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Performance Evaluation Of Locally Sourced Additives For Water Based Drilling Fluid Formulation

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ABSTRACT

In pursuit of providing an indigenous substitute for foreign bentonite as a drilling fluid in oil and gas industry in Nigeria, local clay was obtained from Buan-khana, Rivers State, Nigeria. Also used were two local viscosifiers, Daterium microcarpum and Brachystegia eurycona flour. Water-based mud was formulated from the clay and its properties determined and compared with those of a standard choice mud produced from imported materials. The result showed large difference in the formulated drilling fluids rheological properties and the pH values. Addition of the local viscosifiers; Daterium microcarpum and Brachystegia eurycona respectively at a concentration of 7.5g to 350ml of the local mud yield a noticeable improvement in the rheological properties of the formulated mud. When beneficiated with 1.0g of soda ash (Na_2CO_3), the mud pH value increased by 38% from an initial value of 5.60 to 9.0 while the rheological properties increased by over 220%. This implies that, at considerable concentration, the Buan clay showed good rheological properties that would compare favorably well with those of imported clay with either Daterium microcarpum or Brachystegia eurycona and soda ash (Na_2CO_3). Meaning a possible drilling fluid could be produced from Buan-Khana clay and Daterium micropum or Brachystegian eurycona.

Key Words: Buan Ken-Khana Ogoni clay, Beneficiation, viscosifiers, Rheological properties

1. INTRODUCTION

In Nigeria drilling for hydrocarbon had recorded a resonating success following the discovery of oil reserves at Oloibiri in present day Bayelsa State in 1956. Drilling is the process of creating a passage for the discovered oil hydrocarbon to be produced to the surface. It involves the boring of the earth's crust to thousands of feet to access the underground accumulation of the hydrocarbon. Drilling fluid consists of diverse phases (solid, liquid, gas) or components (chemicals, water, or oil and clay materials) that sustain drilling operation. The use of drilling fluids are as far back as rotary drilling method in the petroleum industry. They invigorate drilling operation as they are used to clean the rock fragments from beneath the bit and carry them to the surface, provide sufficient hydrostatic pressure in the system which prevents formation fluids from flowing into the well, cool and lubricate the rotating drill-string and bit. However, drilling fluids should not:

- Have properties likely to cause damage to a suitable formation evaluation techniques.
- Have hostile or contending effect upon the drilled formation.
- Cause any corrosion of drilling equipment and the subsurface tubular.

It is the role of the drilling engineer to select and maintain the best drilling fluid for the job. Most problems encountered during drilling are caused directly or indirectly by drilling fluid, which in most cases has resulted to abandonment of the well. Here in Nigeria drilling fluid cost often exceeds 1 million USD on a single deep well due to the fact that the additives required to maintain the drilling in good condition are imported.

Though there is a wide scope of drilling fluids to choose from for a drilling operation some factors are considered for selection or giving preference to a particular drilling fluid, such factors includes:

- The type of formation to be penetrated
- The temperature, strength, permeability, and pore fluid pressure of the formations.
- The formation evaluation method used.
- The water quality available
- Ecological and environmental impact.

However the mud engineer always on the search for drilling fluid that yields the lowest drilling cost in an area, this is usually determined by trial and error.

Over the years drilling activities have been carried out in Nigeria using imported drilling fluid materials; this has been of great concern for the industry and researchers considering its effect on our economy and foreign exchange.

The suitability of a certain drilling fluid for a particular formation depends on the characteristic behavior of that fluid, which is continuously modified to meet the formation conditions encountered as drilling progresses. Drilling fluid plays a major role in the success or failure of drilling a well, as such expertise is required in the formulation of this fluid to meet its designed function for successful drilling and completion of the well.

Most of this imported chemicals are not environmentally friendly and cannot be recycled as such, there is need to source for local materials, (clay and additives) as alternatives. The present consumption of bentonite in the drilling operations in Nigeria is put at over 50 thousand tons a year and all of it is imported from the USA (Odumugbo, 2005). An over dependency on this foreign input has been foreseen as we continue to record shoot-up in hydrocarbon exploration and exploitation in the Niger Delta basins and some Northern parts of the country. In cognizance of this the Federal Government of Nigeria took a swift action by establishing the Nigeria Local Content Initiative in the Oil and Gas Sector to encourage the use of local substitute to foreign consumables, such as drilling fluid materials. Thus, to salvage the country's economy and the future of our hydrocarbon industry it is crucial to go for readily obtainable local materials for drilling fluid production and evaluate the diverse characteristics of the produced fluid that can be used in drilling processes. The purpose of this paper is to produce drilling fluid using clay obtained from a deposit at Buan community in Ken-khana kingdom of Khana Local Government Area in Rivers State of Nigeria, with two local viscosifiers*; Brachystegia eurycona and Daterium microcarpum* flour, locally called *Achi* and *Offor* respectively, these viscosifiers are popular recipes for local soup, as such they are always in market and very cheap.

2. MATERIALS AND METHODS

Sample Preparation

The clay obtained from Buan-Khana deposit was soaked in water and stirred to release organic materials. The water was poured off gently from it. The concentrated clay was then transferred into a fabric for dewatering. The clay sample was dispersed on a pan, sun-dried and grinded to a fine size with mortar and pestle while continuously sieving with a 200µm Tyler sieve until a uniform sample was gotten.

The local viscosifiersBrachystegiaeurycona and Dateriunmicrocarpum were cooked, dried and grinded into powdery form and then sieved to a particle size of about 75µm. For proper dissolution and solubility, the mixture of clay and viscosifiers were soaked in 350ml of water, for all samples.

Mud Preparation

In preparing the mud, the American Petroleum Institute (API) standard of 25g of non-treated bentonite per 350ml of water was used in the preparation of bentonite and Buan Ken-Khana mud sample. The prepared mud samples were by standard kept for 24hours to age and its characteristics such as pH, density, rheological properties were determine and result shown in Table 1.

Measurement Procedure

pH: The mud sample to be measured was poured into a glass beaker, about 1 inch strip of the indicator paper was removed from the dispenser, placed on the surface of the mud and allow it to remain until the liquid wets the surface of the paper and the colour had stabilized (usually about a few seconds to a couple of minutes). The pH was then obtain from the indicator chart.

Density: The mud balance was standardized using distill water. The balance cup was cleaned, dried and filled to the brim with the mud sample to be measured. The lid was placed on the cup as some mud flowed out of the hole on the lid to ensure that there was no trapped air in the cup. The cup and lid were wiped to dry off any mud on the surface in order to obtain accurate measurement as the knife edge was placed on the fulcrum and the rider adjusted until the cup content and the rider were at equilibrium (balance). Later, the density of the mud sample was read on the calibrated arm of the mud balance.

Rheological Properties: To determine the rheological properties of the formulated mud, a rheometer (OFITE Model900 viscometer) was used. The equipment was put on and allowed to stabilize. The thermal cup was filled to 2/3 full of the mud sample. The thermal cup was placed on the viscometer stand and adjusted with the stand until the rotor sleeve was immersed in the formulated mud at the scribe-line. The viscometer stand was held in position by tightening the lock screw on the left leg of the instrument. The button 'mud test' was pressed on the equipment and the dial readings at 600rpm, 300rpm, 200rpm, 100rpm, 60rpm and 3rpm were taken. The Plastic Viscosity (PV), Average viscosity (AV), Gel Strengths and Yield Point (YP) were automatically calculated and recorded.

Their respective dial readings were obtained at steady values and recorded. The dial readings obtained as well as rotor speed values were respectively converted to shear stress and shear rate values using the equations (1) and (2):

Shear stress (τ) = 1.06*0.4788*(θ) ……… (1)

where:

(θ)= Dial reading

1.06 = Geometry factor of the viscometer

0.4788 = Conversion factor from lb/100ft2 to Pascal

Shear rate (γ) = 1.703*(RPM) ……… (2)

where:

RPM = Viscometer (Rotor) speed

1.703 = Factor derived from the sleeve and bob geometry of the viscometer.

Fluid Loss: To determine loss filtration, the mud cell was detached from the filter press. The bottom of filter cell was removed, and the right size filter paper was placed in the bottom of the cell. The mud to be tested is then introduced into the cup assembly, putting filter paper on top of the mud, tighten and screw clamp. With the pressure valve closed, the mud cup assembly was clamped to the frame while holding the filtrate outlet end finger tight. Place a graduated cylinder underneath to collect filtrate.

Open air pressure valve and start timing at the same time. Amount of filtrate collected is reported for time interval of 5, 10, 15, 20, 25, and 30 minutes.

Table 1: Properties of Bentonite, Buan mud and locally produced drilling fluid

Properties	Bentonite	Local Clay per 130ml of water	Local clay+7.5 g of DM+1g of Na_2CO_3 per 130ml of water	Local clay+7.5 g of BE+1g of Na_2CO_3 per 130ml of water	Standard mud
Density, lb/gal	8.80	8.65	8.84	8.84	7.0
Specific gravity	1.06	1.04	1.055	1.061	0.83
pH value	10.60	5.60	9.0	9.0	7.0

Sand content, %	0.30	0.44	0.44	0.44	0.30
Apparent viscosity, cP	12.00	1.55	94	91	124
Plastic viscosity, cP	7.0	1.5	63	50	42
Yield point, lb/100ft^2	10.00	0	62	82	62
Gelstrength(10sec), lb/100ft^2	4.00	1.1	40	25	74
Gel strength (10 min), lb/100ft^2	8.00	2.1	45	44	77

Chemical Additives: chemicals are commonly used to control pH, viscosity, and fluid loss. Often soda ash (Na_2CO_3), caustic (NaOH) are used to modify mud pH. High pH level is essential for corrosion inhibition, and precipitation of Ca^{2+} and Mg^{2+}. Furthermore high pH create favorable environment for proper solubility of organic additives, such as used in viscosity control like starch.

Clay Mud Beneficiation

Beneficiation is the addition of chemicals to low-quality clay to improve its performance. The Buan-khana mud was beneficiated with *Daterium microcarpum*, *Brachystegia eurycona* as well as soda ash (Na_2CO_3) to improve the mud density, rheological properties and pH values respectively. *Detarium microcarpum* flour was added to mud samples formulated in increasing proportions of 5%, 10%, 15%, 20%, 25%, 30%, of the dry clay sample, (i.e, 1.25g, 2.5g, 3.75g, 5.00g, 6.25g, 7.50g) the samples labeled A through F (see Table 2). The mixture of clay, water and viscosifiers were vigorously mixed and the homogeneous mixture with increased viscosity was allowed to age for 24 hours. The same procedure was repeated for of *Brachystegia eurycoma.* Finally,1g of soda ash was added to the produced fluid with7.50g of local viscosifiers and the pH values and rheological properties of the produced fluid were tested and recorded as shown in Table 3.

Table 2: Effect of *Daterium Microcapum* and *Brachystegia Eurycona* on the Density of Buan Clay

Conc.of additives %/25g of clay	Conc. of *Daterium microcarpum* (g)	Density (ppg)	Specific gravity	Conc. of Brachystegia eurycona (g)	Density (ppg)	Specific gravity
A=5	1.25	8.65	1.038	1.25	8.65	1.038
B=10	2.5	8.65	1.038	2.5	8.65	1.038
C=15	3.75	8.65	1.038	3.75	8.65	1.038
D=20	5.00	8.65	1.038	5.00	8.68	1.042
E=25	6.25	8.70	1.044	6.25	8.69	1.043
F=30	7.50	8.79	1.055	7.50	8.84	1.061

Table 3: Rheology of Buan clay +*Daterium microcarpum (offor)* + 1g of Na_2CO_3

Sample	Weight of DM/350ml of water (g/ml)	Θ_{600}	Θ_{300}	PV	YP	AV	Mud Weight
A	1.25	80	75	5	70	40	8.65
B	2.5	85	80	5	75	42.5	8.65
C	3.75	90	85	5	80	45	8.65
D	5.0	95	90	5	85	47.5	8.68
E	6.25	115	95	20	75	57.5	8.69

F	7.50	135	115	20	95	67.5	8.84
F+Na_2CO_3	7.50+1g of Na_2CO_3	188	125	63	62	94	8.84

Table 4: Rheology of Buan clay + *Brachystegia eurycona (achi)* + 1g of Na_2CO_3.

Sample	g/350ml of water	Θ_{600}	Θ_{300}	PV	YP	AV	Mud Weight
A	1.25	86	82	4	78	43	8.65
B	2.5	90	84	6	78	45	8.65
C	3.75	95	90	5	85	47.5	8.65
D	5.0	102	95	7	88	51	8.65
E	6.25	108	98	10	88	54	8.65
F	7.50	142	118	24	94	71	8.70
F+1g of Na_2CO_3	7.50+1g Na_2CO_3	182	132	50	82	91	8.79

Table 5: Volume of fluid loss (ml) vs time (mins) for mud samples

Time (mins)	5	10	15	20	25	30
Vol. of fluid loss for standard mud (ml)	2.4	4.3	5.1	5.8	6.3	6.6
Vol. of fluid loss for *Dateriummicrocarpum* mud (ml)	1.0	2.6	3.2	4.5	5.0	5.2
Vol. of fluid loss for *Brachystegiaeurycona* Mud (ml)	1.2	3.5	4.3	5.2	5.6	5.8

3. RESULT AND DISCUSION

A comparison of the prerequisite properties of Buan-Khana clay here referred to as local clay with Bentonite as presented in Table 1 shows a significant variance. This discrepancy necessitated the beneficiation of the local clay still with local materials (The *Daterium microcarpum and Brachystegia eurycona*flours, locally called *ofor* and *achi* respectively in southern Nigeria). This short fall in rheological properties of the local clay can be attributed to insufficient concentration of sodium cations (Na^{++}), as its absence hinders the swelling tendency of clay, (Okon and Udoh, 2010)

The result of the determination of the density of mud prepared from local clay sample showed that as the concentration of the local viscosifiers (Ofor and Achi) increased, the density also increase (Table 2). This increase in density was gradual as the viscosifiers increased in concentration with the highest density recorded as 8.84ppg and 8.79ppg for *Daterium microcarpum and Brachystegia eurycona*flours respectively at 7.50g (which is 30% of the concentration of the clay).

Also, comparing the rheological properties of the local mud with those of bentonite (table 1) showed an auspicious improvement with the addition of *Daterium microcarpium* (*Offor*) and *Brachystegia eurycona* (*Achi*). This notable modification in Buan mud rheology with *Daterium microcarpium and Brachystegia eurycona* can be explored commercially, considering the abundant availability of these local thickeners in Nigeria.

The rheological properties such as plastic viscosity, apparent viscosity, yield point and gel strength of the sample (25g of clay in 350 ml of water) showed a significant increase as the concentrations of *Daterium microcarpum and Brachystegia euryconа*increase in the mud sample. This shows capacity for drilling purpose. The results are shown in Table 3 and 4.

Rheology of Buan mud beneficiated with local viscosifiers and 1.0g of Na_2CO_3

With the addition of 1.0 g of Na_2CO_3, the dial reading increased remarkably. This is because the stability of the mud samples improved by a modification of the surface charge of the clay particles (Miano and Rabaioli, 1993). An appreciable dial reading was noticed with clay sample beneficiated with 7.5g of *Daterium microcarpum*.

When Na_2CO_3 was added, the dial reading increased appreciably. With the addition of 1.0g of Na_2CO_3 to 25g of Buan clay + 7.5g of *Daterium microcarpum* / 350ml of water , the reading increased from 135cp to 188cp for 600rpm Rotor Speed. This is because most viscosifiers requires an environment with pH greater than 9 (pH>9) to operate, (Okon and Udoh, 2010). In clay based systems, the differing surface and edge charges of clay platelets lead to a formulation of a gel-like network (Tehrani, 2004), the Na_2CO_3 provides the enabling environment for the gel-like network to form.

In the process the local clay exchange Calcium-ion with Sodium ion which resulted to this noticeable sharp improvement in dial reading. Also the formation of insoluble calcium carbonate contributed to its wall building property (filter cake formation).

$$Ca^{2+} + 2OH^{-} + Na_2CO_3 \rightarrow CaCO_3\downarrow + 2Na^{+} 2OH^{-}$$

In the process **Na_2CO_3** performed two roles:

- Remove calcium as a calcium carbonate precipitate for filter cake formation.
- Provide enabling environment for proper disssolution of the local viscosifiers which improves its slurriness.

Table 6: Dial reading and gel strength of muds produced using local materials + 1.0g of Na_2CO_3

RPM	DIAL READING			GEL STRENGTH					
	Standard mud	DM mud	BE mud	10sec. for standard mud	10min. for standard Mud	10sec. for DM mud	10min. for DM mud	10sec. for BE mud	10min. for BE mud
30	54.5	85	88	74	77	40	45	25	44
60	74.5	95	98						
100	155	100	112						
200	189	120	126						
300	206	125	132						

600	246	188	182						

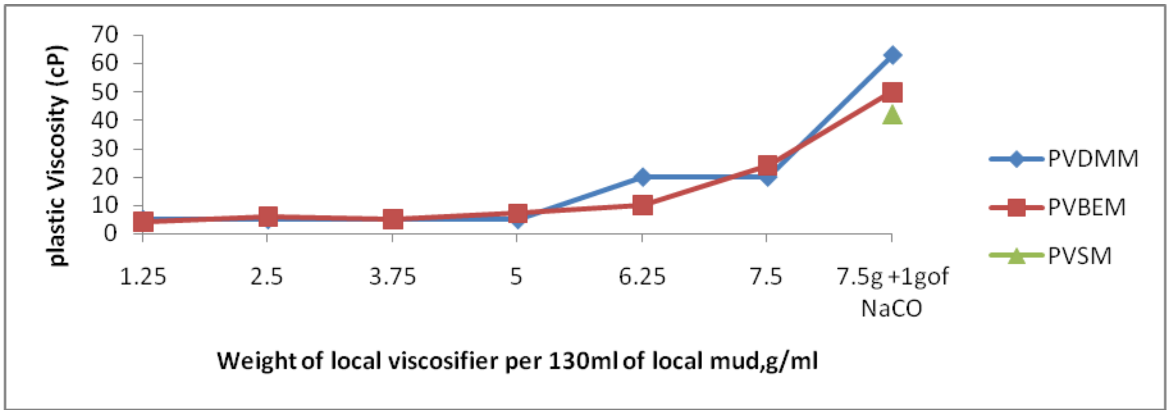

Figure 1: A comparison of the plastic viscosity of drilling fluid produced usinglocal materials and Na_2CO_3 with standard mud

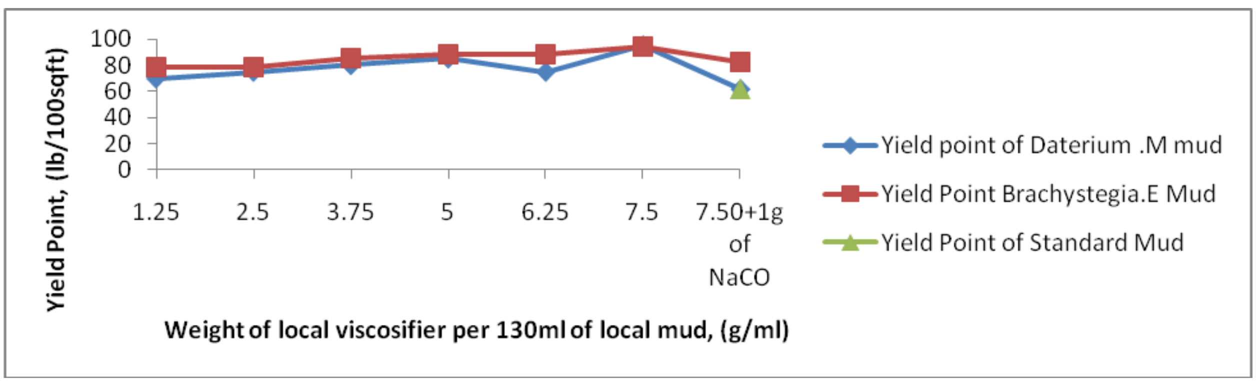

Figure 2: A comparison of the yield point of drilling fluid produced using local materials and Na_2CO_3 with standard mud

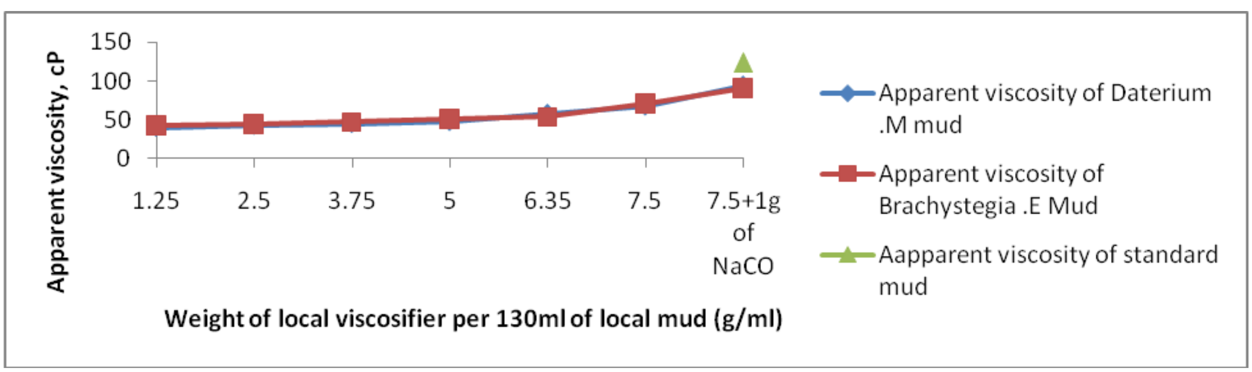

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Figure 3: A comparison of the apparent viscosity of drilling fluid produced using Local materials and Na_2CO_3 with standard mud

Again, Darley and Gray (1988) stated that the interaction between sodium (mono-valent) and montmorilonite determines the swelling of the clay particles. As can be seen in the result, *Daterium microcarpum* and *Brachystegia eurycona* have a close effect in viscosifying Buan mud.

The rheological properties of Buan mud showed remarkable improvement at 1.0g of **Na_2CO_3** and 7.5g of *Daterium microcarpum* in 25g of Buan clay per 350ml of water, and 1.0g of **Na_2CO_3** and 7.5g of *Brachystegia eurycona* in 25g of Buan clay per 350ml of water. These results are comparable to that given by a standard drilling fluid as seen in Table 1 and Fig 1.

Fluid Loss of Fluids Produced using Local Materials (Local Viscosifiers + 1g of Na_2CO_3)

From Table 5, the volume of water collected between 5-10 minutes for the standard mud is rapid but between 10–30 minute the volume collected became less with increase in time which was as a result of the formation of mud cake with time,

For the *Daterium microcarpum* mud, it can be seen that here is initial high rate of fluid loss. This also decreases rapidly with time. The decrease is suspected to be as a result of mud cake even forming faster to minimize fluid loss within a shorter time as it is deposited.

A higher initial rate of fluid loss is also recorded in *Brachystegia eurycona* fluid. This later decreased with time. This also is attributed to the formation of filter cake on the filter paper which minimizes the fluid loss as it is deposited.

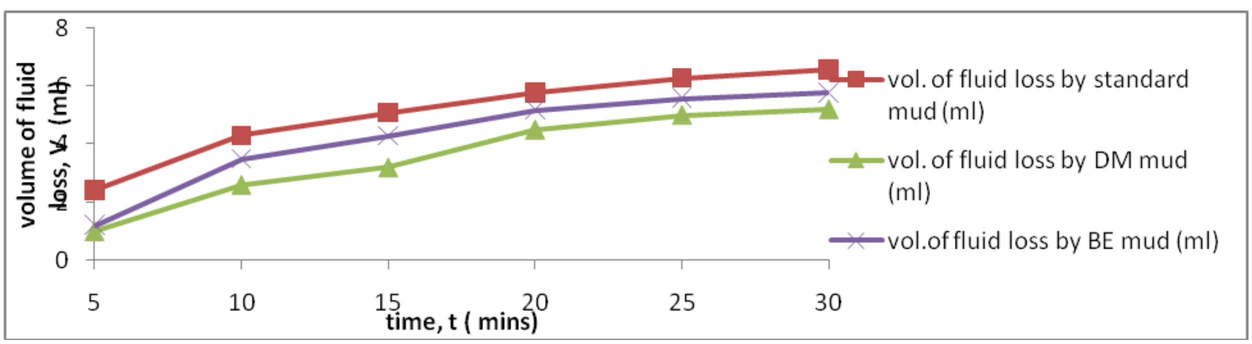

Fig 4.17: Plot of Volume of fluid loss against time of (a) Standard mud (b) 7.5g DM + 1g of Na_2CO_3 mud (c) 7.5g BE + 1g of Na_2CO_3 mud

From the figure 4, the volume of fluid loss in *Daterium microcarpum* mud was much more less as compared to standard mud and *Brachystegia eurycona* mud. This decrease was suspected to be as a result of formation of mud cake which seems to be deposited faster when compared to the standard mud and *Brachystegia eurycona* mud

Shear stress and shear rate

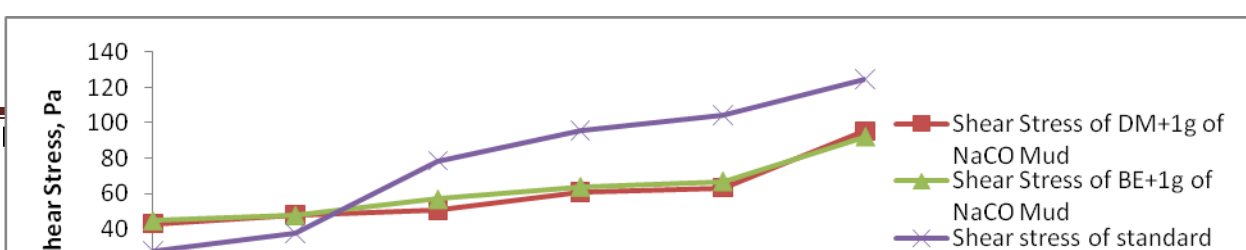

Figure 3: Plot of shear stress against shear rate of (a) 7.5g DM+25g of Buan clay+1g $NaCO_3$ (b) 7.5g BE+25g of Buan clay+1g $NaCO_3$ (c) 25g of Buan clay (d) Standard mud

The incongruity in shear stress and shear rate of local mud and that of beneficiated local mud is to a great extent connected to the concentration of sodium cation (Na^{++}), as its deficiency impedes the swelling tendency of the local clay. The shear stress is a constant function of the mud's rheological property which increases as swelling tendency of the clay increases. Shear stress is the force required to sustain the shear rate as the shear rate is the rate at which one layer of a fluid is moving past the next layer, (Okon and Udoh, 2010)

Also there is an observable increment between shear rates and shear stress. Consequently, the shear stress of drilling fluid produced here from the clay increases with increase in shear rate, thus showing behavior close to Bingham Plastic model which translates to marked deviation from the Newtonian fluid model since the line do not pass through the origin as observed in figure 3.

Shear stress is the resistance which opposes shearing and until the applied force exceeds the yield stress, flow will not be initiated, (Okeigwe *et'al*, 2013). The stress that must be exceeded for flow to be initiated is the "yield point".

4. CONCLUSION

This research work is a detailed laboratory analysis for qualifying some local materials for the production of drilling fluid. Key parameter such as density, rheology were evaluated. The Buan clay at its raw, natural state is deficient in the required rheological properties for use in the production of oil well drilling fluid. However, when beneficiated with *Daterium microcarpum*(DM), *Brachystegia eurycona* (BE) and Soda ash (Na_2CO_3) there was a notable improvement in the drilling mud which was formulated from the Buan clay. From the result obtained, it was observed that the Buan clay's rheological properties when beneficiated with *Dateriummicrocarpum*and *Brachystegiaeurycona* respectively, increased drastically.

Also, the addition of a 7.5g *Dateriummicrocarpum*, 1.0g of soda ash (Na_2CO_3) content and *Brachystegiaeurycona* respectively to 350ml of the formulated drilling fluid resulted in a dramatic increase in the plastic viscosity, apparent viscosity and pH of the formulated fluid by about 230%, 164% and 60% respectively.

Daterium microcarpum and *Brachystegia eurycona* can control fluid loss in drilling mud significantly and even better with a reasonable concentration in water based mud, hence these two local viscosities can be used as substitutes for other expensive chemicals.

In this connection, it can be concluded that, at significant concentration, the Buan clay exhibit good rheological properties that would compare favourably with those of bentonite when beneficiated with *either Daterium microcarpum* and soda ash (Na_2CO_3) or *Brachystegia eurycona* and soda ash (Na_2CO_3)

It is therefore recommended that further research be carried out to determine the effect of temperature changes on the Buan clay and the local additives rheology and fluid loss. Hence, simulating its suitability for different well depth or temperature zone. Additionally, particle size play a very weighty role on the performance of drilling fluid in a geological formation, a very small particle most times penetrate the surrounding rock formation, resulting in irreversible damage to the pay zone. It is on this premise that extensive research is needed in other to understand how to adapt the particle size of mud constituents to accomplish the required performance of an explicit rock formation.

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