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A Study of the Beneficiation Potential of Cow Bone and Coconut Husk (*Cocos nucifera*) as Additives on Local Clay for Mud Quality Improvement

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Abstract: *Activities involving oil and gas exploration as well as production exist virtually every part of the globe where hydrocarbon deposits are deemed to occur. In order to produce these hydrocarbons, the industry relies on a number of oilfield chemical formulations; one of such chemical formulations is the drilling fluid. The dependency on foreign materials in drilling mud formulation poses environmental, supply chain disruptions and sustainability challenges. This study explores the beneficiation of local clay using cow bone and coconut shell as additives to enhance its properties for use in drilling mud. The approach involves blending local clay and foreign bentonite to reduce importation and dependency on foreign material while maintaining or improving the required rheological and filtration properties. Laboratory experiments assess the impact of these additives on key drilling mud parameters such as rheological properties, viscosity, pH, fluid loss control, filtration control. The obtained data showed that the beneficiated mud samples, (Sample B, C, and D) did not meet the API standard specifications in terms of rheological and filtration properties with sediments seen. While the samples, (Sample A and D) both fell within the API standard specifications with sediments seen been negligible, making them suitable for drilling mud operations. A notable recommendation to this study would be to try more blended ratios and possibilities of using foreign and other locally sourced additives.*

Keywords: Beneficiation, Cow bone, coconut husk (*cocos nucifera*), additives, local clay, foreign clay, mud quality, drilling mud, sustainable additives, environmental impact, mud rheological and filtration properties.

1.0 INTRODUCTION

Drilling mud, the fluid mixture used in rotary drilling, is as important to petroleum resource development as blood is to the human body (Barett, 2011). Activities involving gas and oil exploration as well as production exist virtually every part of the globe where hydrocarbon deposits are deemed to occur. In order to produce these hydrocarbons, the industry relies on a number of oilfield chemical formulations; one of such chemical formulations is the drilling fluid (Kevin, Anthony, Bala and Izunna, 2020). For drilling operations to be successful, the use of drilling fluids must be employed which is formulated from combination of clay (mostly bentonite) and other materials to aid drilling. Though Nigeria has a substantial amount of clay deposits, it is not fully used during drilling operations in the country due to its inability to meet API standards for drilling fluid (Igwilo, Uwaezuoke, Okoli, Franklin and Emeka, 2020).

The most commonly used clay in drilling fluid formulation is Bentonite. Bentonite having sodium cation 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 and is required in the formulation of drilling fluid (Suleiman and Bilal, 2019). Since the success of drilling operations depends on the proper selection of drilling fluid system, some of the bentonites used in mud formulation in Nigeria are imported to avoid catastrophe related to using substandard bentonite. According to previous research, beneficiation of Nigerian bentonite from its predominant calcium-based composition to sodium-based clay can go a long way in improving its properties. Bentonite is the main substance which provides fluid loss control in the drilling fluid as it aids filter cake formation. Other fluid loss control agents are additives that are added to drilling mud during formation to reduce the loss of fluid from the mud into the drilled formation. These additives help to minimize formation damage, maintain hole integrity, reduce log analysis problems, protect water sensitive shale, reduce fluid loss to protective formation and reduce hole washout to achieve better casing and cementing jobs (Igwilo *et al.*, 2020).

However, these additives are non-biodegradable and environmentally hazardous. Therefore, there is a need to seek to identify alternate additives that are environmentally friendly, biodegradable, and sustainable, while also maintaining the properties of efficient drilling fluids such as activated carbon (Jasper, Emeka, Elizabeth, Kinigoma, Mary and Azubuike, 2023).

Aim and Objective of the Paper

The aim of this study is to explore the potential of cow bone and coconut shell as additives for improving the properties of local clay-based drilling mud.

i. To prepare local additives from locally sourced material (cow-bone and coconut shell) and prepare the blended clay samples
ii. To investigate the effects of cow bone and coconut husk additives on the rheological properties, filtration, and lubrication properties of drilling mud.
iii. To optimize the formulation of drilling mud using the selected additives.

2.0 LITERATURE REVIEW

Oil and gas had already been used in some capacity, such as in lamps or as a material for construction, for thousands of years before the modern era, with the earliest known oil wells being drilled in China in 347 AD. From these initial discoveries, new businesses were created, with the coal industry now also seeking to create the oils developed by Young and Gesner. Polish engineer, Ignacy Łukasiewicz improved Gesner's method to more easily distil kerosene and petroleum in 1852, opening the first 'rock oil' mine in Bóbrka, Poland in 1854. The late 18th century and the early 19th century marked the creation of major oil companies that still dominate the oil and gas industry today. In the late 20th century, changes in the oil market moved influence from generally oil-consuming areas such as the US and Europe to oil-producing countries. Iran, Iraq, Kuwait, Venezuela and Saudi Arabia formed the Organization of the Petroleum Exporting Countries (OPEC) in 1960 in response to multinationals in the 'Seven Sisters' including ExxonMobil – at the time split into Esso and Mobil – Shell and BP, which operated from oil-consuming countries (UMAR, 2019).

They are various drilling methods use to carry out drilling processes: Cable tool drilling; auger tool drilling and rotary tool drilling. (Yuvika, Suraj, Serisha, and Amir, 2018) Drilling fluids are used principally in rotary drilling since the early 20th century, which is the practice of well drilling implemented by means of a rotating bit. (Gerali, 2019). Drilling fluids consists of several types: Water based fluids; Oil based fluid or synthetic based fluids; Pneumatic based fluids. Drilling fluid selection is a crucial component in reducing drilling time and expense; water-based drilling fluids are preferred over oil and synthetic fluids for drilling oil and gas wells in sensitive locations where oil-based fluids are not required owing to cost and environmental implications. As a result of the development of high-performance and ecologically friendly fluids, water-based fluids are preferred (Nachiket, 2021).

There are specific properties which influences the performance and stability of drilling operations. Common properties include: Fluid Density; Viscosity; Filtration control and filter cake; Sand content; Mud pH.

METHODOLOGY

3.1 Materials

3.1.2 Local Clay and Foreign Clay

Local clay (Okada clay) and foreign clay (Bentonite) were sourced from Baroid Nigeria.

3.1.2 Plant Waste

Fresh coconut husk waste gotten from the fruiterer in front of PTI school gate.

3.1.3 Animal Waste

Fresh cow bone was gotten from Port Harcourt Market. The open air burnt cow-bone was sourced from Osubi Market

3.1.4 Other Materials

Material	Model
Oven	(Thermo Fisher)
Furnace	(Carbolite Gero)
200 mesh sieve size	(W.S Tyler)
Analytical Balance	(Mettler Toledo)
Direct Indicating Viscometer (Rheometer)	Model 35SA (Fann Instrument)
pH indicator paper	(Fisher Scientific)

Mortar and Pestle	(Fisher Scientific)
Distilled water	
Mud Balance	(OFITE)
API Filter Press	(OFFITE)
API Standard Filter Paper	(Fahn Instrument Company)

3.2 Methods

3.2.1 Additive Preparation

3.2.1.1 Coconut Husk Additive (Akinlabi, Quardi, Bankole, and Koleoso, 2015)

The coconut husk was gotten from the fruiterer in front of PTI school gate. It was dried constantly underneath the sun for two weeks to remove moisture and was sectioned into two batches; Batch A and Batch B.

Batch A was grinded with a grinder at Effrun Market to minute particle size and sieved with a 200-mesh sieve size.

Batch B was burnt in the furnace of the Institute biology laboratory at a 493 degree Celsius till it turned into black soot and was crushed to powder form with the mortar and pestle. It was sieved after using the 200-mesh particle size sieve.

Both are then stored away in well labelled containers.

3.2.1.2 Cow Bone Additive (Akinlabi *et al.,* 2015)

i. **Furnace Burnt**

The fresh cow bone was collected from the abattoir in Port-Harcourt city market. It was washed of blood and beef remnants to keep it clean. After which, it was properly oven dry to remove all forms of moisture.

The furnace was set at a temperature of 693 degree Celsius and the cow bone was burnt 15 minutes and the burnt bone was retrieved back and crushed into black powder solid using a mortar and pestle.

The solid powder was sieved using a 200-mesh particle size sieve.

It was then stored in a well labelled container.

ii. **Open Air Burnt**

A visit was paid to Osubi Market where cow bones are burnt in the open. Some quantity of these burnt cow bones were collected in a sample bag. The collected samples were grinded to powder form. The white powdered solid was sieved using the 200-mesh particle size sieve. It was then stored in a well labelled container.

Table 3.1: Showing The Ratio of Foreign and Local Clay Blending

Sample	Ratio	Foreign Clay (Bentonite Clay)	Local Clay (Okada Clay)	Additives used
A	7:3	15.4g (70%)	6.6g (30%)	Burnt coconut husk
B	5:5	11g (50%)	11g (50%)	Open air-dried coconut husk

C	3:7	6.6g (30%)	15.4g (70%)	Burnt furnace cow bone
D	1:1	22g (100%)	Nil	Open air burnt cow bone
E	1:1	Nil	22g (100%)	Open air burnt cow bone
F	Control	22g (100%)	Nil	Poly Aonic Cellulose (PAC)

3.3 Formulation of Drilling Mud (American Petroleum Institute (Api) Drilling Mud Production Standards)

The various quantities of the clay in different ratios which sum up 22g was measured using an electronic weighing balance and 350ml of water was measured using a graduated cylinder. The raw materials was poured, one after the other with an interval of 5 minutes into the steel cup of the single spindle mixer. As each material was being put into the mixer, the mixer was powered to cause the spindle to rotate and mix the contents inside the steel cup being held at a fixed position. The contents in the mixer steel cup was allowed to age for about 30 minutes after all materials was completely applied into the mixer steel under stirring condition and total uniformity of the materials was obtained which gave finely formulated water-based drilling mud whose color appeared brownish. The production methods and determination of the rheological and allied properties of the drilling muds was carried out based on the American Petroleum Institute (API) drilling mud production standards. The mixing method used was adopted.

Drilling mud balance was used to measure the density of the mud. Viscometer was used for the measurement of rheological properties of the formulated drilling mud. The rheological readings, API Testing, 600 revolution per minutes (RPM), 300 RPM, 6 RPM and 3 RPM were recorded. Also,10 seconds and 10 minutes gel strength values were recorded. The plastic viscosity and yield point values was appropriately evaluated. The pH meter was used to measure the pH of the formulated drilling mud as well as drilling additives (Cyprian, Gordian and Monday, 2021)

Note: The process was repeated for all six samples and the additives were added after a complete cycle for all analysis in a 2g proportion for each sample.

3.4 Mud Filtration Test (API Recommended Practice 13B-1)

i. **Preparation:** The drilling mud was heated to the desired temperature (usually 150°F or as specified). The mud was stirred to ensure it was well-mixed.

ii. **Set Up:** A filter paper was placed in the filtration apparatus (API filter press). The mud sample was poured into the apparatus.

iii. **Pressure Application:** 100 psi of pressure was applied using nitrogen or compressed air. The timer was set for 30 minutes.

iv. **Filtrate Collection:** The filtrate (water and small particles) was collected over 30 minutes. The volume of the filtrate was recorded.

v. **Cake Measurement:** After the test, the filter cake was removed. Its thickness was measured using a vernier caliper.

vi. **Reporting:** The filtrate volume and filter cake thickness was reported in (ml) or (inches or mm). This test measured the fluid loss and cake formation of the drilling mud.

Figure 4.1 furnace burnt cow bone additive.

Figure 4.2 open-air burnt cow bone additives.

4.0 RESULTS AND DISCUSSION

4.1 Results

4.1.1 The 200-mesh sieve size particle of cow-bone are represented in figure 4.1 and 4.2 respectively are

4.1.2 The 200-mesh sieve size particle of coconut shell are represented in figure 4.3 and 4.4 respectively

Figure 4.3 furnace burnt coconut husk additive

Figure 4.4 open-air dry coconut husk additive

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4.1.3 Investigation of the effects of cow bone and coconut shell additives on the rheological properties, filtration, and lubrication properties of drilling mud.

Table 4.4: Addition of 6g drilling mud local additives

WITH 6 GRAMSOF ADDITIVES					
Rheological Properties	Sample A (7:3)	Sample B (5:5)	Sample C (3:7)	Sample D (FC)	Sample E (LC)
pH	10	6	8	12	6
600 rpm	16	16	6	23	3
300 rpm	11	11	3	16	1
200 rpm	7	9	1	13	0
100 rpm	4	7	0	10	0
6 rpm	2	4	0	6	0
3 rpm	0	3	0	5	0
10 sec. gel strength	1	3	0	5	0
10 min. gel strength	1	4	0	7	0
mud weight	8.65	8.3	8.55	8.7	8.45
plastic viscosity	5	5	3	7	2
apparent viscosity	8	8	3	11.5	1.5
Yield point	6	6	0	9	-1
Yeild stress	-2	2	0	4	0
Power law index (n)	0.540254628	0.540254628	0.999419586	0.523258073	1.584042566
consisttency index (k)	1.93495607	1.93495607	0.030120903	3.129170729	0.000262086

Table 4.5: Filtration Properties of Drilling mud formulated

Samples	**Fluid Loss (ml)**	**Filter Cake (mm)**
Sample A	36ml/30mins	1.2mm
Sample B	102ml/30mins	2.85mm
Sample C	47ml/30mins	1.0mm
Sample D	23ml/30mins	1.6mm
Sample E	119/30mins	1.5mm
Control	8.4ml/30mins	1.4mm

Table 4.6: API specification 13A (SPEC 13A)for drilling fluid/clay test cited from (Ajugwe, Oloro and Akpotu, 2012).

Drilling Fluid Properties	**Numerical Value Requirements**
pH @ room temperature	8.5-10.5
Mud weight	8.5 min – 9.60 max
Plastic viscosity	8 – 10 cp
Apparent viscosity	10 – 50 cp

Yield point (lb/100ft^3)	3 * plastic viscosity
Yield stress(lb/100ft^2)	5-30
Power law index (n)	1
Consistency index (k)	0.1 – 1 Pa.s^n
Fluid loss (ml)	15ml max/ 30 minutes
Filter cake (mm)	<2 mm
Gel Strength (10 seconds)	2-10 (lb/100ft^2)
Gel Strength (10 minutes)	5-30(lb/100ft^2)

4.2 Discussion of Results

4.2.1 Comparison on the optimization of the formulated drilling mud using the selected additives with control and API standard.

Rheological experiments were performed to determine the parameters of interest in this paper. The test was conducted on six mud samples which included the control sample with different additives (Table 3.1). Foreign clay and local clay from Bariod Nigeria were use as the base clay. Table 4.1- Table 4.5 displayed the data of the results gotten across each sample which are in turn compared with the API standards for each rheological parameter to check if they met the API specifications.

4.2.1.1 Mud Density

API Standard: 8.5- 10.5 (ppg)

The results gotten for the densities of the mud samples are shown in Table 4.1- Table 4.4. It was observed as the individual additives increased from 2 g to 6 g, the densities of samples A, B, C, D, E and control sample, also increased/decreased from 8.55 ppg to 8.65 ppg, 8.55 ppg to 8.35 ppg, 8.5 ppg to 8.55 ppg, 8.6 ppg to 8.75 ppg, 8.35 ppg to 8.45 ppg and 8.6 ppg to 8.85 ppg for samples A, B, C, D, E and control sample respectively. On the other hand, the difference in the densities of samples A, B and C is minimum. The mud densities for Sample A (8.65 ppg), C (8.55 ppg) and D (8.7 ppg) and control sample (8.85) satisfied the API standard when 6 g of individual additives were added to the fluid (Tables 4.1 to 4.4). In comparison, the locally sourced drilling mud and the imported mud densities were nearly the same.

Unlike the other samples, Sample B and E did not meet the API standard,

4.2.1.2 pH Level

The results gotten for the pH of the mud samples are shown in Table 4.1 to Table 4.4. Respectively, it was observed that upon addition of 6 gram individual additives, the pH of mud sample A increased from 10-12 in sample D, with sample A, E and control sample remained the same with no change and sample B had a pH decrease from 9 to 6.

Sample A, D and control sample met the API standard specifications of (pH 8.5-12.5).

4.2.1.3 Plastic Viscosity (PV) and Apparent Viscosity (AV):

table 4.4 showed the increased value of PV and AV respectively for each sample upon addition of individual additives when compared to Table 4.1. This shows the significant increase of PV and AV from the blended samples without additives to when additives were added.

The values gotten met the API standard specification (Table 4.6).

4.2.1.4 Yield Point

Results gotten for the yield point was shown in Table 4.1 to Table 4.4. Respectively, it indicated a significant increase for the yield point across each sample upon addition of individual additives, with an exception to sample C whose yield point remained at zero upon addition of additives.

4.2.1.5 Power Law Index (N) & Consistency Index (K):

Table 4.1 to Table 4.4, shows the significant increase of 'n' and 'k' values of respective beneficiated samples. The values seen falls in the accepted range of 0.1 to 1 specified by API. This makes it suitable for industrial activity

4.2.1.6 Fluid Loss

The result for the fluid loss value across each sample after beneficiation is shown in Table 4.5. The test was separately carried out for sample A, B, C, D, E and Control at room temperature and each had a result of 36ml, 102ml, 47ml, 23ml,119ml and 8.4ml. Sample A, B, C, D and E failed to meet the API standard which is 15ml maximum.

4.2.1.7 Filter Cake Property

The results of the filter cake measurements of the beneficiated samples are shown in Table 4.5. The filter cake measurement across each sample A, B, C, D, E and control sample were 1.4mm, 1.2mm, 2.85mm, 1.0mm, 1.6mm, 1.5mm and 1.4mm. With an exception of sample C, all other samples fell in the within the API standard specification of less than two (< 2).

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

Generally, in the rheological properties analysis carried out above, it was observed that the difference in the mud density, plastic viscosity, apparent viscosity, yield point, filter cake measurements, filtrate volume and pH values of the local clay samples:

i. **Sample B, C and E:** The results gotten from the analysis of these three samples showed how the increasing concentrations of individual local additives used had minimal significant effect on the drilling mud rheology of each sample which had local clay in higher proportions. An observation on the sedimentation property of all three samples was that sedimentation occurred. Thus, making them unfit to carry out drilling mud operations as they do not fall within the API RP–13B standard for drilling mud fluid.

ii. **Sample A and D:** The results gotten from the analysis of these three samples showed how the increasing concentrations of individual local additives used had a significant effect on both beneficiated mud samples which had foreign clay in higher proportion, with the initial rheology of the mud increasing. An observation on the sedimentation property of both samples were made, with (Sample D) having no sediments and (Sample A) having minimal sediments which can be considered negligible. Thus, both fell within the API RP–13B standard for drilling mud fluid.

This study shows that a beneficiated local mud sample gives a good promise for any drilling purpose at optimum clay and additives concentrations. it has been seen that the utilization of these clays after proper beneficiation and treatment will pose no harm to surface and subsurface facilities, and will also represent a value added to the nation's economy by preventing the importation of high-quality bentonite clay.

5.2 Recommendation

i. A possible ratio of 6:4 an 8:2 between the foreign and local clay can be tried.
ii. The use of these local additives across each individual mud samples.
iii. The use of foreign additives on a blended clay drilling mud sample.
iv. Evaluate the aging tendency of the mud sample as a comparison to non-aging sample.
v. The combination of two or more of these locally sourced additives in beneficiating the drilling mud formulated.

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