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Comparative Evaluation of Rheological Properties of Standard Commercial Bentonite and a Locally Beneficiated Bentonitic Clay from a Marine Deposit in Upper Benue Basin, Nigeria

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Research Article

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ABSTRACT

Nigeria is ranked the seventh largest exporter of crude oil in the world. On a daily basis, it produces over two million barrels of crude Oil from hundreds of Oil wells drilled in the Niger Delta area. Not a single of these Oil wells are drilled without the use of Bentonite. Bentonite is a clay powder that is mixed with water (drilling mud) and forced through a drilling string into the wellbore during drilling operations in order to float and lift drilled cuttings out of the well, control the down-hole temperature, lubricate drilling bit, prevent corrosion and stabilize the wall of the hole from collapsing among other things. A very large sum of money is being spent by the Oil companies operating in Nigeria on the importation of millions of tons of Bentonite from overseas for Oil well drilling. Nigeria has large reserve of Bentonitic clay deposit that if properly utilized will go a long way in supporting the Oil well drilling demand in the country. This will translate into retaining the large sum of money sent overseas for importation of foreign Bentonite, create employment opportunities, bring external investment and boost the country's economy. Though the Bentonite deposits studied are Ca-based, it can be beneficiated to a level that is comparable with the standard compliance. This study has beneficiated local Bentonitic clay using Na_2CO_3 as the beneficiating agent and ion exchange as the procedure. The rheological properties of the beneficiated clay were determined together

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with that of a standard commercial Bentonite and compared with the United State API grade and European OCMA standard for complience. The recorded values for viscosity at 600rpm, yield, filtration, fineness and moisture content of the locally beneficiated Bentonitic clay and the standard commercial Bentonite are 35, 1 -6, <15, 2.8%, 8% and 27, 2.3, <15, 3.7%, 12%, respectively. While these values for the United State API grade and the European OCMA standards are ≥30,≤3, ≤15, ≤4%, ≤13% and ≥30, ≤6, ≤16, ≤2.5%, ≤13%, respectively. This indicates that the local Bentonite reserve can be beneficiated using Na_2CO_3 as beneficiating agent and ion exchange as beneficiating procedure to a level that is even a little better than the studied standard commercial Bentonite also studied.

Keywords: Drilling; rheological properties; bentonitic clay; ion exchange standards;

1. INTRODUCTION

Nigeria produces over two million barrels of crude oil per day; it is one of the largest exporters of crude oil in the World (leadership newspaper). This crude oil is produced from hundreds of oil wells drilled in the Niger Delta area where new oil wells are being drilled. Not a single out of these hundreds of oil well was drilled without the use of Bentonite (drilling mud). Hundreds of millions of dollar is spent by the oil companies on importation of Bentonite from overseas while Nigeria has enough reserve of Bentonitic clay deposit all over the country which requires just a little beneficiation to meet the required standard for use as a drilling mud in oil well drilling operations. The sample studied came from the Benue trough in northeastern part of Nigeria. The Benue Trough is an integral part of the “West and Central African Rift System” (Giraud et al., 1989). It is conventionally subdivided into a “Lower Benue Trough”, a “Middle Benue Trough” and an “Upper Benue Trough”. The Upper Benue Trough includes an east-west trending Yola arm and a north-south trending Gongola arm. According to Benkhelil (1985) these two branches are separated by an area structurally dominated by four major NE - SW trending sinisterly strike-slip faults, the Gombe, Bima Teli, Kaltungo and Burashika faults; basement inliers are associated with them.

The Cretaceous succession in the Upper Benue Trough comprises Early Cretaceous continental clastics, the Bima Group, The Yolde Formation; which It consist largely of alternations of coarse to fine-grained cross-bedded or ripple-bedded sandstones and grey to greenish shale. Thin limestone occurs especially in its upper part where oyster beds are common (Zaborski 1998), The Pindiga Formation, which consist of five members namely: Kanawa Member, The Deba Fulani Member, The Gulani Member, The Dumbulwa Member and The Fika Member. This study is based on samples obtained from the Fika member of the Pindiga Formation.

The Fika Member produces a low featureless topography. Its outcrop can often be recognized from the black, shrinking clay soil to which it gives rise (Zaborski et al., 1997). The exposures that do occur mostly reveal shaly mudstones, dark grey when fresh but weathered to lighter blue-green to grey colors indistinguishable from those of Kanawa Member.

Both local Bentonitic clay and standard commercial Bentonite samples collected were subjected to both physical and elemental analysis to determine the elemental, rheological and other physical properties, these properties were compared to the United State API and European OCMA standard to evaluate their compliance. It was found that Both Local Bentonitic clay sample and the standard commercial Bentonite complied with the standard, both the locally beneficiated Bentonitic clay was found to compare a little better than the standard commercial Bentonite. This study was carried out to determine the properties and worth or otherwise of Bentonitic clays from north-eastern Nigeria for use as drilling mud in oil and gas well drilling, it has confirm that local Bentonitic clay deposit can be beneficiated to meet the standard required for use as a drilling mud in oil and gas well drilling operations.

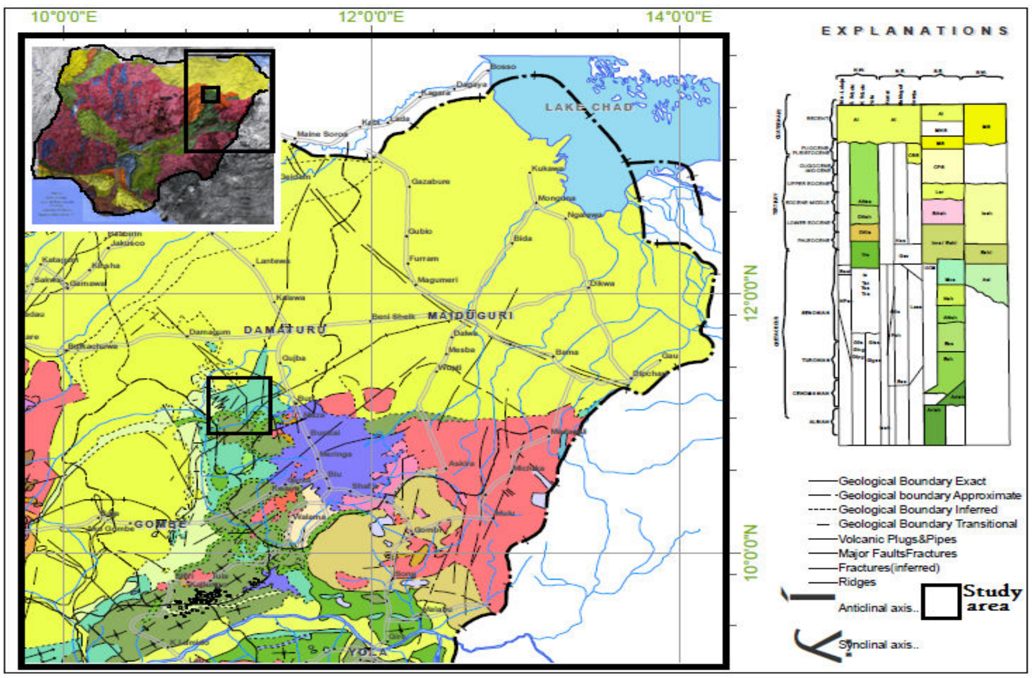

Fig. 1: Geological map of part of north-eastern Nigeria showing location of the study area (modified from GSNA, 2004) inset is a map of Nigeria depicting the outlined area

2. MATERIALS AND METHODS

In April, 2009, samples suspected to be Bentonitic clay was collected from a marine deposit in Upper Benue trough in north-eastern Nigeria. The sample was collected along river channel where they were cut across by deep gullies created by streams and river in the areas. Sample was collected using standard procedure where surface of an exposed sample was carefully removed using plastic shovels and the sample collected and packed into plastic container, properly labeled to reflect location name, date and time of collection. This was also recorded into a samples details book together with coordinates of the sampled point.

In the laboratory, the sample was subjected to different experimental works with the aim to determine the elemental, rheological and other physical properties of raw sample in order to determine what percentage of the beneficiating agent to be added, the proper procedure to be adopted and so on. Initial elemental analysis was carried out to determine either a sample will require no, little or intense beneficiation. For example, if a sample is discovered to be a Na-based, rheological property determination will proceed immediately to determine whether their property has met that of a standard. If a sample is discovered otherwise, elemental analysis is carried out to determine the extent of addition of beneficiating agent for ion exchange procedure as provided in figure 2.

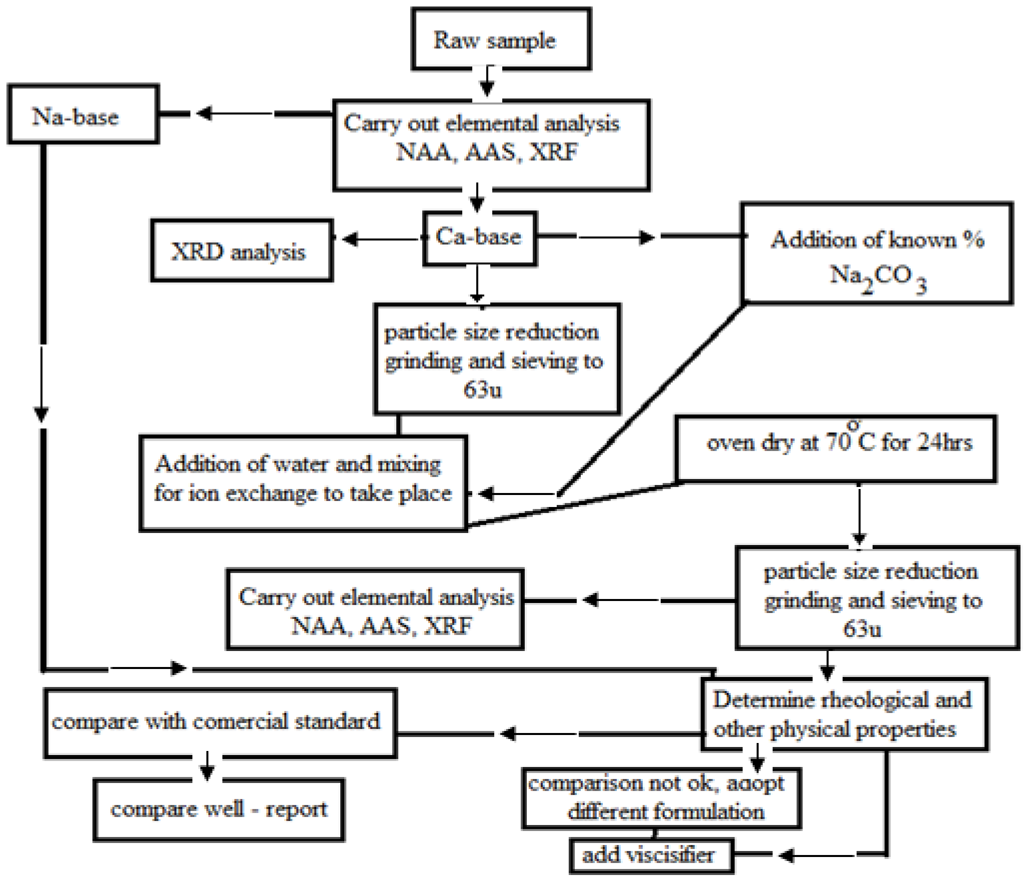

Fig 2: Flowchart of the entire beneficiation procedure adopted for the work

Analysis of raw Bentonitic clay was carried out using Instrumental Neutron Activation Analysis (INAA), X-Ray fluorescence (XRF) and X-Ray Diffractometry (XRD) to determine the elemental composition, especially the Ca and Na content and rheological properties before beneficiation was carried out. Sample preparations include the following;

2.1 Addition of Beneficiating Agent

The sample was divided into ten portions each weighing 100g and to each portion, different percentage of Na_2CO_3 was added. The percentage added ranges from 2 to 10% (2 to 10g) and from this process, a total of 11 samples were generated and further steps of the beneficiation procedure were followed.

2.2 Kneading of Samples

To each of the samples (sample with sodium carbonate), 50ml of deionized distilled water was added and kneaded into a dough like mass and allow to stay overnight for ion exchange to take place.

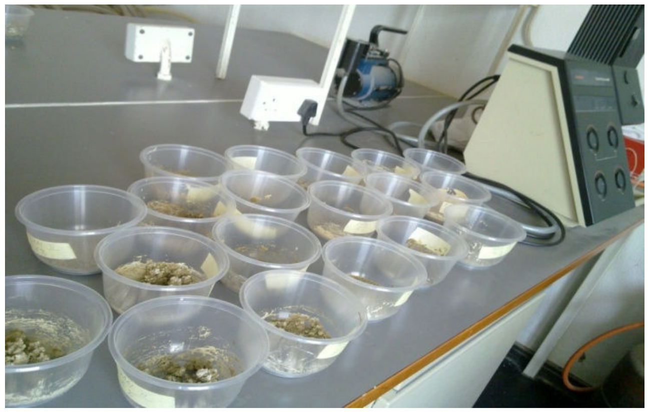

Fig. 3: A set of Kneaded Bentonitic clay samples ready for oven drying

2.3 Drying of Kneaded Samples

The kneaded samples is allowed to stay overnight for ion exchange to occur after which each samples was oven dried at 75^{o} for eight hours.

2.4 Re-Grinding and Sieving of Beneficiated Samples

The beneficiated samples were re-grinded and sieved again to achieve the 63µ. A direct indicating OFITE MODEL 900 VISCOMETER was used to determine the viscosity of the samples, Moisture Content and Loss On Ignition were determined at 110ºC and 1000ºC after 30 and 45minutes, respectively using “Labcon” Furnace Model 2-1200 while Sand content was determined by Bariod sand kit equipped with a set of sand screen.

3. RESULTS AND DISCUSSION

Analysis of chemical compositions of the samples was carried out using X-ray fluorescence and results were compared with that of a standard commercial Bentonite, this result is presented in table 1. Loss on Ignition (LOI) at 1000^{0}C and moisture content at 110^{0}C were also determined using Labcon oven and these results are given in Tables 1 and 2.

Results obtained show that both standard commercial Bentonite and the locally beneficiated Bentonitic clay satisfied the requirement that Al/Si ratio be 1:3 or 0.33. The recorded value for this requirement for the standard commercial Bentonite was 0.37 while it is 0.32; this value is closest to the requirement for locally beneficiated Bentonitic clay than for the standard commercial Bentonite (Table 1).

Table 1: Results of analysis of chemical composition of local Bentonitic clay and standard commercial Bentonite

Elements			Local Bentonitic clay	Standard commercial Bentonite
SiO_2	Si	(%)	35.17	48.80
Al_2O_3	Al	(%)	13.05	15.54
Fe_2O_3	Fe	(%)	7.35	6.44
MnO	Mn	(%)	0.27	0.07
MgO	Mg	(%)	6.17	3.50
CaO	Ca	(%)	10.36	5.22
Na_2O	Na	(%)	0.06	2.19
K_2O	K	(%)	1.69	0.75
TiO_2	Ti	(%)	0.64	0.49
P_2O_5	P	(%)	0.31	0.13
SO_3	S	(%)	0.08	0.73
LOI	LOI	(%)	24.20	15.73
Sum of conc.		**(%)**	**99.36**	**99.59**

The recorded value for Los on Ignition for local Bentonitic clay is 0.12 or 24.2% while for standard commercial Bentonite, it is 0.08 or 15.73%. The moisture contents are 0.02 and 0.03 for locally beneficiated Bentonitic clay and standard commercial Bentonite, respectively (Table 2).

Table 2: Results of loss on ignition and moisture contents of the studied sample and the Studies standard commercial Bentonite give unit for the data presented

Sample ID	Local Bentonitic clay (%)	Standard commercial Bentonite (%)
Moiture Content at 110ºC	0.02	0.03
Loss on Ignition	0.12	0.08
% Loss On Ignition	24.20	15.73

X-Ray diffraction result of both commercial and beneficiated Bentonite shows that both sample had high quartz content represented by the high peak on the spectra on fig. The result also show that while both samples had montmorillonite, dolomite, ankerite, quartz and microcline, the standard commercial Bentonite had calcite, beidellite and barite in addition. These indicate that the standard commercial Bentonite was blended with barite power to enhance some of the rheological properties (Table 3).

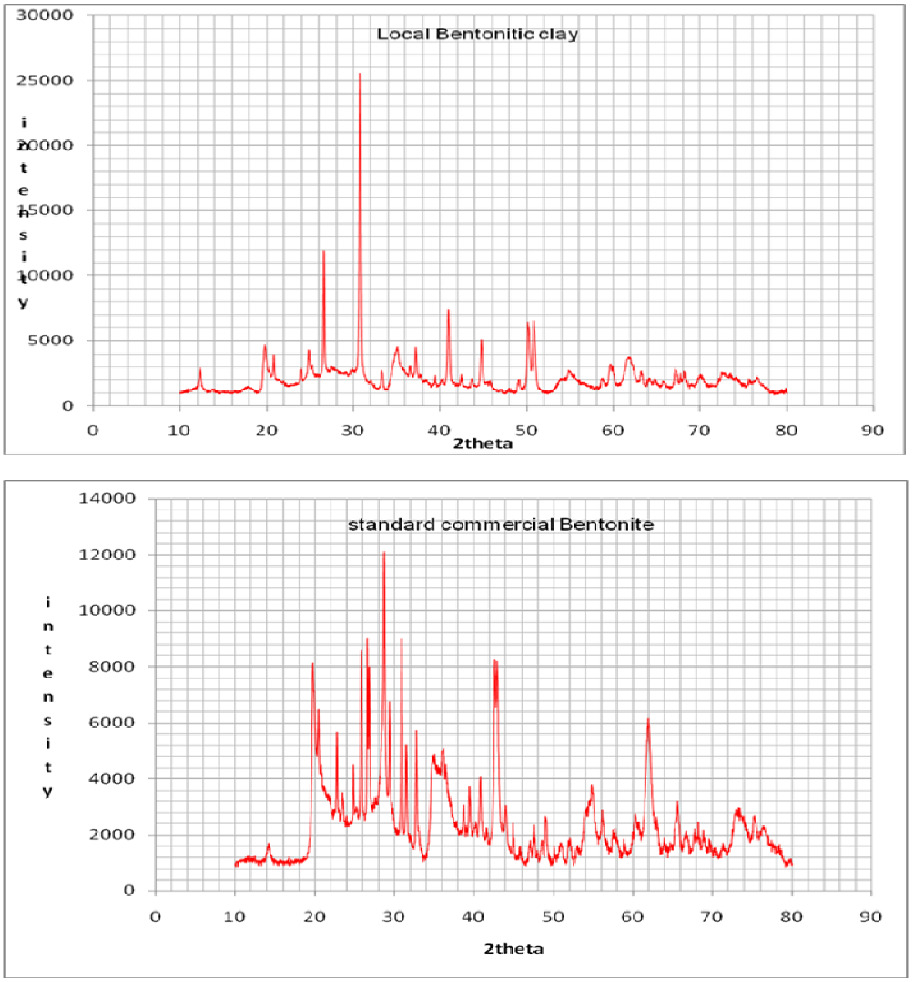

Fig.4: X-Ray Diffraction spectra for local Bentonitic clay (top) and standard commercial Bentonite (bottom)

Table 3: Mineralogical phases from X-Ray Diffractometry of the studied sample (NGL) and Studies standard commercial Bentonite (WYM)

Samples	Mineral Phases
Local Bentonitic clay	Montmorillonite, Kaolinite, Dolomite, Ankerite, Quartz and Microcline
Standard commercial Bentonite	Montmorillonite, Calcite, Dolomite, Barite, Quartz, Microcline, Beidellite and Ankerite

The viscosity of the nine samples generated from beneficiation procedure together with that of the standard commercial Bentonite were determined at 300rpm and 600rpm using a direct indicating "OFITE" model 900 viscometer. Results of this measurement are presented in a bar graph (Fig. 5 to 9). The first set of samples measured for viscosity are sample that were crushed but were not sieved, to these sample, different percentage of the beneficiating agent were added as shown in Fig. 5 and the beneficiation flow chart in fig. 2 was followed before viscosity was determined. The result obtained showed that the sample had its highest viscosity recorded was at 3% Na_2CO_3 (11 at 600rpm and 7 at 300rpm) while for the standard commercial Bentonite, this value was 15 and 22 at 300rpm and 600rpm, respectively. At this stage, the viscosity of the locally beneficiated Bentonitic clay did not meet neither the API nor the OCMA standard.

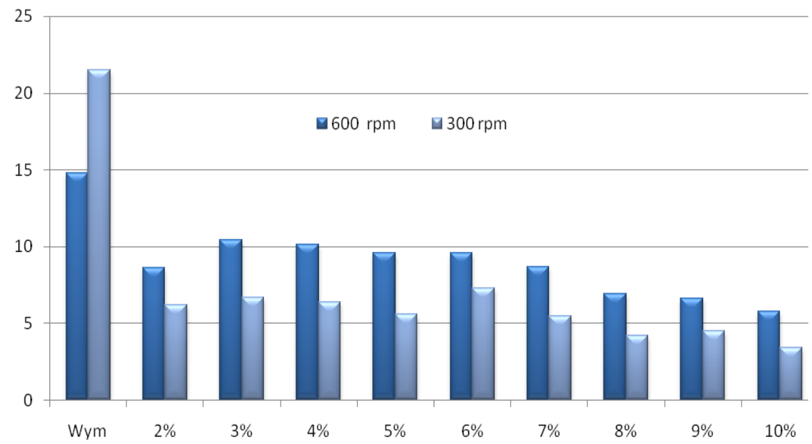

Fig. 5: Comparison of Viscosity at 300rpm and 600rpm of Standard commercial Bentonite (WYM) and a trend change for crude local Bentonitic clay samples on addition of 2 to 10% Na_2CO_3

When the sample was sieved before beneficiated, the result of viscosity changed dramatically, i.e. the viscosity change became linear as see in Fig. 6 but the highest value recorded shifted to 9% Na_2CO_3 which is below the standard.

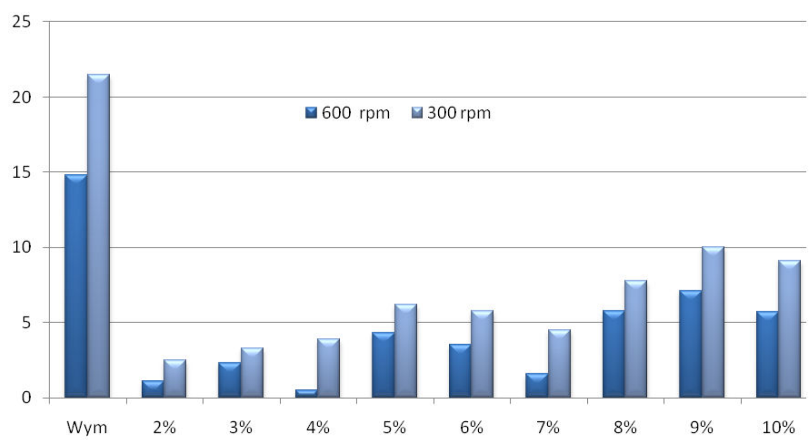

Fig. 6: Comparison of Viscosity at 300rpm and 600rpm of Standard commercial Bentonite (WYM) and a trend change for sieved local Bentonitic clay samples on addition of 2 to 10% Na_2CO_3

On addition of viscosifier in the range of 0.2 to 1g to the sieved beneficiated sample, the viscosity increases considerably from 10 and 14 at 300rpm and 600rpm, respectively at 0.2g voscosifier to 22.5 and 35 at 300rpm and 600rpm, respectively at 1g viscosifier (Fig. 7). At this stage, the viscosity of the locally beneficiated Bentonitic clay met both the API and OCMA standard of ≥30, ≤3, ≤15, ≤4, ≤13 and ≥30, ≤6, ≤16, ≤2.5%, ≤13%, respectively (Schlumberger oil field glossary, 2011). For the locally beneficiated Bentonitic clay, its recorded results even superses the values recorded for the standard commercial Bentonite (Table 4).

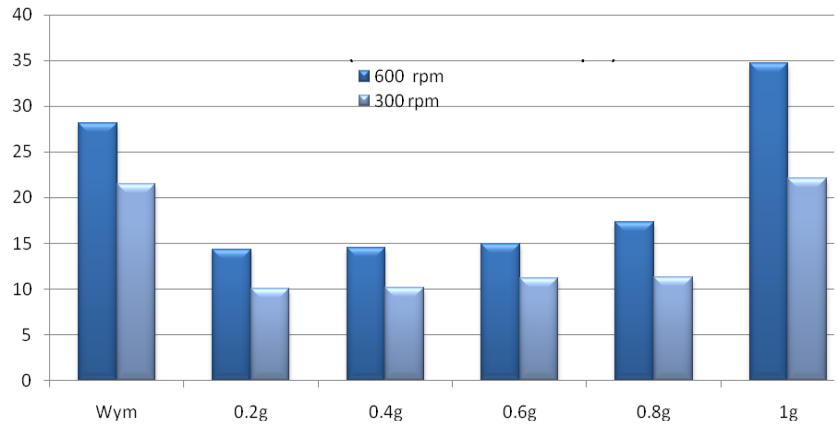

Fig. 7: Comparison of Viscosity at 300rpm and 600rpm of Standard commercial Bentonite (WYM) and trend change for sieved local Bentonitic clay samples on addition of 0.2 to 1g of viscosifier

Yield points were also determined for unsieved and sieved beneficiated local Bentonitic clay, it was also determined for beneficiated clay with added viscosifier and the results obtained were compared with the standard commercial Bentonite as presented in Figures 8 and 9.

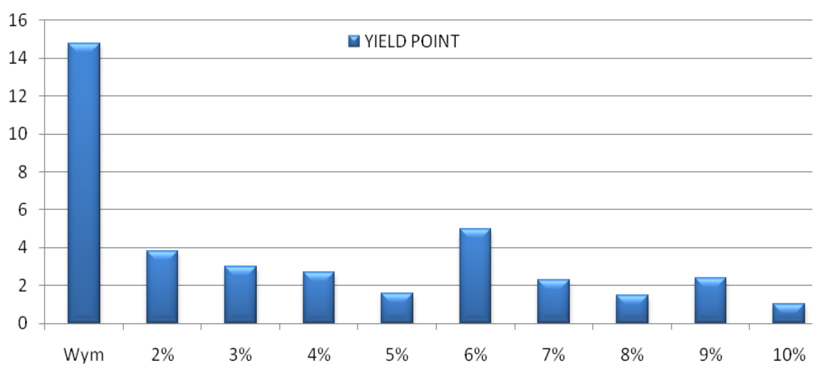

Fig. 8: Comparison between Yield of Standard commercial Bentonite (WYM) and trend change for crude local Bentonitic clay samples on addition of 2 to 10% Na_2CO_3

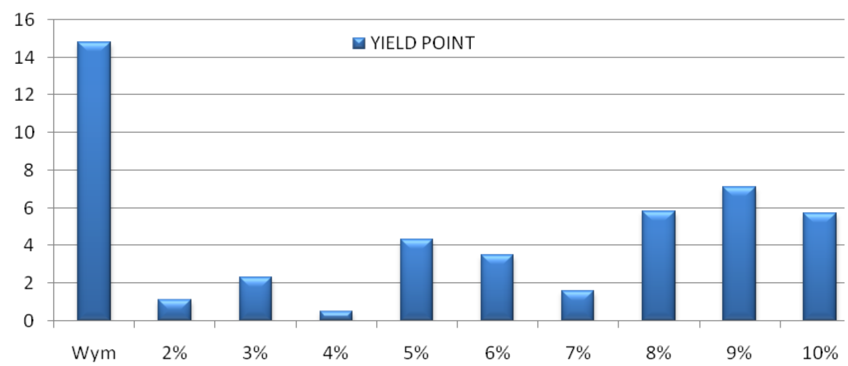

Fig. 9: Comparison between Yield of Standard commercial Bentonite (WYM) and trend change for a sieved local Bentonitic clay samples on addition of 2 to 10% Na_2CO_3

The yield results obtained showed that almost all the yield values recorded for locally beneficiated Bentonitic clay were within the API and OCMA values of ≤3 and ≤6, respectively (Table 4).

Table 4: Standard values for Bentonite and those obtained for Standard commercial Bentonite and locally Beneficiated Bentonitic Clay

Parameters	API	OCMA	Standard commercial Bentonite	Local Bentonitic clay
Viscosity(600rpm)	≥30	≥30	27	35
Yield	≤3	≤3≤6	>3	1 - 6
Filtration	≤15	≤16	<15	<15
Residue 75µm	≤4	≤2.5%	3.7%	2.8%
Moisture	≤13	≤13%	12%	8%

API = American standard, OCMA = European standard

But when viscosifier was added, the yield went up beyond the values recommended by both API and OCMA indicating that the addition of viscosifier to the samples had its own disadvantage i.e. it affects negatively the yield of the studied Bentonitic clay.

4. CONCLUSION

This work has identified that Bentonitic clay from Fika member of the Pindiga Formation in Upper Benue trough in north-eastern Nigeria are Ca-based, therefore, it can only be used as drilling mud when effectively beneficiated to a Na-based. The use of ion exchange procedure utilizing sodium carbonate as beneficiating agent was capable of beneficiating a Ca-based local Bentonitic clay to Na-based Bentonitic clay. The rheological properties of the beneficiated local Bentonitic clay was determined vis-a-vis a standard commercial Bentonite and compared with the United State API and European OCMA standard, it was discovered that the rheological properties of the locally beneficiated Bentonitic clay compared very well with the standard and presented some rheological properties that are a little better than the studied standard commercial Bentonite. The studied clay had some properties that met standard even before beneficiation, these are loss on ignition, Al/Si ratio, moisture content for example whereas other clays from other parts of Nigeria e.g. Obakala Bentonitic clay had no property on their own for use as drilling mud (Apugo-Nwosu *et al.,* 2011).

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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