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Suitability of Using Agbarha Clay for Drilling Mud Formulation in Oil and Gas Industry

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Abstract In this research, a locally sourced clay from Niger-Delta Agbarha clay deposit formation was processed and treated to meet up with API standard specification for drilling fluid. Clay concentrations of 17.5 g, 21.0 g and 24.5 g of the local mud (Agbarha clay) and foreign Bentonite mud was prepared and analyzed using a standard measuring techniques. Laboratory analyses of the Properties of the Sample Mud (Agbarha clay) was compared with that of API Numerical Value Specification before and after beneficiation. The result shows that sample mud Weight, Apparent Viscosity (cp), Plastic Viscosity, Yield Point, Gel Strength (10 sec), Gel Strength (10min) showed values lower or a little short of API minimum numerical value standard while pH, Sand Content and "n" factor give a values that are higher than thatof standard API minimum numerical value after aging for 48 hrs without beneficiation. Therefore, there is a need to beneficiate this local mud sample (Agbarha clay) to meet that of API standard specification. After beneficiation with 5g Hydroxyl Ethyl Cellulose (HEC), the sample mud sand content remains the same; Mud weight, Apparent Viscosity, Plastic Viscosity, Yield Point, Gel Strength(10sec) Gel Strength (10min), "n" factor increased, pH of the mud sample reduced; all to values within API numerical value specification for standard drilling mud. Based on this research, Agbarha clay can therefore be recommended for formulation of drilling mud and can also serve as a substitute to foreign Bentonite mud. This will conserve foreign exchange, generate more employment and also enhance Nigerian local content development in the drilling component of oil and gas industry.

Keywords Beneficiation, Filtration properties, Rheological properties, Agbarha clay, Drilling fluid

Introduction

A drilling fluid, or mud, is any fluid that is used in a drilling operation in which the fluid is circulated or pumped from the surface, down the drill string, through the bit, and back to the surface via the annulus with the main aim of aiding tools during oil and gas well (hole) drilling operations. This drilling fluid is a mixture of clay, water or oil and special minerals and chemicals. Clay is a stiff, sticky fine-grained earth, typically yellow, red, or bluish-gray in color and often forming an impermeable layer in the soil. Clays as they occur in nature are composed of various clay minerals, such as montmorillonite, illite, and kaolinite, of which montmorillonite is by far the most active. Clay minerals are particularly active colloids, partly because of their shape—tiny crystalline platelets or packets of platelets—and partly because of their molecular structure, which results in high negative charges on their basal surfaces, and positive charges on their edges. Interaction between these opposite charges profoundly influences the viscosity of clay muds at low flow velocities, and is responsible for the formation of a reversible gel structure when the mud is at rest. When clays are mixed with water, the viscosity of the resulting mud per unit weight of clay added depends on the proportion of the various clay and other minerals present. Commercial clays that are used in drilling muds are rated by their yield, which is defined as the number of 42-gallon barrels (0.16 m3) of mud with an apparent viscosity of 15 centipoises produced by a ton (2,000 Ib; 907 kg) of clay. Example of such commercial clay is Wyoming bentonite, which contains about 85% montmorillonite, has by far the greatest yield [9]. It has been reported that the occurrence of more than 2 billion metric tons of bentonite reserve in Nigeria and the successful development of oil-well drilling mud from same. As of today, proven reserve has risen to more than 4 billion MT [3]. The industrial demand of bentonite clays is as a result of the distinct characteristics of bentonite clays; thixotropic, swelling and absorption properties. Research over the past several years has clearly shown that drilling activities in the petroleum and ground-water development industries in Nigeria have consumed, and are still consuming large amounts of clays (mostly bentonite) for drilling muds, all of which are imported despite the presence of large reserves of clay in Nigeria [11]. Prior to the government's initiative to develop local content, the cost of importation of bentonite for drilling activities in Nigeria runs to millions of dollar annually which has been detrimental to the economy of the country considering that about 5 to 15% of the cost of drilling a well which ranges between $1 million to $100million accounts for drilling fluids [4].The selection of the most suitable mud type and mud properties, and the efficient engineering support whilst drilling will help to ensure a safe and successful operation. Any problem where the mud fails to meet its requirements can not only prove extremely costly in materials and time, but also jeopardize the successful completion of the well and may even result in major problems such as kicks or blowouts. Several authors [7],[9], [10], [11], [13],[14] had worked on Nigerian local clay samples, but none has been able to work on suitability of using Nigeria local clay from Agbarha community in Delta State as a drilling fluid. The objectives of this study is therefore to investigate the suitability of using Agbarha clay for drilling fluid (mud) formulation in oil and gas industry in regard to its properties and compare them with that of imported bentonite properties using the API (American Petroleum Institute) specifications. Subsequently, Agbarha clay will then be recommended or qualify as substitute to the imported bentonite clay. This study will enable the performance of Nigerian clay to be benchmarked against the imported bentonite.

2. Material and Methods

2.1. Sample Collection

The clay sample used for this project work was collected at the appropriate depth of about 5ft and at appropriate horizontal strata where sodium, calcium and magnesium base elements tend to accumulate. The clay sample for this work was collected along Agbarha-Emevor road, Agbarha town which is located in Ughelli North Local Government Area of Delta State, Nigeria. It is located within $5^{o}32^{l}4^{ll}$North of the equator and $6^{o}4^{l}29^{ll}$East of the prime meridian. Sample of Aqua gel clay from Agbarha was then prepared using multi-mixer, direct sunlight, weighing balance, graduated measuring cylinder, spatula, metallic tray, mortar and pestle, sieve, beakers and reagents like; Distilled water, sample, masking tape, recording book e.t.c.

2.2. Sample Preparation

Clay sample collected from Agbarha deposit was dried under moderate temperature spreading it out in a metallic tray under direct sunlight. Clay sample was then pulverized by pounding it using mortal and pestle, the pulverized clay sample was then sieved using 200mm sieve to obtain smoothed powdered clay particles. The sieved clay sample was collected in a beaker and labeled appropriately using a masking tape. Then 24.5g, 21.0g and 17.5g of the smooth clay sample was weighed using a spatula to put the smooth powdered clay sample on the weighing balance in order to obtain the required quantities and then labeled appropriately. 350ml of distilled water was measured using a 500ml measuring cylinder and transfer into the multi-mixer, and was allowed to run for 10secs, then the already weighed clay samples were added to obtained three mixtures different masses but of same composition. The mixture of the clay and water was vigorously agitated with the aid of the multi-mixer for about 10 mins, to obtain homogeneous mixture. This represents mud without treatment or beneficiation. Then the three laboratory barrels of mud produced was allowed to age for 48 hours for proper hydration where the clay particles absorbed water. After 48 hours of aging, the mud was re-stirred and re-agitate for characterization in term of weight, the rheological properties, the pH, the sand level and the water loss were tested using the procedures below:

Rheological Properties Determination

i. **Reagent/Materials:** Agbarha clay sample, foreign clay sample, distilled water, Hydroxyl Ethyl Cellulose (HEC), freshly prepared sample, masking tape, recording book and biro.

ii. **Apparatus/Equipment:** Rheometer.

iii. **Procedure:** 24.5g, 21.0g and 17.5g of Agbarha clay Sample was mixed with 350ml of water and then agitated using multi-mixer. The agitated high concentration (24.5g) drilling fluid was poured into a thermos-cup and then placed the thermo -cup on the Rheometer stand, ensuring that the surface of the prepared mud was adjusted to the scribed line on the rotor sleeve, the switch was on a high-speed position with the gear shift all the way down started the Rheometer. A steady indicator dial value was attained for the 600rpm reading after it was regulated to the 300rpm speed and a steady indicator value was also recorded. The Plastic viscosity of the prepared samples was calculated in centipoise by subtracting the 300rpm value from that of the 600rpm value. The yield point of the prepared sample was also calculated in $1b/100ft^2$ by subtracting the calculated value of the Plastic viscosity of the prepared sample in centipoise from the 300 rpm reading. To determine gel strength of the prepared sample, the mud sample was agitated for about 10-15seconds at 600rpm, the Rheometer was then switched off and the gear was set at the middle position and then left the sample for the stipulated time, say 10seconds and 10minutes when these stipulated time were reached, the Rheometer was immediately switched-on and the gear being set at 300rpm then the readings was taking at the highest point of deflection. These same procedures were repeated for medium concentration (21.0g) of drilling fluid and lowest concentration (17.5g) of drilling fluid. The above procedure was also repeated using foreign clay sample.

Mud Weight Determination

i. **Reagent/Materials:** Agbarha clay sample, foreign clay sample, distilled water, Hydroxyl Ethyl Cellulose (HEC), freshly prepared sample, masking tape, recording book and biro.

ii. **Apparatus/Equipment:** Mud balance

iii. **Procedure:** The lid of the mud balance cup was removed and the cup was filled with the already prepared mud from the Agbarha samples, some quantity of the sample mud was allowed to rushed out the hole of the lid in order to avoid some quantity of air not to be trapped in the cup, then the cup was carefully positioned on a mud balance. The balance arm was placed on the vase, with the knife edge resting on the fulcrum of the mud balance, the rider was moved until the graduated arm was leveled as indicated by the level vial on the beam, the mud weight was read at the edge of the rider, then I recorded the weight of mud samples in lb/gal; same procedure was out on foreign clay sample.

Sand Content Determination

i. **Reagent/Materials:** Agbarha clay sample, foreign clay sample, distilled water, Hydroxyl Ethyl Cellulose (HEC), freshly prepared sample, masking tape, recording book and biro.

ii. **Apparatus/Equipment:** Sand content set

iii. **Procedure:** the sand content in the mud samples was estimated by wet screen analysis using 200-mesh (74microns) screen Bariod sand content set. The glass measure tube was filled with mud sample to be measured to the ‘mud’ line as water was added to the next scribed mark, thumb was placed over the tube mouth and then shaken vigorously. Then the mixture was poured on a clean screen and ore water added to the tube and shaking. Again, the mixture was poured on screen, the liquid that passed through the screen was discarded, the screen assembly was Slowly inverted and the tip of the funnel inserted in the glass tube. The sand was then washed on the screen back into the tube with wash water. sand was allowed to settle in the tube and the volume was recorded as volume percent sand content of the mud sample. This procedure carried out on the prepared local fluid, and foreign fluid before beneficiation and after beneficiation.

pH Determination

i. **Reagent/Materials:** freshly prepared sample, masking tape, recording book and biro.

ii. **Apparatus/Equipment:** Phydrion dispenser paper, Multi-Hamilton beach mixer.

iii. **Procedure:** The prepared fresh drilling fluid sample was re-stirred and placed it gently on the surface of the paper strip, sufficient time was allowed to elapsed (about few seconds) for the paper to soak up the filtrate and change colour. Then the soaked paper strip was matched with chart on the dispenser from which the strip was taken. The pH range of the mud was read and the value recorded in the table of result respectively. The procedure was repeated for other concentrations of the drilling fluid say medium and low concentrations of both the Agbarha clay and the foreign clay before beneficiation and after beneficiation.

2.3. Filtration Rate Determination

Laboratory barrel of Agbarha drilling fluid was prepared and was agitated for about 10mins using the multi-mixer; the mud cell of the Standard API Filter Press was detached from its frame, I the bottom of the filter cell was removed and placed the right size filter paper at the bottom of the cell, then the prepared Agbarha drilling fluid was poured into the cup assembly, putting the filter paper and the screen on top of mud tighten screw clamp. With the air pressure valve closed, the mud cup assembly was clamped to the frame while holding the filtrate outlet end finger tight. Then graduated cylinder was placed underneath to collect the filtrate. I the air pressure valve was opened and time was started counting at the same time, the filtrate collected for 5mins intervals up to 30mins. The results were recorded. The procedure was repeated using foreign clay, and the results were also recorded.

3. Result and Discussion

Table 1: Mud Sample without Beneficiation after 48 hrs of Aging

Properties of drilling fluid	24.5g Agbarha clay	21.0g Agbarha clay	17.5g Agbarha clay
Mud Weight (lb/gal)	8.4	8.4	8.4
pH	10	10	10
Sand Content (%)	1.6	1.6	1.6
Apparent Viscosity (cp)	3	2	0
Plastic Viscosity(cp)	3	1.5	1.2
Yield Point(lb/100ft^2)	0	1	0
Gel Strength 10sec (lb/100ft^2)	0.4	0.5	0.25
Gel Strength 10min (lb/100ft^2)	1	1	1

Table 2: Bentonite Mud without Beneficiation after 48hrs of Aging

Properties of drilling fluid	24.5g Foreign clay	21.0g Foreign clay	17.5g Foreign clay
Mud Weight (lb/gal)	7.12	7.12	7.12
pH	8	8	8
Sand Content (%)	5	5	5
Apparent Viscosity (cp)	23.5	11	8.5
Plastic Viscosity(cp)	17	9	7
Yield Point(lb/100ft^2)	13	4	3
Gel Strength 10sec (lb/100ft^2)	3	1	1
Gel Strength 10min (lb/100ft^2)	18	4	3

Table 3: Mud Sample with Beneficiation after 48hrs of Aging Using 5g of Hydroxyl Ethyl Cellulose (HEC

Properties drilling fluid	24.5g Agbarha clay	21.0g Agbarha clay	17.5g Agbarha clay
Mud Weight (lb/gal)	8.7	8.7	8.65
Ph	9.6	9.6	9.5
Sand Content (%)	1.6	1.6	1.6
Apparent Viscosity (cp)	60	53	30
Plastic Viscosity(cp)	9	8	7
Yield Point(lb/100ft^2)	27	22	21
Gel Strength 10sec (lb/100ft^2)	0.67	4	4
Gel Strength 10min (lb/100ft^2)	8	5	19

Table 4: Comparison of Mud Properties with API Numerical Value Specification (17.5g)

Property of drilling fluid	API (Min)	Agbarha clay before beneficiation	17.5g Foreign clay	Agbarha clay after beneficiation	API (MAX)
Mud Weight (lb/gal)	8.65	8.4	8.7	8.65	9.0
pH Value	9.5	10	9	9.5	12.5
Sand Content (%)	1	1.6	1.3	1.6	2
Apparent Viscosity (cp)	15	0	8	30	
Plastic Viscosity (cp)	8	1.2	5	7	10
Yield Point ($lb/100ft^2$)	24	0	6	21	30
Gel Strength 10sec ($lb/100ft^2$)		0.25	0.7	4	
Gel Strength 10min ($lb/100ft^2$)		1	12.1	5	
"n" factor		0.45	0.76	0.70	1.0

Analysis on 17.5 g sample mud concentration

Comparison of laboratory analyses of the sample Mud (Agbarha clay) Properties result with API Numerical Value Specification before and after beneficiation is shown in Table 4, it was observed that sample mud weight, Apparent Viscosity (cp), Plastic Viscosity, Yield Point, Gel Strength (10sec), Gel Strength (10min) showed values lower or a little short of API minimum numerical value standard while pH, Sand Content and "n" factor give a values that are higher than that of that of standard API minimum numerical value. Therefore, there is a need to beneficiate this local mud sample to meet that of API standard specification. After beneficiation with 5g H.EC. as shown in table 4, the sample Mud weight increased from 8.4 lb/gal to 8.65 lb/gal which now fell within API numerical value standard for drilling mud (i.e. 8.65lb/gal-9.60lb/gal), pH of the mud sample reduced from 10 to 9.5 , Apparent Viscosity increased from 0 cp to 30 cp, Plastic Viscosity increased from 1.2 to 7, Yield Point increased from $0lb/100ft^2$ to 21 $lb/100ft^2$,Gel Strength (10sec) increased from 0.5 $lb/100ft^2$ to 4.0 $lb/100ft^2$, Gel Strength (10min) increased from $1lb/100ft^2$ to 5 $lb/100ft^2$, "n" factor increased from 0.45 to 0.7,sand content of the sample mud remain the same as 1.6%. All above values fell within API numerical value standard for drilling mud.

Table 5: Comparison of Mud Properties with API Numerical Value Specification (21.0g)

Property of drilling fluid	API (Min)	Agbarha clay before beneficiation	21.0g Foreign clay	Agbarha clay after beneficiation	API (MAX)
Mud Weight (lb/gal)	8.65	8.4	8.7	8.70	9.0
pH Value	9.5	10	9	9.6	12.5
Sand Content (%)	1	1.6	1.3	1.6	2
Apparent Viscosity (cp)	15	2	8	53	
Plastic Viscosity (cp)	8	1.5	5	8	10
Yield Point ($lb/100ft^2$)	24	1	6	22	30
Gel Strength 10sec ($lb/100ft^2$)		0.5	0.7	4	
Gel Strength 10min ($lb/100ft^2$)		1	12.1	5	
"n" factor		0.40	0.76	0.79	1.0

Analysis on 21.0g sample mud concentration

Table 5 shows Comparison of 21.0g concentration of the sample Mud Properties result with API Numerical Value Specification before and after beneficiation, it was observed that sample mud weight, Apparent Viscosity (cp), Plastic Viscosity, Yield Point, Gel Strength (10sec), Gel Strength (10min) showed values lower or a little short of API minimum numerical value standard while pH, Sand Content and “n” factor gives a value that is a little higher than that of standard API minimum numerical value. Therefore, there is a need to beneficiate this local mud sample to meet the API standard specification. After beneficiation with 5g H.EC. as shown in Table 5, the sample Mud weight increased from 8.4 lb/gal to 8.7 lb/gal which is within API numerical value standard for drilling mud (i.e. 8.65lb/gal-9.60lb/gal), pH of the mud sample reduced from 10 to 9.6, Apparent Viscosity increased from 2 cp to 53 cp, Plastic Viscosity increased from 1.5 to 8, Yield Point increased from 1lb/100ft^2 to 22 lb/100ft^2, Gel Strength (10sec) increased from 0.5 lb/100ft^2 to 4.0 lb/100ft^2, Gel Strength (10min) increased from 1lb/100ft^2 to 5 lb/100ft^2, “n” factor increased from 0.4 to 0.79, sand content of the sample mud remain the same as 1.6%. All above values fell within API numerical value standard for drilling mud.

Table 6: Comparison of Mud Properties with API Numerical Value Specification (24.5g)

Property of drilling fluid	API (Min)	Agbarha clay before beneficiation	24.5g Foreign clay	Agbarha clay after beneficiation	API (MAX)
Mud Weight (lb/gal)	8.65	8.4	8.7	8.70	9.0
pH Value	9.5	10	9	9.6	12.5
Sand Content (%)	1	1.6	1.3	1.6	2
Apparent Viscosity (cp)	15	3	8	60	
Plastic Viscosity (cp)	8	3	5	9	10
Yield Point (lb/100ft^2)	24	0	6	27	30
Gel Strength 10sec (lb/100ft^2)		0.4	0.7	0.67	
Gel Strength 10min (lb/100ft^2)		1	12.1	8	
“n” factor		0.43	0.76	0.8	1.0

Analysis on 24.0g sample mud concentration

Table 6 shows Comparison of 24.0g concentration of the sample Mud Properties result with API Numerical Value Specification before and after beneficiation, it was observed that sample mud weight, Apparent Viscosity (cp), Plastic Viscosity, Yield Point, Gel Strength (10sec), Gel Strength (10min) showed values lower or a little short of API minimum numerical value standard while pH, Sand Content and “n” factor gives a value that is a little higher than that of that of standard API minimum numerical value. Therefore, there is a need to beneficiate this local mud sample to meet the API standard specification. After beneficiation with 5g H.EC., the sample Mud weight increased from 8.4 lb/gal to 8.7 lb/gal which now fell within API numerical value standard for drilling mud (i.e. 8.65lb/gal-9.60lb/gal), pH of the mud sample reduced from 10 to 9.6 , Apparent Viscosity increased from 2 cp to 53 cp, Plastic Viscosity increased from 1.5 to 8, Yield Point increased from 1lb/100ft^2 to 22 lb/100ft^2 ,Gel Strength (10sec) increased from 0.5 lb/100ft^2 to 4.0 lb/100ft^2, Gel Strength (10min) increased from 1lb/100ft^2 to 5 lb/100ft^2, “n” factor increased from 0.4 to 0.79,sand content of the sample mud remain the same as 1.6%. All above values fell within API numerical value standard for drilling mud.

Table 7: The filtration rate of Agbarha drilling fluid collected in ml at 5mins interval up to 30mins

Time (mins)	5	10	15	20	25	30
Filtrate volume (ml)	13	18.3	22.5	26	29	31.8

Table 8: The filtration rate of foreign clay collected in ml at 5mins interval up to 30mins

Time (mins)	5	10	15	20	25	30
Filtrate volume (ml)	11	15	18.5	21.7	25	28

4. Conclusion

Based on the result of this research work, it can be concluded that most of the properties of the local clay mud such as: sand content, pH, consistency index and power law index met the minimum required API specification. While others such as: Mud weight, Apparent Viscosity, Plastic Viscosity, Yield Point, Gel Strength(10sec), Gel Strength (10min), "n" factor needed little treatment with additives for favorable comparison with API standard for drilling fluid. Agbarha clay can therefore be utilized for formulation of drilling mud.

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