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Evaluation of the Suitability of some South Eastern Nigeria Clays for Drilling Mud and Oil Field Applications

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Abstract
In Nigeria it has been estimated that over 50,000 tons of bentonite is being used and imported per a year by oil drilling companies. This work therefore was to evaluated the Nigeria clay local content with emphasis on five geographical zones in south eastern Nigeria viz; Abia, Anambra, Enugu, Imo, and Ebonyi state. At the end of the evaluation, the clay mud were found to be out of API standard when compared to American bentonite that serves as a control during the experiment. The rheological properties are not up to required standard for bentonite production. They are discovered to be more of calcium-based clays. The collected clay samples were beneficiated with some additives such as barite (Baso4) potassium chloride (KCL) soda ash (Na2Co3) to improve the rheological strength and pH respectively. The result obtained showed that local clay densities increased from 8. 80b/gal to 9.20b/gal at barite concentration of 2g to 10g.This shows that (BaSO4) barite can be used as weighing material in the formulation of drilling fluid using South Eastern clays. It improves due to increase in sodium cat ions (NaH) and addition of soda ash concentration against pH of the local clay samples also indicates a remarkable improvement in the pH of the mud formulated with the local mud sample to API specification thus Viscosity (cp) increased from 4.00ap, 8.01b/100ft2 and 6.0cp to 10.0ap, 12.01b/100ft2 and 14.00cp respectively. The apparent viscosity (ap) Yield point (YP) and plastic viscosity (cp) also increased from 6.00cp, 4.01b/100ft2 and 4.0cp to 12.40ap, 10.01b/100ft2 and 8.00cp respectively

Keywords **—Clay, Viscosity, Drilling companies, Rheological properties, Sodium cation, and Bentonite**

I. INTRODUCTION

The research was necessitated due to the present consumption of bentonites in the oil drilling process/operations in Nigeria, which has been estimated to over 50 thousand tons per year and it is imported from abroad [1]. This trend is expected to continue as drilling activities keep increasing. The large consumption and the high important cost of this materials led to an attempt to find a local substitute, hence this research.

This research evaluated mineralogical properties of clay deposits from (5) five South Eastern Nigeria clay deposits, (Ebonyi, Enugu, Abia, Imo, Anambra State), their suitability for drilling mud, and oil field application comparing them with imported U.S.A. bentonite which serves as a control during the analysis.

2.0 LITERATURE REVIEW

Drilling the oil well is one of the most expensive steps in the oil exploration and exploitation. Expenditure for drilling represents 25% of the total oil field exploitation cost is concentrated mostly in exploration cost and development of well drilling [2]. Drilling mud (Bentonite) which represent about one-fifth of the total cost of oil field application must comply with certain standards such as: They should be easy to use, not too expensive and environmentally friendly. When oil and gas operations began in Nigeria in the early fifties, local clay was used in the preparation of drilling mud and cement slurries [3]. The introduction of imported

commercial bentonites started in the year 1960 and drastically reduced the use of Nigeria local clay in the oil and gas industries [4].

Nigeria is blessed with abundant reserve of oil, gas and clay minerals [5] but yet spends millions of dollars yearly importing drilling mud despite proven reserve of clay deposits. If these local clay deposits are beneficiated and efficiently enhanced, they would be readily used as drilling mud [6].

A lot of previous works done in the area of characterization of Nigeria bentonite deposits was based on a regional study of the locations containing them (Tables 3 – 5).

However, such studies have indicated that the Nigeria bentonite clays are mostly low-grade Calcium montmorillonile and would require beneficiation using sodium salt as part of methods to improve its quality.

Table 1: Proven Bentonite Reserve of some Clay Deposits as at 2010 (Aguru et al., 2015)

Location	*Reserve Estimated (Tons)*
Bende, Umuahia, Arochukwu Ikwuanu, Isikwuato (Abia State SE. Nigeria),	5.8 to 7.5 million
Orlu, Isu, Orlu, Okigwe (Imo State SE Nigeria)	5.8 to 7.5 million
Ngala, Gamburu, Di kwa, Monsunu, Marte, (Borno State WE, Nigeria)	700 million

Table 2: Bentonite clay deposits in Nigeria that require reserve estimation and quantification as at 2010 (Agwu et al., 2015).

Location	*Reserve Estimated (Tons)*
Ogurude (Cross River State SS Nigeria)	Not yet estimated
Ohaozara (Ebonyi State SE Nigeria)	Notyet estimated
Awka (Anambra State SE Nigeria)	Not yet estimated
Jega (Kebbi State, NW Nigeria)	Not yet estimated
Itu (Akwa Ibom State, SS Nigeria)	Not yet estimated

Table 3: Some Previous Research Work Done on Nigerian Bentonite Clays from Different Regions.

Researcher (s)	Number of locations	Specific areas studied	Experiment done
Oyawoye and Hirst (1994)	1	Ropp, Plateau Province (Plateau State)	Mineralogical characterization using XRD and thermal analysis
Omoleet al. (1989)	20	Bama-Mubi, Maiduguri-Bama, Maiduguri-Gamboru, Dikwa-Marte, Dikwa-Maiduguri, Maiduguri-Bui, Bui-Numan, Yola-Fufore. Numan-Gombe (Borno State)	Sodium carbonate and Trona was used to upgrade the raw bentonite clays; XRD. Rheological, filtration and physio-chemical analysis was carried out.
Ademibawa (1999)	1	Pindiga (Gombe State)	XRD analysis
Onize (2003)	2	Afuze (Edo State) and Maiduguri	CMC, PAC and soda ash was used to improve the properties of the clay. Rheological analysis was done.
Falode el al. (2008)	1	Pindiga (Gombe Stale)	Rheological and filtration analysis
James et al. (2008)	1	Yola (Adamawa State)	XRK, XRD, Theological analysis. Sodium carbonate was used for beneficiation.
Salarn et al. (2010)	2	Ewekoro (Ogun State)	Local gum Arabic and sodium carbonate was used for the beneficiation, Rheological analysis and model development.
Lafia (2010)	1	Nassarawa State	Rheological analysis. Starch was used as beneficiating agent.
Abdullahi et al. (20ll)	1	Fika (Benue Trough)	Mineralogical characterization using XKF. XRD. Rheological Analysis

3.1 Sample Collection and Sampling Technique

The clay samples used for this research work and evaluation were collected at the appropriate depth of 7ft at appropriate geological formation where minerals like sodium, calcium and magnesium base elements tend to accumulate.

3.2. Equipment and Apparatus

Costwald Viscometer, Thermometer, Distil weighing scale balance, pipette; mechanical cylinders, stopwatch, mechanical agitator, 200 mesh Tyler sieve (approximate 75 num size); Hammer mills, jaw crusher, grinder/mortar and pestle, plastic buckets.

3.2 Mud Preparation

The collected clay samples from the five geopolitical zones in South Eastern Nigeria (Abia, Anambra, Enugu, Imo and Ebonyi State) were dried under moderate temperature spread out in a plastic tray in a drying oven in the workshop of ceramic and glass department Akanu Ibiam Federal Polytechnic, Unwana, Ebonyi State.

The dried clay samples were then subject to pulverization by pounding it in a mortal. The pulverized clay samples were sieved by using particle sieve analysis in order to obtain fine clay. Each sieved clay sample of the five different areas were collected in a beaker and labelled appropriately using a masking tape.

Sample preparation

Five different samples were prepared and labelled as follows:

Ubakala sample	A
Ishiagu sample	B
Udi sample	C
Awka sample	D
Orlu sample	E

Sample A: 50g of clay/700ml of distilled water
SampleB: 50g of clay/700ml of distilled water + 2wt, % Na_2Co_3
Sample C: 50g of clay/700ml of distilled water + 6wt. % Na_2Co_3
Sample D: 50g of clay/700ml of distilled water + 8wt.% Na_2Co_3
Sample E: 50g of clay/700ml of distilled water + 1O wt.% Na_2Co_3

Procedures

Each sample of the clay was washed with distilled water and completely dried. They are all heated on heating stirrer setting the temperature at 30^0C and rotor at 100 rpm. And each clay sample from the five South East geopolitical zones is then introduced one after another through tube, using a long pipette to minimize wetting the tube above the mark.

Precautions are taken such as clamping the tube vertically and allowed to stand to maintain equilibrium. Api RP-13B stand and procedure were employed throughout the laboratory work to determine rheological and fluid loss properties. All the samples of clay collected for the analysis are based on the formulation of 350ml of fluid that contains only fresh water.

Determination of Rheological Properties

The viscometer in the physical laboratory of ceramic and glass department of Akanu Ibiam Federal Polytechnic was connected to power supply and the power button switched on. The mud sampled from the five Eastern States, fresh prepared was poured into the sample cup of the viscometer one after another, the ENTER Button pressed and the rotor was allowed to rotate for few seconds for stabilization.

The root sleeve was then immerging until the rotor was allowed to rotate for few seconds for stabilization. The rotor sleeve was then immense until the mud touched the scribed line of the rotor sleeve; the mud button was pressed and the viscometer automatically carried out the measurement of the 600rpm and 300rpm. The equipment automatically calculated the 10 seconds and 10 minutes gel strength. It was observed that at the end of every 10 minutes the machine displayed, the value of plastic viscosity (pv) and the yield point (yp) along with 10 seconds and 10 minutes gel strength were recorded

pH Determination of the Clay Samples

The degree of acidity or alkalinity of mud is indicated by the hydrogen ion concentration, which is commonly expressed in terms of pH [7].

A neutral mud has a pH of 7.0. An alkaline mud has pH readings ranging from just above 7 for slightly alkalinity, to 14 for the strongest alkalinity. Acid mud range from just below 7 for slight acidity to less than 1 for the strongest acidity.

The determination of the Ph value of collected clays was aimed to indicate presence of impurities or contaminants within the sedimentary rock (clay). Mostly, pH of clay is mostly influenced by the environment and geological history of the deposit in a sedimentary basin.

The pHs of the collected samples were determine by using a freshly prepared mud which was re-stirred to obtain near to homogenous mixture.

The equipment employed to the determination of pH value include phydrion dispense, paper, masking tape, recording book, repents and multi-Hamilton beach mixer equipment.

Strip of the phydrion dispenser paper was removed and placed gently on the surface of each freshly prepared mud and the sufficient time was allowed to elapsed, for the paper to sock up filtrate and change colour.

The soaked paper strip was matched with chart on the dispenser from which the strip was taken pH was then obtained and the respective values recorded. The procedure was repeated for all the five samples of clay.

Determination of the Mud Weight

Mud weight is very important property of a good drilling mud [8]. It provides sufficient hydrostatic pressure to prevent influx by formation fluids, must have stronger density to float out the Lithology of the walls of the Bore-hole or oil well, but should not reduce the rate of penetration.

This test is necessary because it determine whether the prepared local mud samples posses all minimum required weight for oil well drilling.

The multi-Hamilton beech mixer and Bariod mud balance were the equipment used in this study while freshly prepared clay samples, rag, water, masking tape, recording book and biro were the reagents materials used.

The procedure involved pouring in the freshly prepared clay samples into a clean, dried mud balanced cup.

It was ensured some mud spilled on the outside of the cup through the vent, and the instrument base was set up so that it is approximately levelled.

The reading of the mud balance scale is taken and recorder properly against the mud type.

Table 6: Comparison of Properties of Local Clay with Foreign Bentonite Clay as a control

Table 4:Sample (Local Clay Mud)

Properties	Control/Sample (American Bentonite)	Ebonyi A	Abia B	Imo C	Enugu D	Anambra E
Density (ppg)	9.00	8.80	8.40	8.20	8.40	8.10
PH	9.0-11.00	5.65	4.5	5.4	5.8	5.2
Sand content (%)	0	0.50	0.80	1.20	1.40	1.60
Marsh funnel viscosity (sec/qt+)	52.00	30.00	30.00	30.60	30.4-	30.20
Filtrate volume (ml)	28.00	4.00	4.00	5.00	4.00	4.00
Cake thickness (inch)	$\frac{1}{32}$	$\frac{1}{32}$	$\frac{1}{32}$	$\frac{1}{32}$	$\frac{1}{32}$	$\frac{1}{32}$
Specific gravity	1.08	1.06	1/06	1.06	1.06	1.06
Methylene blue capacity	4.00	2.50	2.50	2.60	2.40	2.20
Bentonite equivalent (kg/m3)	20	35.625	35.00	37.00	38.00	38.00
Plastic viscosity (cp)	8.00	3.00	2.00	3.00	3.00	2.80
Apparent viscosity (cp)	13.00	4.50	5.00	4,80	5.00	3.80
Yield point (1b/100ft2)	11.00	4.00	4.00	4.00	4.00	4.00
Ca mg/lit	O	1001	1001	1001	1001	1001
Gel strength @ 10 min	9.00	3.00	3.00	3.00	3.00	3.00

RESULTS AND DISCUSSION

Some of the results from clays mud originated from five South Eastern Nigeria were found to be out of API Standard compares to American Bentonite mud that serves as a control. The rheological properties (PV, YP, and Gel strength, Filtration Loss and pH) of the local clays are not up to the API Standard when compared with the control.

The major differences in their rheological properties such as plastic viscosity, yield point and apparent viscosity as well as pH value of the local clay mud necessitates the beneficiation of the clay samples. The collected clay samples were beneficiated with barite ($BaSo_4$) derived starch, Potassium Chloride (KCL) Soda ash (Na_2CO_3) to improve the mud density, rheological strength and pH respectively.

Table5present the impact and effect of Barite ($BaSO_4$) on the clay sample A B C D E to enhance its density. The result obtained showed that local clay densities increased from 8. 80b/gal to 9.20b/gal at barite concentration of2g to 10g.

This shows that ($BaSO_4$) barite can be used as weighing material in the formulation of drilling fluid using South Eastern clays. It improves due to increase in sodium cat ions (NaH) and addition of soda ash concentration against pH of the local clay samples also indicates a remarkable improvement in the pH of the mud formulated with the local mud sample to API specification

Table 5:The Density of the Drilling Mud Close to API Specification

Local Clay Mud	Sample A Ebonyi	Sample B Abia	Sample C Imo	Sample D Enugu	Sample E Anambra
Barite content $BaSO_4$ (g)	2.00	4.00	6.00	8.00	10.00
Density 1b/gal	8.80	8.90	9.00	9.10	9.20

Pac R was also used during beneficiation process in order to improve the performance of the clay samples from South East Nigeria. The result is presented on the table **6** below.

Table 6: Effect of PAC R on the Rheological Properties of the Collected Clay Samples

Local Clay Mud Samples	Sample A Ebonyi	Sample B Abia	Sample C Imo	Sample D Enugu	Sample E Anambra

Pac R (g)	5.00	10.00	15.00	20.00	25.00
Apparent Viscosity (ap)	4.00	5.00	6.00	7.00	10.00
Plastic Viscosity (cp)	6.00	**8**.00	10.00	12.10	14.00
Yield Point 1b/100ft^2	**8**.00	**9**.00	10.00	11.00	12.00

Table 7: The Effect Soda ash and KCL on the Local Samples

Local Clay Mud Samples	**Sample A Ebonyi**	**Sample B Abia**	**Sample C Imo**	**Sample D Enugu**	**Sample E Anambra**
Soda ash, (Na_2CO_3) (g)	2.00	3.00	4.00	4.50	5.00
KCL (g)	5.00	10.00	15.00	40.00	50.00
Apparent Viscosity (ap)	6.00	7.00	9.00	10.00	12.40
Plastic Viscosity (cp)	4.00	4.00	6.00	7.00	8.00
Yield Point 1b/100ft^2) (YP)	4.00	7.00	8.00	9.00	10.00
PH	8.20	9.05	9.80	10.00	10.12

The analysis on the table 6 shows that the formulated drilling fluids rheological properties increased significantly with increase in the Pac R.

Thus, the apparent viscosity (ap) Yield point (YP) and plastic viscosity (cp) increased from 4.00ap, 8.01b/100ft^2 and 6.0cp to 10. 0ap, 12.01b/100ft^{2}and 14.00cp respectively.

Table7 present the impact of Soda ash (Na_2CO_3) and Potassium Chloride (KCL) on the clay samples (A-E).

The results indicate that an increase in the Soda ash (Na_2CO_3) and Potassium Chloride (KCL) content resulted in an increase in the strength and properties of the clay mud samples. Thus, the apparent viscosity (ap) Yield point (YP) and plastic viscosity (cp) increased from 6.00cp, 4.01b/100ft^2 and 4.0cp to 12.40ap, 10.01b/100ft^{2}and 8.00cp respectively.

CONCLUSION

South Eastern clay falls short of API minimum numerical value standard, though it was discovered that beneficiation process increases the rheological properties of the clay sample. The clay sample pH increased from an initial value of 8.20 to 10.12 at a concentration of 2.0g of Soda ash (Na_2CO_3) and 50g of Potassium chloride (KCL). The increase in pH value created an alkaline medium in the local clay mud that enhanced the solubility of the Pac R which in turn resulted in increase in the rheological properties of the clay samples, due to cat ion exchange in clay in reaction to the concentration of sodium cat ions. The apparent viscosity of the clay

In conclusion South Eastern clays could compete and total replaced foreign American bentonite when beneficiated with soda ash, potassium chloride and Pac R.

RECOMMENDATIONS

It is recommended that government should channel interest in research, exploration and exploitation of south eastern clay in Nigeria; this will help in reduction of imported clay bentonite by oil drilling companies in Nigeria, increase in employment and also boost the local content policy.

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