel Strength for Warsale Muds Treated with 1g of CMC

Filtration Properties of the Sample Muds

The ability of the mud to seal permeable formations exposed by the bit with a thin, low permeability filter cake is another major requirement for successful completion of the hole. Because the pressure of the mud column must be greater than the formation pore pressure in order to prevent the inflow of formation fluids, the mud will continuously invade permeable formations if a filter cake is not formed.

Effect of Na_2CO_3 Concentration on Fluid Loss

The fluid loss properties of a mud indicate how well the mud forms a seal against permeable formations. Fig. 7 illustrates the fluid loss behaviour of the sample muds at 6%, 8% and 10% Na_2CO_3 concentration. The muds without treatment displayed poor filtration properties, but when treated with CMC a dramatic improvement in fluid loss was observed. See Table 5 for API specifications for drilling fluids. 50% reduction in fluid loss was observed when treated with 1g CMC for all the sample muds tested. The reduction was more pronounced at lower Na_2CO_3 concentration. The CMC being a synthetic polymer does the work by using its polymer chain to bind the flocculated particles together in the presence of salt concentration.

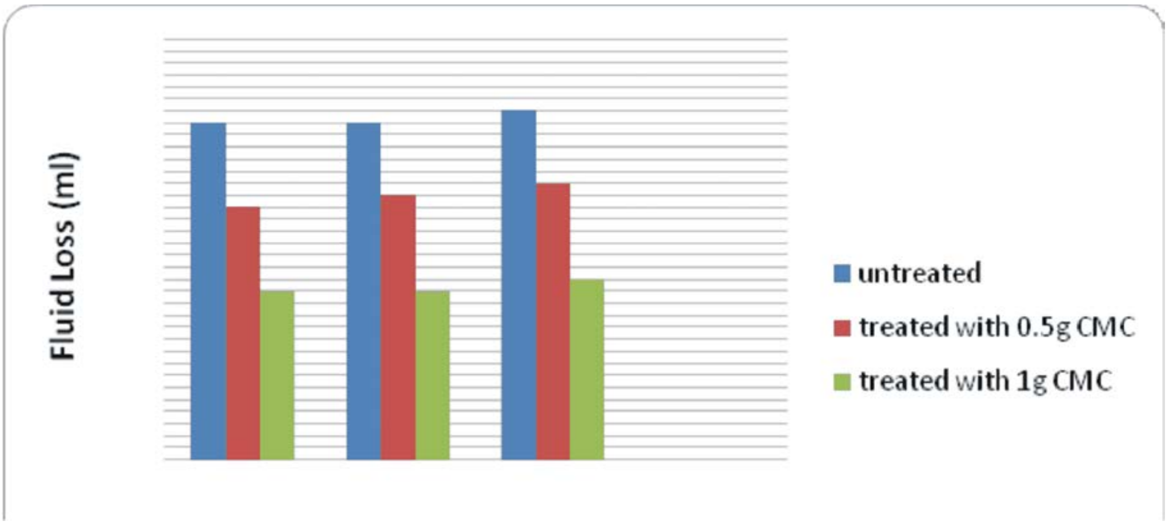

Fig. 7: Filtration Properties of Warsale Sample Muds treated with CMC

This indicates that the CMC is a good filtration control agent. The result obtained corroborates the work of Falode et al (2007) who improved on the filtration properties of Pindiga clay mud using starch. High fluid loss mud will build up a thicker, sticker wall cake that is likely to lead to problems such as differential sticking. This phenomenon occurs when part of the drill string bears against the side of the hole while drilling, and erodes away part of the filter cake. When rotation of the pipe is stopped, the part of the pipe in contact with the cake is isolated from the pressure of the mud column, and subject only to the pore pressure of the filter cake. The differential pressure thus created may be great enough to prevent the pipe from being moved. Furthermore, filtration properties must be controlled in order to prevent thick filter cakes from excessively reducing the gauge of the borehole. Ideally the mud should build up a thin, tough, and impermeable cake fairly quickly.

Table 5.0: API Standards for Drilling Fluids

Parameter	Specification
Dial Reading at 600rpm	30cp minimum
Plastic viscosity	8cp-10cp
Yield Point	3* PV maximum
Fluid Loss	15ml/30 minutes
Sand Content	(1-2%) maximum
pH Level	8.5-12.5
Moisture Content	10% maximum
YP/PV	3

CONCLUSION

Chemical activation of the local bentonitic clay was carried out using Na_2CO_3 as the activating agent. Chemical and mineralogical compositions analyses of the clay samples were undertaken using the X-ray fluorescence and X-ray diffraction methods respectively. Cation exchange capacity and particle size distribution analysis were equally conducted using the methylene blue test and hydrometer method respectively. Rheological and filtration tests were conducted on drilling fluids formulated from the Warsale bentonitic clay sample. The following conclusions can be made from this work.

1. The sample muds formulated with the beneficiated Warsale bentonitic clay showed little improvement on flow properties and falls short of API standard. However, improvements in rheological and filtration properties were observed when treated with CMC.
2. The optimum values for yield point and plastic viscosity were obtained at 6% and 8% Na_2CO_3 concentration for the Warsale sample mud, while the gel strength was obtained at 10%.
3. From the results obtained, the yield point and gel strength of the sample muds formulated using Warsale bentonite are low. The plastic viscosity of the sample muds from the Warsale local clay when treated with CMC meets the API standards required for drilling fluid. Evidently, muds from Warsale bentonitic clay displayed poor filtration properties, but when treated with CMC the filtration property was improved and found to be in consonance with API standards. In all cases the wet method of beneficiation gave a better results than the dry technology method.
4. Treatment of the sample muds with sodium carboxymathyl cellulose (CMC) improved both rheological and filtration properties, and therefore confirmed that CMC is a good rheological and filtration control agent.

REFERENCES

Adebayo TA, Ajayi O. (2011). Unprocessed Ota Kaolin As A Weighting Additive In Drilling Fluid . Asian Transactions on Engineering 1(3).

Adeleye JO, Salam KK, Ayetunde IA. (2009). Analysis of Rheological Properties of Treated Nigerian Clay using Factorial Design. European Journal of Scientific Research 37(3), 426-438.

Ajugwe C, Oloro J, Akpotu D. (2012). Determination Of The Rheological Properties Of Drilling Fluid From Locally Sourced Clay From Various Geographical Areas. Journal of Engineering and Applied Science 4, 38-49.

Apugo-Nwosu TU, Mohammed-Dabo IA, Ahmed AS, Abubakar G, Alkali AS, Ayilara SI. (2011). Studies on the Suitability of Ubakala Bentonytic Clay for Oil Well Drilling Mud Formulation. British Journal of Applied Science and Technology 1(4), 152-171.

Arabi AS, Ibrahim AA, Muhammad AM, Kwaya MY, Mustapha S. (2011). Comparative Evaluation of Rheological Properties of Standard Commercial Bentonite and a Locally Beneficiated Clay from Marine Deposit in Upper Benue Basin, Nigeria. British Journal of Applied Science & Technology 1(4), 211-221.

Bilal S, Mohammed-Dabo IA, Dewu BBM, Momoh OR, Funtua II, Oladipo MOA, Arabi AS, Muhammad T. (2015). Effect of Quartz (free silica) Removal on the Quality of Nigerian Bentonytic Clays for Application in Drilling Fluid Formulation. Journal of Experimental Research. 3;(2): 98-101.

Bilal S, Mohammed-Dabo IA, Dewu BBM, Momoh OR, Aminu AH, Abubakar U, Adamu MS, Mashi AH. (2016). Determination of Morphological Features and Molecular Interactions of Nigerian Bentonytic Clays using Scanning Electron Microscopy (SEM). Bayero Journal of Pure & Applied Sciences 9(2), 279-285.

Okugbue CO, Eneleri GE. (2008). Geochemical and Geotechnical Characteristic and the Potential for use in Drlilling Mud of some Clay Bodies in Southestern Nigeria. Journal of Mining and Geology 44:(2).

Darley HCH, Gray GR. (1988). Composition and Properties of Drilling and Completion Fluids, 140-183. Houston: Gulf Publishing.

Deer WA, Howie RA, Zussman J. (1992). An Introduction to the Rock-Forming Minerals, 279-606. London: Longman.

Dewu BBM, Oladipo MOA, Funtua II, Arabi AS, Mohammed-Dabo IA, Muhammad AM. (2011b). Improvement of Rheological Properties of Bentonytic Clays using Sodium Carbonate and Synthetic Viscosifier. International Archive of Applied Science & Technology 2;(2): 43-52.

Dewu BBM, Oladipo MOA, Funtua II, Arabi AS, Mohammed-Dabo IA, Muhammad AM, Hamidu I. (2011a). Evaluation and Beneficiation of Bentonytic Clays from Pindiga Formation in Benue Trough. American Journal of Engineering & Applied Sciences 4;(4): 497-503.

Dewu BBM, Oladipo MOA, Funtua II, Arabi AS, Mohammed-Dabo IA, Muhammad AM. (2012). Evaluation of Rheological and Other Physical Properties of Bentonitic Clays From Fika Formation in Parts of North-Eastern Nigeria. Petroleum Technology Development Journal. 2;(1): 12-23.

Falode OA, Ehinola OA, Nebeife PC. (2007). Evaluation of Local Bentonytic Clay as Oil Well Drilling Fluids in Nigeria. Applied Clay Science 39, 19-24.

Inglethorpe SDJ, Morgan DJ, Highley DE, Bloodworth AJ. (1993). Industrial Minerals Laborotory Manual;BENTONITE. Technical Report WG/93/20 Mineralogy and Petrology Series. London: British Geological Survey Agency.

James OO, Adeniran FAA, Adebunmi EO, Adekeye JID. (2008). Beneficiation and Characterization of Bentonite from North-Eastern Nigeria. Journal of North Carolina Academy of Science 124(4), 154-158.

Kirk-Othmer. (1980). Encyclopaedia of Chemical Technology, Vol.3. New York: John Wiley & Sons.

Ogbeide, S., & Audu, T. (2006). The Relevance of Local Content in the Development of Nation's Economy. Petroleum Training Journal. 2;(1):60-64.

Okorie OM. (2009). Modification of Drilling Fluid pH with Local Nigerian Additives. Petroleum Technology Development Journal. 2;(1): 1-11.

RMRDC. (2010). Non-Metallic Mineral Endowments in Nigeria: Bentonite. Abuja: Raw Materials Reserch and Development Council.

Sabiu B. (2017). Determination of Montmorillonite Content in Nigerian Bentonytic Clays using Fourier Transform Infrared Spectroscopy (FTIR). Journal of Experimental Research 5(2), 27-34.

Song S, Zhang Y, Liv T, Zhaw M. (2005). Process for Upgrading Calcium Bentonite. Journal of Dispersion Science & Technology. 20;(3): 375-379.

Udoh FD. (2012). Formulation of Synthetic-Based Drilling Fluid Using Palm Oil Derived Ester. Journal of Microbiology, Biotechnology & Environmental Science. 14;(2):175-180.