

## Laboratory Investigation of Rivers State Clay Samples for Drilling Mud Preparation

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### ABSTRACT

Drilling fluids are an integral part of any oil and gas industry, providing the ease to which wells are drilled to access subsurface reservoir fluids. Certain rheology and mineralogical properties of the clay material used for drilling mud preparation must be critically investigated since clay deposits in different location exhibits different characteristics. Clay samples were collected from three different geographical locations namely; Egbamini (Emolga), Afam Street (Port Harcourt) and Oboboru (onelga) local government areas in Rivers state. Their rheological and wall building properties were measured in the laboratory to determine their suitability for drilling mud formulation. Results showed that in their respective native states, they proved unsuitable for drilling mud preparation when compared to standard Bentonite because they were observed to show responses far below the required API standards for mud formulation.

**Keywords:** Clay, Drilling mud, properties, Salt Concentration

### I. INTRODUCTION

The use of water to cool and lubricate drill bits during drilling in early drilling practices encountered quite a number of problems traceable to the inability of water to perform certain drilling mud functions. The introduction of mud for such problems in the industry became widespread between the late 80's and early 90's with the purpose of continuously removing drill cuttings from the hole. As rotary drilling advanced, more engineering attention was needed to critically analyze mud composition and efficiency for its performance [1]. The use of only water as drilling fluid was kicked against because of the tendency of formation damage as a result of hole instability. Early drillers encountered such problems and used muddy water to control a potentially catastrophic sand problem. [2],[3].

The investigation of the use of the mud-laden fluid as a mixture of water with any clay, which will remain suspended in water for a considerable length of time was conducted by Hegen et al. They concluded with the recommendation that a fine sticky clay described as "gumbo" was a good component for drilling mud. [4]. A good mud besides been able to suspend clay materials in water for a long time should be free of sand cuttings and similar materials of specific gravity within the range of 1.05 – 1.15 ( density 8.77ppg – 9.58pppg. [4], [5]. The introduction of weighting the mud using additives and fine grains from oxide was recommended for weighting in water slurries, given a mud weight in the range of 15 – 18 ppg. The use of these materials was short lived due to its dark color and skin straining effects. Further

research on this methodology led to the advancement of barium sulphate (barite) for mud weighting due to its high specific gravity, low abrasive properties and toxicity level. The discovery of Bentonite for mud preparation was later introduced to the industry, with subsequent tests showing its ability not only to suspend heavy cuttings but having comparatively good mud properties such as moderate filtration loss and good wall building properties, viscosity and gel strength . [6], [7] This study tends to analyze both the rheological properties and mineralogy of three clay samples retrieved from various locations in Rivers state, Nigeria. These three samples will be subjected to certain laboratory experiments to confirm or ascertain their suitability for drilling mud formulation and results of their properties will be compared to Wyoming bentonite which is a standard for mud preparation.

Clays are the most abundant class of sedimentary rocks, making up to 40% of mineral contents in these sedimentary rocks. These relatively cheap sources off colloidal materials with an average particle size of about 2microns have the ability to exhibit the plasticity phenomenon [8]. The alternating sheets of silica and alumina with slightly different arrangements that make up the unit layers of each clay material. The geographic location, chemical and colloidal nature of the retrieved clay is also a contributory factor in determining certain properties such as its swelling capacities. Montmorillonites, illites. Kaolinites, attapulgites and sepiolites are common clay classifications with montmorillonite being the most suitable class for drilling mud preparation [9], [10].

## II. MATERIALS AND METHODS

Three clay samples were collected from different locations within Rivers state in Egamini, Afam and Oboburu with samples labeled sample A, B and C respectively were retrieved, dried and sieved using a 200-micron screen. The rheological and wall building capacity of these distinct samples were determined in the laboratory. Proportions of 10, 20 and 40g of each sample was mixed with 350cm<sup>3</sup> of water in a Hamilton beach mixer for several minutes to attain a uniform mixture and also to hydrate the clay particles. The samples were subsequently treated with chemical additives in different proportions such as sodium carboxyl methylcellulose CMC, sodium hydroxide, NaOH and quick Trol in order to upgrade the rheological and wall building abilities of these three distinct clay samples

### 2.1 Mud weight determination

- i. The lid of the mud balance was taken off and the cup was filled with the already prepared mud from the samples and carefully positioned on a mud balance.
- ii. The balance arm was placed on the vase, with the knife edge resting on the fulcrum of the mud balance.
- iii. The rider was moved until the graduated arm was leveled as indicated by the level vial on the beam.
- iv. The mud weight was read at the edge of the rider.
- v. Weight of mud samples were recorded in lb/gal.

### 2.2. Apparent Viscosity, Plastic viscosity and Yield point Determination

- Samples in different fractions of 10, 20 and 40g were mixed with 350cm<sup>3</sup> of water and agitated.
- i. The agitated sample was placed in a thermo cup and the surface of mud adjusted to the scribed line on the rotor sleeve.
  - ii. Placing the switch on a on a high-speed position with the gear shift all the way down started the viscometer. A steady indicator dial value was attained for the 600rpm reading and recorded.
  - iii. The switch was regulated to the 300rpm speed and a steady indicator value was recorded too.
  - iv. Plastic viscosity of the samples was calculated in centipoise by subtracting the 300 value from that of the 600 value.
  - v. The yield point in 16/100ft<sup>2</sup> was calculated thus 300 reading minus plastic viscosity in centipoise.
  - vi. Apparent viscosity in centipoise was also calculated (600reading/2).

### 2.3. API fluid loss determination

- i. 100psi air/gas pressure was made available.
- ii. With the mud lid removed from the bottom, cleaned and dried, the O-ring was placed in an undamaged groove and then inverted to fill it. This inlet was sealed with an index finger.
- iii. With the cell filled with mud to ¼ inch of O-ring groove, the filter paper was then placed on top of the O-ring and the lid was also placed on the filter paper with the flanges of the lid between the flanges of the cell and rotated clockwise until it was tight. The cell turned over and the male cell coupling was inserted into the female filter press coupling and turned clockwise to engage.
- iv. A suitable graduation cylinder was placed under the filtrate opening to receive the filtrate.
- v. The inlet valve was opened applying pressure to the cell.
- vi. The normal API test period was 30min. at the end of the test, the valve was closed. The pressure was shut off at sources and pressures bleed out automatically. The cell was then removed..
- vii. The filtrate loss was presented in in cm<sup>3</sup>.
- viii. The cell was disassembled, mud discarded and extreme care was used to save filter paper with a minimum disturbance of cake. The cake was gently washed to remove excess mud. The thickness of the filter cake measured and reported in 1/32 inch.

### 2.4. pH Determination

- i. An indicator stick was placed in the clay/water mixture and allowed to remain until the colour was sterilized, usually less than a minute, the stick was rinsed off with deionized water but was not wiped.
- ii. The color of the stick was compared to a provided standard and pH estimated.
- iii. The pH of the mud was reported is the nearest 0.5-pH units.

### 2.5. Swelling Test

1. 2g weight of all three samples was properly measured using a balance of low weight accuracy.
  2. With the measuring cylinder filled with water to the 100ml, sample was transferred in small amounts (about 0.25g) unto the surface of the water (sample in powdered form) using the thin scapula. This was done without stirring.
  3. The process was done patiently until the 2g powdered clay had disappeared into the water.
- Assessment

1. Wait 18hrs, then measure the thickness of the layer of the clay sludge on the bottom of the cylinder
2. Do not shake otherwise disturb the sample during the waiting period or measurement process.
3. Clays which are suitable for use as a drilling mud should have swelling to the 12 - 16ml (cm<sup>3</sup>) mark on the measuring cylinder.
4. If clays have swelled only to the 4-6ml mark, they will not effectively coat the side of your

borehole during drilling and should not be used as the thickening agent.

### III. RESULTS AND DISCUSSION

The analysis of results from the experiments conducted would be based on comparative analysis and graphical illustrations on the behavior and properties of the clay samples in before and after chemical treatments. The table below shows results of the sample analysis with respect to some properties of sample D being the standard mud specification to be compared with the retrieved samples.

Table 1- Investigated properties of sample A, B, C and D

Sam ples	g/30 0cm <sup>3</sup> of wate r	θ600	θ 300	Pv (θ600- θ300)	YP (θ600- YP)	AV	10min gel strength	pH	MW ppg	Filtrate loss(cm <sup>3</sup> )	Filter cake thickness (1/32 in.)
<b>A</b>	10	2	1	1	0	1	1.1	8	8.5	152	1.4
	20	2.5	1.5	1	0.5	1.35	1.1	8	8.55	120	2.8
	40	3	1.5	1.5	0	1.55	1.6	8	8.75	94	3.4
<b>B</b>	10	1.5	0.5	1	0	0.8	1.0	8	8.45	92	0.65
	20	2	1	1	0	0.5	1.5	8	8.50	92	1.3
	40	3	1.5	1.4	0	1.55	2	8	8.65	55	2.5
<b>C</b>	10	1.5	1	0.5	0.5	0/8	1.5	8	8.45	100	0.7
	20	2.5	1.5	1.1	0.5	1.3	1.5	8	8.50	136	1.4
	40	3.5	2	1.4	0.5	1.8	2	8	8.80	82	3.2
<b>D</b>	10	3.5	2	1.5	0.5	1.75	3.6	9	8.45	32	0.65
	20	6	4	2.0	2.5	3.0	15	9	8.60	19.5	1.4
	40	124	83	41	42	62	24	9	8.80	13	2.65

The clays were found to be unsuitable for production of drilling mud in their native states from the table above. This was because the rheological properties (PV, YP, gel strength as well as filtration loss and cake thickness ) were all not up to the API standard API specifications for Na-Montmorillonite is 11cm<sup>3</sup> fluid loss, 8.2 for pH and 15cp. the experiments showed that rheological properties were low as compared to that of Bentonite. The PV of samples A, B and C were almost the same. For sample C the PV values were found to be 0.5, 1.1 and 1.4 for concentrations of 10, 20 and 40g respectively. As compared to that of bentonite were 1.5, 20 and 41 for 10, 20 and 40grams respectively. Fig 1 below shows the gel strength plot against mud weight and showed the comparison for all four samples.

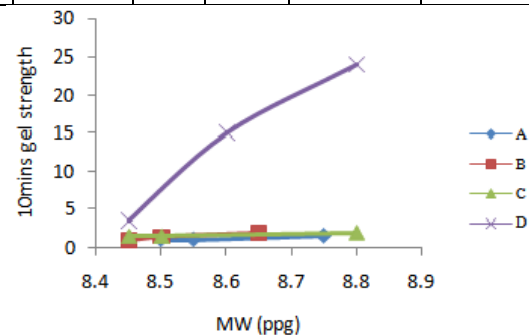


Fig 1 Plot of gel strength plot against mud weight

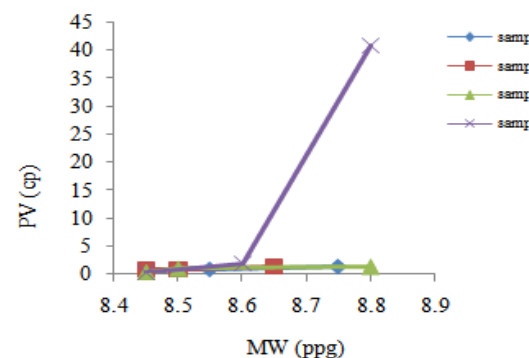


Fig 2 Plot of plastic viscosity against mud weight

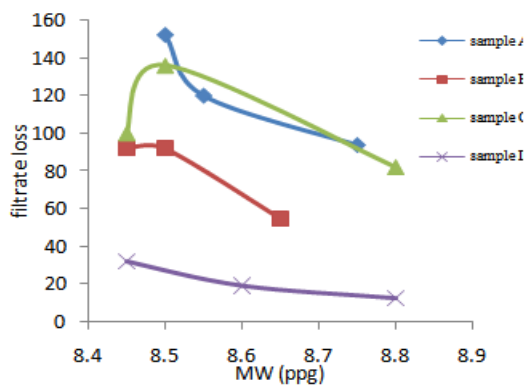


Fig 3 Plot of filtration loss against mud weight

Sample gel strengths were relatively low. For sample A, the 10mins gel strength values were 1.1, 1.1 and 1.6lbs for concentrations of 10, 20 and 40g respectively as against 3.5, 15 and 249lbs at same concentrations for bentonite. This confirmed the absence of contain, rather they contained kaolinite, Illite such that their hydration powder was very low and resulted to low swelling when it came in contact with water. As soon as stirring of the mud stopped, the clay particles that were separated by mechanical forces clung together to form clusters of particles precipitating from the continuous phase as a result of neutralization of the negative charges in them. This observation concludes the inability of the system to form gel strength and porous filter cakes. When not agitated, the particles didn't stick together depicting low mud thixotropic characteristics. This implies that when used as drilling mud, if drilling stops for any reason, the rock particles tends to slip back down into the hole causing differential sticking of the pipe.

The densities for the 10, 20 and 40g of mud for each sample gave almost the same values with slight variations due to difference in viscosity, which was compared to bentonite Fig 4.1 shows that the native clays had a pH value of about 8, implying the alkaline nature of the muds. The figures below give a graphical presentation of the experimental results of mud properties including the gel strength plastic viscosity and filtration loss against mud weights of 4 samples. Threeof which are the locally retrieved samples and that of standard bentonite assigned the character sample D.

Analysis of clay samples

Since the samples recorded lower values of mud properties when compared to the API specifications, some chemical modifications were made by incorporating additives to these samples to improves its mud properties. For this case, the following chemical additives were resorted to improve the mud properties.

**3.1. Treatment X: Addition of 2g of Bentonite and 0.25g NaOH.**

To each measured sample of various concentrations (10, 20 and 40g), 2g bentonite and 0.25g of NaOH was added. This showed no significant improvement in the apparent viscosity, plastic viscosity, yield point and gel strength. However, the pH of the three samples changed from 8 to 10 with a significant reduction in filtrate loss and cake thickness. For example, sample A recorded 40, 33 and 23.5cc filtrate loss for 10, 20 and 40g respectively. The filter cake thickness was also reduced considerably to 0.7, 1.4 and 2.0 from 1.3, 2.8 and 3.9 for their equivalent gram concentrations.

Table 2. Showing properties of samples after treatment X

Sam ples	g/300c cm of water	θ60 0	θ3000	PV (θ600-θ300)	YP (θ600-YP)	AV (θ600/2)	10min gel strength	pH	Mud weight (ppg)	Filtrate loss(cm³)	Filter cake thickness (1/32 in.)
<b>A</b>	10	2.5	2	0.5	1.4	1.3	1.8	10	8.5	40	0.7
	20	3	2	0.85	1	1.5	1.8	10	8.6	33	1.4
	40	3	1.5	1.5	1	1.5	1.8	10	8.9	23.5	2.0
<b>B</b>	10	1.5	0.5	1	0.5	0.75	2.0	10	8.45	56	1.3
	20	2.0	1	1	0	1.0	2.0	10	8.60	40	1.40
	40	2.4	1.4	1	0.5	1.2	2.0	10	8.7	28	1.51
<b>C</b>	10	3	2.0	1	1	1.5	2.0	10	8.40	78	1.04
	20	3.4	2.4	1.0	1.5	1.75	2.0	10	8.83	35	1.3
	40	4	2.4	1.7	1.0	1.3	2.5	10	8.65	20	1.8

**3.2. Treatment Y, Addition of 2g quick troll and 0.25g NaOH**

All gram concentrations of the three distinct samples were treated with 0.2g quick troll and 0.25g NaOH. Stirring with a Beach mixer, sample all foamed with bubbles most likely caused by CO<sub>2</sub> release from thereactions of the organic components trapped in the continuous phase of the mud. Remarkable improvements in yield points of sample A and B were

observed as shown in Table 2. Gel strength of all samples also increased remarkably. The essence of this treatment was owed to the viscosifying nature of Quick Troll to lower the hydrogen bonding energy in a bond system. This aided in the hydration of clay and its dispersion, hence increasing plastic viscosities. The Quick troll also has the ability to link the clay particles together thereby increasing the gel strength of the mud.

Table 3 Properties of samples after treatment Y

Sam ples	g/300 ccm of water	θ600	θ 300	PV (θ600- θ300)	YP (θ600- YP)	AV (θ600/2)	10min gel strength	pH	MW (ppg)	Filtrate loss(cm <sup>3</sup> )	Filter cake thicknes s (1/32 inches)
<b>A</b>	10	32	22	10	12	16	30	10	8.70	17	0.26
	20	52	37	15	22	26	64	10	8.0	16.5	0.6
	40	57	39	18	21	29	84	10	8.35	14.0	1.3
<b>B</b>	10	30	20	10	10	15	55	10	8.0	17	1.0
	20	58	40	18	22	29	85	10	8.30	15.5	1.2
	40	29	18	11	7	25	52	10	8.50	12.5	1.51
<b>C</b>	10	30	19	11	8	15	27	10	8.15	12.5	0.60
	20	44	27	17	10	22	47	10	8.20	15.5	1.0
	40	47	28	19	9	24	65	10	8.35	11	1.0

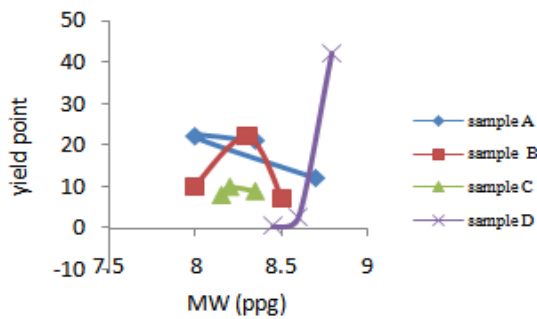


Fig 4 Plot of yield point against mud weight

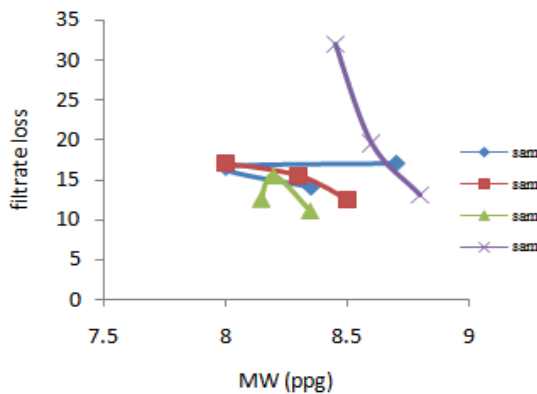


Fig 5 Plot of filtration loss against mud weight

### 3.3. Treatment Z, Addition of quick troll, CMC and NaOH

To further reduce the water loss of the local samples, they were subjected to the above treatment with Quick Trol, Carboxyl methyl Cellulose (CMC) and NaOH in the proportion of 2g, 2g and 0.25g respectively added to each gram concentration of the three local samples. Table 4 shows the relative reduction in fluid loss values. This reduction was as a result of the lateral attraction between the organic compound (CMC) and the clay particles that appeared to be a continuous impermeable layer of filter cake preventing the flow of water through the cake.

Table 4 Properties of samples after treatment Z

Sam ples	g/300 ccm of water	θ600	θ300	PV (θ600- θ300)	YP (θ600- YP)	AV (θ600/2)	10min gel strength	pH	MW (ppg)	Filtrate loss(cm <sup>3</sup> )	Filter cake thicknes s (1/32 in.)
<b>A</b>	10	53	36	17	19	27	65	10	8.30	17.0	1.30
	20	34	20	14	6	17	22	10	8.50	9.5	1.30
	40	41	26	15	11	21	36	10	8.70	8.0	1.30
<b>B</b>	10	40	28	12	16	20	54	10	8.25	24	0.70
	20	56	37	19	18	26	68	10	8.40	13.5	0.70

	40	33	21	12	9	16.5	34	10	8.85	8.5	1.20
<b>C</b>	10	88	26	12	14	17	33	10	8.30	24	1.05
	20	51	33	18	15	25	57	10	8.40	11.5	1.05
	40	71	50	21	29	34	90	10	8.60	7.5	1.20

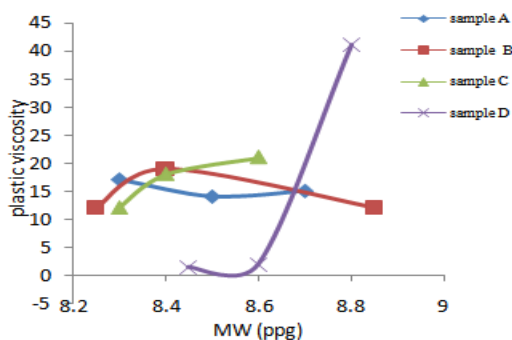


Fig 6 Plot plastic viscosity against mud weight

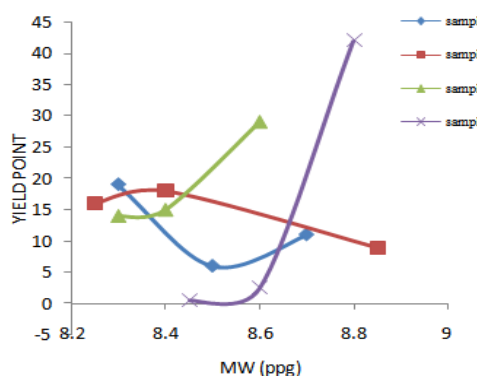


Fig 7. Plot of YP against mud weight

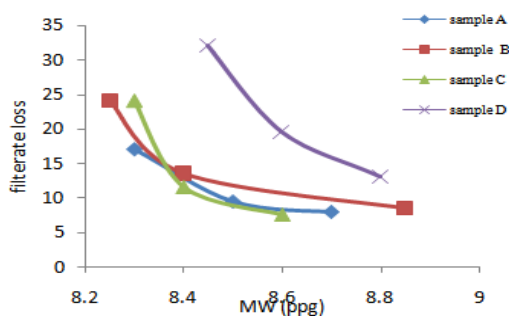


Fig 8. Plot of yield point against mud weight

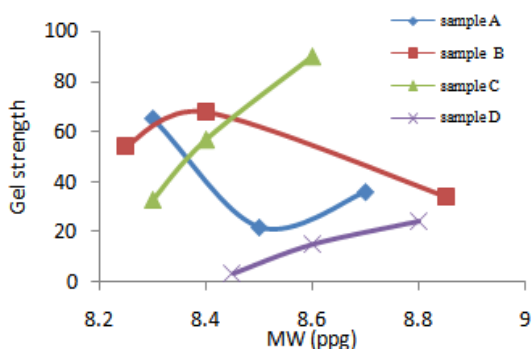


Fig 9. Plot of gel strength against mud weight

### 3.4. Swelling test analysis

All three samples did not meet the swelling test criteria of 12 – 16ml mark on the cylinder. Sample C recorded the highest swelling attaining the 5ml mark. Samples A and B recorded 4ml and 3ml respectively on the measuring cylinder.

## IV. CONCLUSION

This investigation was prompted by the inherent oil and gas activities within the geographical area, so as to maximize its clays rather than importation of clay material by drilling companies. However, from the figures and graphical representation of samples analysed, it is evident that these clays from Egbamini (Emolga), Afam Street (Mile 1 PH) and Oboboru (Onelga) local government areas in Rivers state proved to be poor potential drilling mud materials far below the API standards for drilling mud formulation.

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