Comparative Analysis of a locally Sourced Edjeba Clay Material for drilling processes

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Abstract

Nigeria is greatly blessed with abundance of clay reserves but it has not been fully harnessed over the years for drilling operations in the oil and gas industry despite the cost of importation of the foreign bentonite, which takes a high percentage of the drilling operations. Attempts to use the local clay in Nigeria have yielded little or no result because of its low rheological properties and inability to meet up with API specification. Hence, this study after due experimental comparism of these local materials were adequately analyzed, it showed that Edjeba clay is suitable for oil and gas drilling operations which could substitute for the imported materials. Five mud samples were prepared using 350mL of fresh water to mix 25g of the local Clay. Another five mud samples were prepared using 350mL of water to mix 25g of the imported sodium-based bentonite. The high speed mixer was used to mix each mud samples until homogenous mixture was attained. The results obtained showed that the power law index (n) before and after beneficiation meet up with the API standard of n<1. These showed that the mud hydraulic property is effective i.e. it has the ability to lift and transport the cuttings. It also has the ability to clean the hole effectively. This study showed that local mud samples prepared from local clay possess little property of their own, but beneficiated local mud samples gave a good promising future to substitute the imported bentonite used for drilling operations.

Keywords: American Petroleum Institute, revolution per minutes, PAC (Additive), BXP (Additive), CMC (Additive).

Analyse Comparative D'un Materiau D'argile Edjeba D'origine locale Pour les processus de Forage

Resume

Le Nigéria est très doté d'une abondance de réserves d'argile, mais elle n'a pas été pleinement exploitée au fil des ans pour les opérations de forage dans l'industrie pétrolière et gazière malgré le coût de l'importation de la bentonite étrangère, qui prend un pourcentage élevé des opérations de forage. Les tentatives d'utilisation de l'argile locale au Nigéria ont donné peu ou pas de résultat en raison de ses faibles propriétés rhéologiques et de leur incapacité à rencontrer la spécification de l'API. Par conséquent, cette étude après le comparalisme expérimental dû de ces matériaux locaux a été analysée de manière adéquate, elle a montré que l'argile Edjeba convient aux opérations de forage pétrolier et gazier qui pouvaient remplacer les matériaux importés. Cinq échantillons de boue ont été préparés en utilisant 350 ml d'eau douce pour mélanger 25 g de l'argile locale. Cinq autres échantillons de boue ont été préparés en utilisant 350 ml d'eau pour mélanger 25 g de la bentonite à base de sodium importée. Le mélangeur à grande vitesse a été utilisé pour mélanger chaque échantillon de boue jusqu'à ce que le mélange homogène soit atteint. Les résultats obtenus ont montré que l'indice de la loi de l'électricité (n) avant et après la bienfaisance répond à la norme API de N <1. Ceux-ci ont montré que la propriété hydraulique de boue est efficace, c'est-à-dire qu'elle a la capacité de *soulever et de transporter les boutures. Il a également la capacité de nettoyer efficacement le trou. Cette étude a montré que les échantillons de boue locaux préparés à partir de l'argile locale possèdent leur propre propriété, mais que des échantillons de boue locaux ont bénéficié de substituer le bon avenir prometteur pour remplacer la bentonite importée utilisée pour les opérations de forage.*

Mots-clés: American Petroleum Institute, Revolution par minutes, PAC (additif), BXP (additif), CMC (additif).

تنعم نيجيريا كثيرًا بوفرة احتياطيات الطين ولكن لم يتم تسخيره بالكامل على مر السنين لعمليات الحفر في النفط والغاز... على الرغم من تكلفة استيراد البنتونيت الأجنبيالذي يأخذ نسبة عالية من عمليات الحفر لم تسفر محاولات استخدام الطين المحلي في نيجيريا عن نتيجة تذكر أو لم تسفر عن أي نتيجة بسبب خصائصه الريولوجية المنخفضة وعدم قدرته على تلبية مواصفات واجهة برمجة التطبيقات وبالتالي، تم تحليل هذه الدراسة بعد المقارنة التجريبية لهذه المواد المحلية أظهر أن طين إدجيبا مناسب لعمليات التنقيب عن النفط والغاز التي يمكن أن تحل محل المواد المستوردةتم تحضير خمس عينات من الطين من الماء لخلط 25 جرامًا mLمن المياه العذبة لخلط 25 جرامًا من الطين المحلي تم تحضير خمس عينات طينية أخرى استخدام 350 mLباستخدام 350 من البينتونيت المستورد القائم على الصوديوم تم استخدام الخلاط عالي السرعة لخلط كل عينات من الطين حتى يتم الوصول إلى خليط متجانس أظهرت أظهرت هذه أن الخاصية .1 > n النتائج التي تم الحصول عليها أن مؤشر قانون الطاقة (ن) قبل الانتفاع وبعده تلبية معيار واجهة برمجة التطبيقات الهيدروليكية الطينية فعالة لديها القدرة على رفع القصاصات ونقلها كما أن لديها القدرة على تنظيف الحفرة بشكل فعال أظهرت هذه الدراسة أن عينات الطين المحلية أعدت من الطين المحلي يمتلكون القليل من الممتلكات الخاصة بهم، لكن عينات الطين المحلية المفيدة أعطت مستقبلًا واعدًا جيدًا لاستبدال البنتونيت المستورد المستخدم في عمليات الحفر

Introduction

The energy of a nation is largely conditioned by the extent of prospective, surveyed and extracted natural resources. Hence, the Nigeria's economy is largely based on its petroleum resources and she is the largest oil producer in sub-Saharan Africa (Adewale I 2015). The Oil and Gas sector in Nigeria has many aspects where it functions, firstly, the confirmation of any natural resources on the Earth crust is through drilling.

Drilling is the process of making a hole in the Earth's surface for the purpose of creating access to the desired resource (hydrocarbons) below the Earth Crust (Ajugwe C et al. 2012). A lot of technological advancement has been put forth on how drilling operations can be carried out in a best economical and environmentally friendly way possible (Aigbedion I & Iyayi S E 2007). One of the vital elements in drilling operations is the drilling fluid commonly called "drilling mud".

Drilling fluid is basically a heterogeneous mixture of chemicals (such as barite, calcium carbonate), water or oil and bentonitic clay materials that are continuously circulated through the wellbore during drilling process. Drilling fluid has various properties such as Density, Alkalinity, Filtrate (water) loss and Filter cake thickness, Sand content, Mud weight and mud rheological properties (apparent viscosity, plastic viscosity, yield point, gel strength, e.t.c.) which play important role in designing efficient and optimized drilling operations. It is important to ensure that drilling fluids have the right rheological properties.

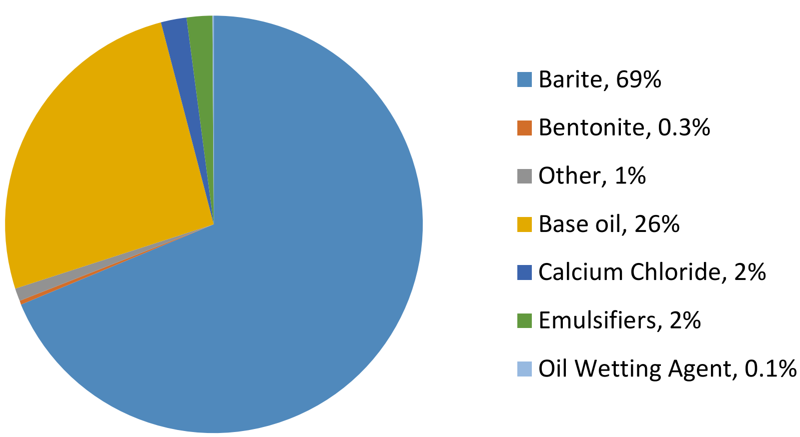
Drilling mud is basically composed of water, bentonitic clay and other chemicals such as barite, calcium carbonate and exhibits properties such as apparent viscosity, plastic viscosity and yield point which play important role in designing efficient and optimized drilling operation. These properties serve the functions of cleaning the rock fragments from beneath the bit and carry them to the surface as well as cooling and lubricating the rotating drill-string and bit (Aliyu A. 1996). Out of the constituents used for the formulation of drilling mud, bentonite has always been sourced from outside of this country ever since 1960 which had drastically led to the neglect of the local bentonite which is unhealthy for the economy of our country (Bloys, B N et al. 1994). This has also made the purchasing cost for drilling materials to be high. Hence, this research devices an alternative and easier means of treating our local bentonitic clay (Caenn, R & Chillingar, G.V 1996). so as to serve as substitute for the foreign grade bentonite.

Convectional Drilling Fluid Systems

A drilling mud is a complex fluid which comprises multitude of additives. The type and amount of additives is based on the drilling method employed and the type of reservoir to be drilled. The drilling mud can be broadly classified as:

- water based systems,
- oil- or synthetic-based systems,
- pneumatic (air, mist, foam, gas) “fluid” systems,
- emulsions and invert emulsions, e.t.c.

Drilling fluids are two-phase compounds: a fluid and solid phase which often contains a variety of chemicals which are formulated as required from a generally limited list of additives (Holdway, 2002). The type and amount of chemical additives included in the mud formulation varies according to the required characteristics of the mud depending on the well to be drilled. In general, the quantities of additives for OBM/SBM are less than that added to WBM (UKOOA, 1999a). Figures1.1a and 1.1b show an example of a typical water and oil-based drilling mud. The composition of drilling mud is continually being altered throughout the drilling process to solve particular down-hole problems that may be encountered (Neff, 2005).



Figures 1.1b: **Example of Typical Oil Based Drilling Mud Composition (Modified from UKOOA drill cutting programme, 1999a)**

Statistics
The preparation of the mud samples and table of results

The mud samples were prepared by weighing out 25grams of the clay samples using the mud balance. These measurements of each of the clay samples were poured into separate mixer cups containing 350mL of fresh water each (Apugo-Nwosu T U 2011). The clay samples and water were vigorously agitated with the high speed mixer to produce a homogeneous mixture. After mixing, the mud samples were kept in different containers and were aged overnight (16 hours) for adequate hydration after which the density, the rheological properties, the pH, the sand level, and the marsh funnel viscosity were tested and recorded in Tables I and II

Table I The Mud Weight, pH value, Sand Content and the Marsh Funnel Viscosity of the Mud Samples before beneficiation.

Mud samples	Weight of mud samples (g)	Mud weight (lb/gal)	pH value	Sand content (%)	Marsh funnel viscosity (sec/quart)	Cation Exchange capacity
Imported bentonite	25	8.6	10	0.2	37.5	75
Local clay	25	8.5	5.5	0.15	26	40

Table II The viscosity and Gel Strength of the Mud Samples before beneficiation.

Mud samples	Weight of mud samples (g)	Viscosity (cp)						Gel strength (lb/100ft^2)	
		3rpm	6rpm	100rpm	200rpm	300rpm	600rpm	10secs	10mins
Foreign bentonite	25	6	7	10	14	16	23	9	18
Local clay	25	1	2	3	4	6	7	1	2

The plastic viscosity, apparent viscosity, yield point, power law index and consistency index were calculated using the viscosities at 600rpm and 300rpm. The values obtained were tabulated in Table III.

Table III: The Plastic Viscosity, Apparent Viscosity, Yield Point, Power Law Index, and Consistency Index of the Mud Samples.

Mud samples	Weight of mud samples (g)	Viscosity (cp)		Plastic viscosity (cp)	Apparent viscosity (cp)	Yield Point (lb/100ft^2)	Power law Index (n)	Consistency index (dyne sec/cm3)
		300rpm	600rpm					511qt

Foreign bentonite	25	16	23	7	11.5	9	0.52	0.63
Edjeba clay	25	3	4	1	2	2	0.42	0.22

Table IV: Comparative analysis of the mud samples parameters with the API Standard of Mud Parameters before beneficiation.

S/N	Mud properties	API standard	Edjeba clay mud			Foreign bentonite clay mud		
			Property value	Discrepancy with API	Remark	Property value	Discrepancy with API	Remark
1	Mud weight (lb/gal)	8.65 – 9.60 (min. and max.)	8.5	0.15 – 1.10	Very low	8.60	0.05 – 1.0	Low
2	pH level	9.5 - 12.5	5.5	4.0 – 7.0	Very low	10	-	Good
3	Sand content (%)	1 – 2 (max.)	0.15	-	Good	0.2	-	Good
4	Marsh funnel viscosity	52 – 56 Sec/quart	26	26 - 30	Very low	37.5	14.5 – 18.5	Low
5	Cation exchange capacity	70 – 130 10 – 40	40	-	Chlorite	75	-	Montmorillonite
6	Viscosity at 600rpm dial reading	30 cp (minimum)	7	23	Very low	23	7	Low
7	Plastic viscosity (cp)	8 – 10	1	7 - 9	Very low	7	-	Good
8	Yield point (lb/100ft^2)	3 x plastic viscosity	2	22 - 28	Very low	9	-	Good
9	Power law index (N)	1 (maximum)	0.42	-	Good	0.52	-	Good

After observing the properties of the mud samples that were obtained, the rheological properties, density, and pH value (except the imported bentonite) were found to be lower than the required API standards. Therefore, there were need to improve or treat the mud samples with different additives to meet with the API standards.

Result

Beneficiation of the mud samples

Beneficiation means to add some additives to the prepared mud sample in order to improve certain properties of the mud. In this analysis, four different types of viscosifiers (also called fluid control agents) were used in order to improve its rheological properties and Caustic Soda, NaOH was also added to improve the pH of the local mud samples. The proportions to which the additives were added to each mud samples are tabulated in table 4.5.

a) ***Local clay:*** Due to the low rheological properties of the mud samples, 2g of different viscosifiers (also called flow control agent) were added separately to four out of the five mud samples to improve their various viscosities. The mud pH value was also improved consecutively with Caustic Soda (NaOH) of 0.5ml, 1.0mL, 1.5mL, and 2.0mL.
b) ***Foreign Bentonite*:** Due to the high rheological properties of the mud samples, different proportion of viscosifiers were added separately to four out of the five mud samples prepared but no pH control agent was added to improve the mud's pH.

Table V: Proportions of the additives that were used.

Additives		**Weight of additives**	
		Foreign Bentonite	Local Clay
Viscosifiers	Poly Aronic Cellulose (PAC)	1g	2g
	Carboxyl Methyl Cellulose (CMC)	1g	2g
	Baravis Xaintain Polymer (BXP)	1g	2g
	Hydroxyl Ethyl Cellulose (HEC)	0.2g	2g
pH control agent	Caustic soda (NaOH)	Nil	2cm^3

Modifying the pH of the Mud with Caustic Soda

The additive used to improve the pH was Caustic soda, NaOH. 0.5ml of NaOH was added consecutively to the mud until it reached 2.0ml and the corresponding pH values were determined using the pH paper strip.

Addition of viscosifiers to improve the rheological properties

- To improve the viscosity of the mud samples formulated with the imported sodium based bentonite, 1.0g of PAC, 1.0g of CMC, 1.0g of BXP and 0.2g of HEX were added to each of the mud samples.
- To improve the viscosity of the mud samples formulated with the local clay, 2.0g of PAC, 2.0g of CMC, 2.0g of BXP and 2.0g of HEX were added to each of the mud samples.
- The mixture of clay, water and viscosifiers were vigorously mixed and the homogeneous mixture with increased viscosity was allowed to age for 24 hours. After which the mud density, pH, and the rheological properties were determined and recorded in table VI, VII and VIII.

Figure I: (a) The local mud after beneficiation and (b) The imported bentonite mud after beneficiation.

Table VI: The Mud Weight of the Mud Samples after Beneficiation.

Mud samples	Additives	Concentration of additives in mud samples (g)	Mud Weight (lb/gal)
Imported Bentonite	BXP	1.0	8.6
	PAC	1.0	8.6
	CMC	1.0	8.6
	HEC	0.2	8.6
Local Clay	BXP	2.0	8.55
	PAC	2.0	8.6
	CMC	2.0	8.55
	HEC	2.0	8.65

Table VII: The Viscosity and Gel Strength of the Mud Samples after Beneficiation

Mud samples	Additives	Viscosity (cp)						Gel Strengths ($lb/100ft^2$)	
		3 Rpm	6 Rpm	100 rpm	200 rpm	300 rpm	600 Rpm	10secs	10mins
Foreign bentonite	BXP	31	32	47	56	60	72	34	41
	PAC	42	44	72	90	100	133	49	87
	CMC	23	25	45	60	70	90	25	58
	HEC	14	15	22	30	35	47	13	20
Local clay	BXP	3	4	15	22	28	43	3	5
	PAC	6	9	43	59	71	94	6	7
	CMC	5	7	39	57	68	95	4	7
	HEC	2	3	17	27	35	50	2	3

Table VIII: The plastic Viscosity, Apparent Viscosity, Yield Point, Power Law Index, and Consistency Index of the Mud Samples after Beneficiation.

Mud samples	Additives	Viscosity (cp)		Plastic viscosity (cp)	Apparent viscosity (cp)	Yield Point (lb/100ft^2)	Power law Index (n)	Consistency index (dyne sec/cm3)
		300rpm	600rpm					511qt
Foreign bentonite	BXP	60	72	12	36	48	0.26	11.8
	PAC	100	133	33	66.5	33.5	0.41	7.75
	CMC	70	90	20	45	50	0.36	7.41
	HEC	35	47	12	23.5	23	0.43	2.40
Local clay	BXP	28	43	15	21.5	13	0.62	0.59
	PAC	71	94	23	47	48	0.41	5.51
	CMC	68	95	27	47.5	41	0.48	3.41
	HEC	35	50	15	25	20	0.51	1.46

Table IX: Comparative analysis of the mud samples parameters with the API Standard of Mud Parameters after beneficiation.

Additives	Mud properties	API standard	Edjeba clay mud			Foreign bentonite clay mud		
			Property value	Discrepancy with API	Remark	Property value	Discrepancy with API	Remark
Caustic soda	pH level	9.5 – 12.5 (min. and max.)	10	-	Good	10	-	Good
BXP	Mud weight (lb/gal)	8.65 – 9.60 (min. and max.)	8.55	0.10 –1.05	Low	8.6	0.05-1.0	Low
	Viscosity at 600rpm dial reading	30 cp (min.)	43	-	Good	72	-	Very good
	Plastic viscosity (cp)	8 - 10	15	-	Good	12	-	Good
	Yield point (lb/100ft^2)	3 x plastic viscosity	13	-	Good	48	-	Good
	Power law index (N)	1 (max.)	0.62	-	Good	0.26	-	Very good
PAC	Mud weight	8.65 –	8.6	0.05-1.0	Low	8.6	0.05-1.0	Low

	(lb/gal)	9.60 (min. and max.)						
	Viscosity at 600rpm dial reading	30 cp (min.)	94	-	Very good	133	-	Very good
	Plastic viscosity (cp)	8 - 10	23	-	Very good	33	-	Very good
	Yield point (lb/100ft^2)	3 x plastic viscosity	48	-	Very good	33.5	-	Very good
	Power law index (N)	1 (max.)	0.41	-	Good	0.41	-	Good
CMC	Mud weight (lb/gal)	8.65 – 9.60 (min. and max.)	8.55	0.10 –1.05	Low	8.6	0.05-1.0	Low
	Viscosity at 600rpm dial reading	30 cp (min.)	95		Very good	90		Very good
	Plastic viscosity (cp)	8 - 10	27		Very good	20		Very good
	Yield point (lb/100ft^2)	3 x plastic viscosity	41		Very good	50		Very good
	Power law index (N)	1 (max.)	0.48		Good	0.36		Good
HEC	Mud weight (lb/gal)	8.65 – 9.60 (min. and max.)	8.65	-	Good	8.6	0.05-1.0	Low
	Viscosity at 600rpm dial reading	30 cp (min.)	50	-	Good	47		Good
	Plastic viscosity (cp)	8 - 10	15	-	Good	12	-	Good
	Yield point (lb/100ft^2)	3 x plastic viscosity	20	-	Good	23	-	Good
	Power law index (N)	1 (max.)	0.51	-	Good	0.43	-	Good

Discussion

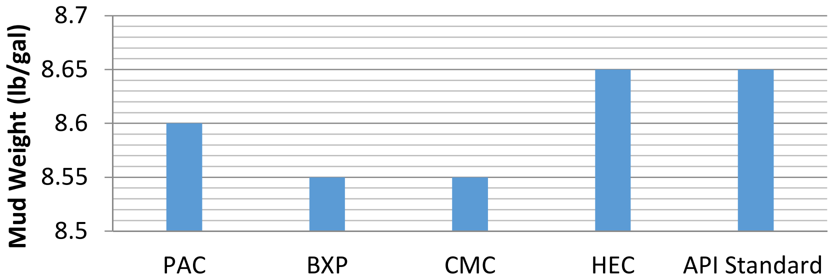


Figure II: Density of local clay samples with 2.0g concentration of PAC, BXP, CMC and HEC

The Sand Content of the Clay Samples

The result obtained from the sand content test, indicates that the sand content of the local clay was okay when compared with that of the imported bentonite and it is also within the limit of the API maximum requirement of 1-2% while the local mud sample showed a sand content of o.15% which is a very good result and that of the imported mud sample gave a sand content of 0.2%. This clay with a sand content of about 0.15% indicates that when it is used for drilling, it can provide lubrication to the drill string and other drill tools, since the mud contains solids softer than the pipe and casing. It will not have the problem associated with clays of high sand over drilling equipment and excess of this sand can also cause the blockage of bit nozzle.

The Rheological Properties of the Clay

The rheological properties were analyzed from Tables VII and VIII, the values of viscosity, plastic viscosity, apparent viscosity and yield point obtained at 300rpm and 600rpm dial readings respectively for the local mud samples were very much less than the minimum requirement of API standard (30cp) as shown in Figure 1 (a) and (b). The imported bentonite possesses rheological properties that are a little bit lower than the minimum requirement of API standard.
These poor rheological properties of the local clay indicate that it cannot be used as substitute for the foreign bentonite that is used for drilling unless it is improved by adding some additives (beneficiation) because of its inability to suspend cuttings in the hole and it cannot provide buoyancy effect to the drill string and casing.

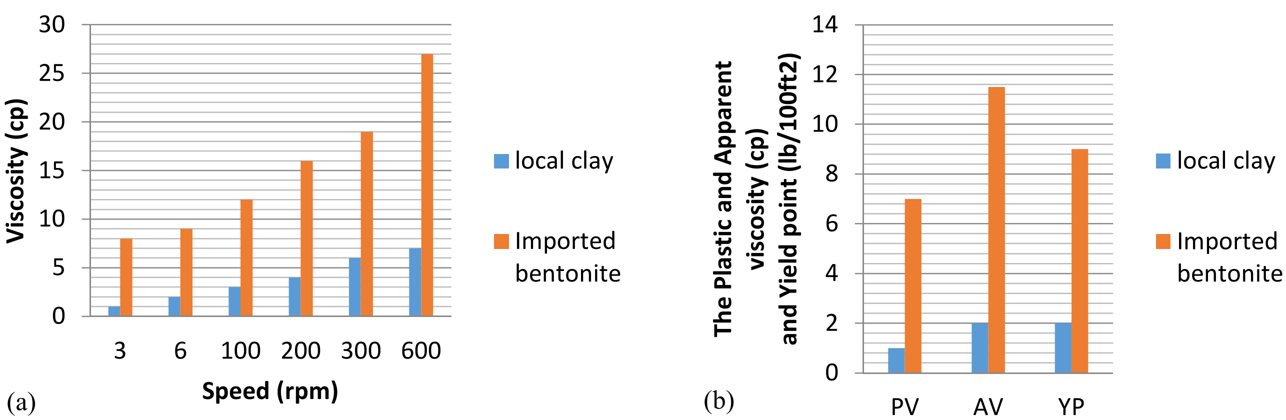


Figure III: (a) The viscosity of the mud samples before beneficiation.
(b) The plastic viscosity, apparent viscosity and yield point of the mud samples before beneficiation.

Therefore, in order to boost the rheological properties of the mud samples, 2g of BXP, CMC, PAC, and HEC were added as viscosifiers to four samples prepared with 25g of the local clay/350mL of fresh water. Also, 1g of BXP, CMC, PAC, and HEC were added as viscosifiers to four samples prepared with 25g of the local clay/350mL of fresh water. From the results obtained in Table VII and VIII, it was observed that all the viscofiers improved the rheological properties of the mud samples above the minimum requirement of API standard (30cp). The rheological properties of both the local and the foreign mud samples showed a remarkable improvement at concentration of 2.0g of PAC in 25g of local clay/350ml of fresh water and 1.0g of PAC in 25g of foreign bentonite/350ml of fresh water (Figure 1.4) thereby increasing the efficiency of the mud to be used in drilling operations and also a better substitute for the foreign bentonite.

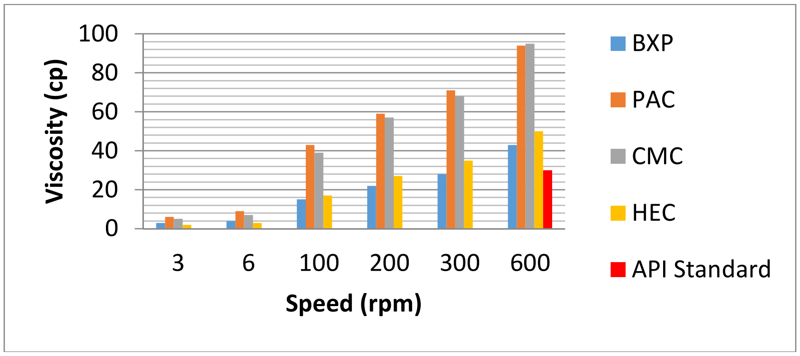


Figure IV: The viscosity of the local mud samples when beneficiated with equivalent concentration (2g) of BXP, PAC, CMC and HEC.

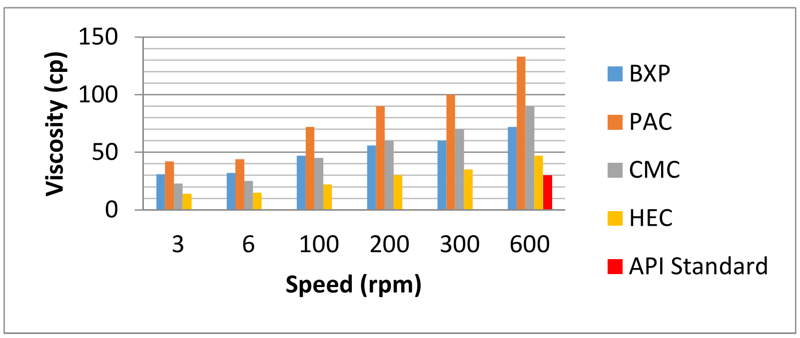


Figure V: The viscosity of the foreign mud samples when beneficiated with equivalent concentration (2g) of BXP, PAC, CMC and HEC

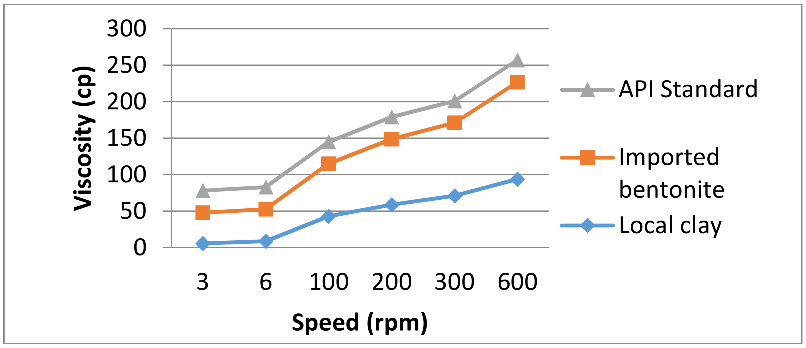


Figure VI: The viscosity of the local and foreign mud samples when beneficiated with 2.0g and 1.0g of PAC

When 1.0g of HEC was added to the imported bentonite, the mud was too viscous and the rheological properties could not be checked. Therefore, the concentration of HEC was reduced to 0.2g which still gave a viscosity above the minimum requirement of API standard (30cp). For the local mud that 2.0g of HEC was added, a distinct separation between the clay and water was observed after ageing for adequate and when it was agitated for 5mins, the mud foams and a de-foamer was used to remove the foam because it could reduce the mud weight property of the mud.
The results obtained in table 1.3 and 1.8 show that the power law index (n) before and after beneficiation meet up with the API standard of $n<1$. These show that the mud hydraulic property is effective i.e. it has the ability to lift and transport the cuttings. It also has the ability to clean the hole effectively.

Conclusion
From the results obtained, it could be deduced that the local clay that was sourced from Edjeba, Warri, Delta state possesses a little property of their own and they fall within the class of chlorite as their clay. But when beneficiated with 2ml of caustic soda, NaOH and 2.0g of concentration of BXP, PAC, CMC, and HEC, it had a great influence on the mud's pH and the viscosity and flow properties.

This study shows that local mud samples prepared from local clay possess little property of their own, but beneficiated local mud samples gave a good promising future to substitute the imported bentonite used for drilling operations.

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