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Laboratory Determination of the Effects of Microorganisms on the Rheological Properties of Niger Delta Clays

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ABSTRACT
The inexorable role of drilling muds in the petroleum industry has prompted the necessity to evaluate cost effective and highly efficient locally sourced additives. It is known that clay mineralogical composition and mud additives amongst other factors can significantly influence mud performance during drilling operations. Hence, a thorough evaluation of these mud components and possible additives is essential. For this study, three clay samples from the Niger-Delta province; Lobia, Omoku and Ughelli were collected. This was done for the purpose of determining the effects of specific microorganisms particularly *Shigella, Serretia* and *Pseudomonas Aeruginosa* on some rheological properties of drilling mud prepared from these clay samples. A total of nine mud samples prepared with clay from each location were subjected to all three microbial cultures. Results from this study show that some mud properties such as apparent viscosity, pH, yield point, mud weight and plastic viscosity can be altered when subjected to these cultures. The acidity of the 6 mud samples prepared from the clays of Omoku and Lobia namely Omoku-1, Omoku-2, Omoku-3 and Lobia-1, Lobia-2, Lobia-3 increased after 144 hours. Mud weight for these samples also increased with time although a slight decrease from 9.90ppg to 9.85ppg was observed in Lodia-1. Samples from Ughelli behaved differently from others as they increased in alkalinity. Ughelli-3 (*Pseudomonas Aeruginosa*) which was initially slightly acidic with pH = 6.40 had a neutral indication of pH =7.00 after 144 hours. Graphical presentation of variations in other mud properties such as YP, PV and AV provide a better comprehension of the effect of these microorganisms on the drilling mud samples.
***Keywords*:** Bacteria, Clay, Drilling mud, Microorganisms, Niger Delta clays, Rheology.

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I. INTRODUCTION

Clays are alumuno-silicate microcrystallines with leaf-like structures, originating from the alteration of primary minerals of soils. Clay minerals are not only one of the most abundant mineral components in the world, but also a mineral showing various applications in cosmetic, environmental protection and in paper, chemical or food industries for the discoloration and stabilization of vegetable oils [1]. Clay minerals include kaolinite, montmorillonite, illite, vermiculite and chlorite [1], [2] while among these minerals those within the in Niger Delta area are mostly Kaolinite, montmorillonite and a small amount of illite [2], [3]. Clays of various kinds and grades abound throughout Nigeria's sedimentary basins [4]. Recent investigation by the Nigeria Mining Corporation established the existence of bentonite clay in Afaze, Edo state reserves over 700 million tons in the country, with the biggest single deposits at Afuze, Edo State holding 70-80 million tones [5], [6].

In the study of [7] and [8], both authors outlined that the Rheological properties of clay must be thoroughly understudied before application so as to accomplish an optimum mud performance during drilling operations. In both investigations, locally prepared clays were processed and evaluated for their suitability in various applications.

An innovative alternative approach to effectively improve rheological properties of clay lies with the combined use of microbes [9], and the success of biological treatments have been demonstrated in other fields such as stabilization of metals [10], environmental stabilization of contaminated soils, encapsulation of hazardous and other contaminants in natural soils and in microbial enhanced oil recovery [11]. However, microorganisms play an important role in soil aggregation, strength and stabilization of the clay internal structure. In drilling muds, microbial action either increases or decreases some of the mechanical properties of these clay materials.

Microorganisms are found in nature and also cultured in the lab. Enzymes are produced through beneficial metabolic processes and perform their duties by providing an efficient system for detecting

organics within subject environs. Studies have been made by [12], [13] on cohesive soils through the impact of microbes on clay engineering properties, such as compressive strength of cohesive soil. The later authors observed in their investigation that the liquid limit and plasticity index for all clay samples decreased while unconfined compressive strength increased using *Bacillus Pasteurii.*

A distinct observation was made in [14] on the effects of bacteria on the flow behavior of clay-sea water suspensions. Their study saw that the presence of glue-like exo-polymer produced by the marine benthic bacterium in concentrations comparable to typical marine mud can improve the yield stress of dilute clay–sea water suspensions typical of sediment-water interface by 60%. This was inferred to be mainly as a result of bacterial attachment to and exo-polymeric bridging between clay fields under nutrient poor conditions. The relative change in the yield stress of a clay-sea-water suspension, and by inference its erosion resistance is dependent on the availability of nutrients and the history of microbial attachment. Their study however was limited to the flow behavior of clay-sea-water without getting to consider the drilling mud properties of these clays. The examination for the influence of clay minerals such as montmorillonite and kaolinite which stimulates the respiration of bacteria was also presented in [12]. They analyzed the effect of microorganism on the viscosity, yield strength of drilling fluid and concluded that these microorganisms can be helpful for meet mud design specifications.

The retention capacity of drill cuttings by a mud is believed to be the primary aim of investigating its rheology. Usually, muds with elevated viscosity at high shear rates tend to exhibit greater retention of cuttings which reduces the efficiency of high-shear. Viscosity at low shear rates reduces the efficiency of high-shear devices like shale shakers [15], [16], [17].Conversely, elevated viscosity at low shear rates reduces the efficiency of low shear devices like centrifuges, inasmuch as particle settling velocity and separation efficiency are inversely proportional to viscosity [17], [18]. Viscosifiers which may be either viscosity enhancers or viscosity reducers play important roles in drilling mud design programs. Clay materials are one of the most commonly used additives for increasing drilling mud viscosity [19]. Their natural absorbent tendency, swelling and gelation propensity makes them perfect viscosity enhancers

This study tends to examine target candidate locations for suitable clay deposits within the Niger Delta region and also tends to identify some rheological properties of clay which can be altered on application of specific microbes during drilling mud preparation. The scope of this work covers a wide range of mud property investigation with its significance being to demonstrate that specific microorganisms when cultured can play important roles in improving some drilling mud properties.

II. RESEARCH METHODOLOGY

2.1 Materials for Mud Preparation and Microbial Culturing

Materials for mud preparation include; Water, Clay samples, caustic soda, Soda ash, Polyanionic cellulose (PAC), Potassium chloride, Xanthan gum, Borax and Bentonite. For the microbial culture, contaminated water, serial dilution solvents, nutrient agar media, *salmonalla shigella* media, and syringes were used.

2.2 Equipment used for Mud Preparation and Culturing of Microbes

The equipment used for mud preparation were: weighing balance, measuring cylinder, beakers, Hamilton batch mixer, pH indicator strip meter, Marsh funnel, bowling crunching machine, stop watch, bucket, 8-RPM Rotary viscometer, spatula, API filter paper, mud cups, heat cups, oven (type 48 BE Apex Tray Drier) laboratory barrels and mud balance. That for the culturing of microbes were weighing balance, measuring cylinder, conical flask, autoclave, oven, incubator, disposable petri dishes, wire loop, stirring rods, and a microscope.

2.3 Microbial Culture

The microbial culture was conducted in the department of Microbiology, Rivers State University. This was done on a culture media under controlled laboratory condition with the microorganisms isolated for proper multiplication in sterilized plates.

2.3.1 Serial Dilution and Growth Media Preparation

The normal bacteriological preparation of nutrient agar (NA) and Salmonella *Shigella* agar (SSA) of which 28 grams of nutrient agar in 1000ml of distilled water and 60grams of *salmonalla shigella* agar in 1000ml of distilled water respectively was adopted. After dissolving the powder in water using a clean material (cotton wool), the conical flask was covered with a foil and autoclaved at 121°C for 15min.

After this process, the medium was poured into different petri dishes and allowed to cool. Serial dilution process was adopted for this analysis since significant amounts of bacteria can be found in drops of water sample used. Suspensions were diluted serially so as to minimize bacterial population by a few cell/ml.

2.3.2 Microbial Isolation and Identification

The processes used involve dropping of 1ml water sample into 9ml of normal saline solution (NaCl, 8.5 grams in 1000ml of water). This was vigorously agitated to form a uniform solution of 10^{-1} concentration. The stock was subjected to a decimal dilution using sterile 1ml pipette to form 10^{-2}, 10^{-3}, 10^{-4}, 10^{-5}, and 10^{-6}concentrations.

A 1ml pipette was used to drop0.01ml of the inoculation into plates and consistently spread over the surface of the agar. The plates inoculated were incubated immediately. After about 24hours of incubation, a streak method was used to isolate pure culture from specimen containing mixed flora. Among the colonies found in the plate were *Shigella*, *Pseudomonas Aeruginosa*, and *Serretia* and these were selected based on their color and morphology. The Gram-Staining method confirmed these organisms microscopically.

- *Serratia*

This is an organism (bacteria) found commonly in water. *Serratia* has the unusual property that 10% of strains produce a bright red pigment which can cause red discoloration of nutrient agar (NA) plates in food.

- *Pseudomonas Aeruginosa*

This organism is also found in water and consists of motile non lactose fermenting gram-negative *bacilli*. The most striking feature of *Pseudomonas Aeruginosa* is the ability to produce discoloration of the medium. This is due to the production of two pigments; pyocynonin which is blue and *Fluorescein* which is greenish-yellow. On solid media (nutrient agar plate), it has an irregularly distributed shape and appear green.

- *Shigella*

This genus is also found in water and consists of non-motile gram-negative *bacilli.*

2.4 Clay Sample Retrieval

Clay samples were retrieved from three different locations within the Niger Delta for the purpose of investigating the effect of microbial actions on their rheological properties when used for drilling mud. These samples were obtained from Lobia in Bayelsa state, Omoku in Rivers state and Ughelli in Delta state, all within the Niger Delta Province.

2.4.1 Clay Preparation

76.8 grams of clay was dissolved in 316.4ml of water and mixed properly using an electric mixer for 5 minutes. The solution was left for 24 hours for proper yielding.

2.4.2 Mud Formulation Procedure

The drilling mud was prepared by mixing together the previously prepared clay solution with specific additives in their right proportions as shown in Table 1 as per [19]. The mixing process was done in the sequence in which they appear on Table 1, each for an interval of 5 minutes and thoroughly agitated using the electric mixer. After about an hour of agitation, the prepared drilling mud was weighed using a mud balance as suggested by [19], [20].

TABLE 1: Mud Composition

Additive	Amount	Function
Water	316.4m/s	Based florid
Caustic soda	0.2g	Alkalinity Control
Soda ash	0.2g	Calcium ion control
PAC	2.0g	Fluid loss control
Xanthan gum	2.0g	Thickness
Potassium Chloride	18.0g	Inhibitor control
Bentonite	2.8g	Viscosifier
Borax	2.5g	Preservative

The drilling mud was prepared using all three clay samples from the different Niger Delta locations with the same quantity of additive in their respective proportions. Each prepared mud sample was carefully labeled UGHELLI, OMOKU and LOBIA for proper identification. Table 2 shows these three samples with their additives in the same proportion.

TABLE 2: Preparation of Experimental Samples

Additives	OMOKU	LOBIA	UGHELI	Function
Barite	76.8g	76.8g	76.8g	Weighting material
Caustic soda	0.2g	0.2g	0.2g	Base fluid
Water	316.4g	316.4g	316.4g	Alkalinity control
Soda ash	0.2g	0.2g	0.2g	Ca^{2+} ion removal
Borax	2.0g	2.0g	2.0g	Preservative
KCl	18.0g	18.0g	18.0g	Inhibition control
Xanthan gum	2.0g	2.0g	2.0g	Thickener
PAC	2.0g	2.0g	2.0g	Fluid loss control
Bentonite	2.8g	2.8g	2.8g	Viscosifier

2.4.3 Distribution of Microorganism in the Various Mud Samples

All 3 prepared mud samples (Ughelli, Omoku and Lobia) were divided into 3 portions, with each portion of the mud to be subjected to each cultured microorganism (*Shigella*, *Serretia* and *Pseudomonas Aeruginosa*). A total of 9 mud samples were contained in beakers and properly labeled for easy identification.

TABLE 3: Nomenclature for Distribution of Microorganisms on Various Mud Samples.

Shigella	*Serretia*	*Pseudomonas Aeruginosa.*
Omoku-1	Omoku-2	Omoku-3
Lobia-1	Lobia-2	Lobia-3
Ughelli-1	Ughelli-2	Ughelli-3

2.5 Mud Property Determination

2.5.1 Determining Mud Density and Specific Gravity using a Mud Balance

After a routine mud balance calibration, the mud cup was filled with drilling mud. This was carefully done to avoid bubble present in the mud cup. The lid was replaced and firmly seated without blocking the vent on the lid. After washing and wiping the excess mud from the exteriors of the balance, the balance was placed on its knife-edges on the fulcrum. Using the mud weight determination technique, the rider was adjusted until the beam was balanced with the spirit level bubble on the center line. The actual mud weight value was taken and the process was repeated for all 9 samples before and after microbial subjection.

2.5.2 Determining Mud Viscosity using 8-Speed Rotary Viscometer

Agitated mud samples were immediately placed in a thermo cup up to the scribed line. With the slot on the rotor sleeve aligned to the lock pin of the main shaft, the standard procedure for engaging the viscometer was observed. The thermo cup with mud sample was placed on the seat and aligned to the holes on the stage.

The gearshift was fully dropped after the scribed mark on the rotor sleeve and lock nub were engaged clockwise. With the motor special switch engaged, the shaft rotation at 600rpm was initiated. A steady readout was recorded on the 600rpm dial and this procedure was repeated to obtain dial readings at 300rpm, 200rpm, 100rpm, 6rpm, and 3rpm.

2.5.3 Determining Mud pH using pH Meter

An indicator strip rod was placed in the mud sample for a while until there were records of color transition. The color transit time was usually less than a minute. After this, the strip rod was washed with de-ionized water. The color on the strip rod obtained from the test was compared to a standard color chart and the pH of each sample was estimated to the nearest 0.5-pH unit.

III. RESULTS AND DISCUSSION

The results obtained from investigating the effect of certain microorganisms on rheological properties of the various muds samples at several intervals are presented in this section. All 9 samples where each injected with 50ml of the designated microbial culture and kept under close observation. Since viscosity stability was one of the target objectives, a bulk of the evaluation on these 9 samples were directed towards plastic viscosity, apparent viscosity and yield point. *Shigella* subjected mud samples were labeled Omoku-1, lobia-1 and Ughelli-1. *Serretia* subjected mud samples were assigned Omoku-2, Lobia-2 and Ughelli-2 while *Pseudomonas Aeruginosa* subjected microbes were assigned Omoku-3, Lobia-3 and Ughelli-3 for easy identification and proper characterization.

TABLE 4: Rheological Properties of the Mud without Microorganisms.

Mud Samples	Specific Gravity	Mud Weight (ppg)	pH	300rpm	600rpm	Plastic Viscosity, PV (cp)	Yield Point, YP	Apparent Viscosity, AV (cp)
Omoku-1	1.180	9.80	7.53	29.0	40.0	11.0	18.0	20.00
Omoku-2	1.180	9.60	7.52	21.0	39.0	18.0	3.0	19.50
Omoku-3	1.140	9.50	7.41	16.0	28.0	12.0	4.0	14.00
Lobia-1	1.190	9.90	7.25	37.5	48.5	11.0	26.5	24.25
Lobia-2	1.150	9.60	7.25	30.0	46.0	16.0	14.0	23.00
Lobia-3	1.195	9.95	7.49	36.8	49.0	12.2	24.6	24.50
Ughelli-1	1.160	9.70	6.40	30.0	44.5	14.5	15.5	22.25
Ughelli-2	1.170	9.65	6.59	26.5	41.2	14.7	11.8	20.60
Ughelli-3	1.175	9.80	6.62	24.0	43.5	19.5	4.5	21.75

3.2 Effects of Microbes on Drilling Mud after48 Hours

TABLE 5: Effects of *Shigella* on Drilling Mud Samples

Clay Samples	Specific Gravity	Mud Weight (ppg)	pH	300rpm	600rpm	Plastic Viscosity (cp)	Yield Point	Apparent Viscosity (cp)	Time (hrs)
Omoku-1	1.18	9.80	7.43	41	59	18	23	29.5	48
Lobia-1	1.17	9.85	7.15	50	64	14	36	32.0	48
Ughelli-1	1.16	9.70	6.50	29	49	20	9	24.5	48

TABLE 6: Effects of *Serretia* on Drilling Mud Samples

Clay Samples	Specific Gravity	Mud Weight (ppg)	pH	300rpm	600rpm	Plastic Viscosity (cp)	Yield Point	Apparent Velocity (cp)	Time (hrs)
Omoku-2	1.18	9.70	7.20	33.0	56.00	23.00	10.00	28.00	48
Lobia-2	1.15	9.65	7.10	43.5	60.75	17.25	26.25	30.38	48
Ughelli-2	1.17	9.70	6.71	30.0	46.00	16.00	14.00	23.00	48

TABLE 7: Effects of *Pseudomonas Aeruginosa* on Drilling Mud Samples

Clay Samples	Specific Gravity	Mud Weight (ppg)	pH	300rpm	600rpm	Plastic Viscosity (cp)	Yield Point	Apparent Viscosity (cp)	Time (hrs)
Omoku-3	1.16	9.65	7.23	26	42	16	10	21.0	48
Lobia-3	1.18	9.93	7.23	44	63	19	25	31.5	48
Ughelli-3	1.17	9.78	6.71	28	47	19	9	23.5	48

3.3 Effects of Microbes on Drilling Mud Samplesafter96 Hours

TABLE 8: Effects of *Shigella* on Drilling Mud Samples

Clay Samples	Specific Gravity	Mud Weight (ppg)	pH	300rpm	600rpm	Plastic Viscosity (cp)	Yield Point	Apparent Viscosity (cp)	Time (hrs)
Omoku-1	1.18	9.85	7.21	59.0	72	13.0	46	36.0	96
Lobia-1	1.18	9.82	7.00	62.5	77	14.5	48	38.5	96
Ughelli-1	1.17	9.70	6.65	32.0	56	24.0	8	28.0	96

TABLE 9: Effects of *Serretia* on Drilling Mud Samples

Clay Samples	Specific Gravity	Mud Weight (ppg)	pH	300rpm	600rpm	Plastic Viscosity (cp)	Yield Point	Apparent Viscosity (cp)	Time (hrs)
Omoku-2	1.18	9.85	7.12	46	63	17	29	31.5	96
Lobia-2	1.17	9.70	6.96	54	71	17	37	35.5	96
Ughelli-2	1.165	9.70	6.83	30	53	23	7	26.5	96

TABLE 10: Effects of *Pseudomonas Aeruginosa* on Drilling Mud Samples

Clay Samples	Specific Gravity	Mud Weight (ppg)	pH	300rpm	600rpm	Plastic Viscosity (cp)	Yield Point	Apparent Viscosity (cp)	Time (hrs)
Omoku-3	1.17	9.70	6.93	35.0	51	16.0	19.0	25.5	96
Lobia-3	1.18	9.91	7.11	61.3	78	16.7	44.6	39.0	96
Ughelli-3	1.16	9.75	6.80	33.0	54	21.0	12.0	27.0	96

3.4 Effects of Microbes on Drilling Mud after 144 Hours

TABLE 11: Effects of *Shigella* on Drilling Mud Samples

Clay Samples	Specific Gravity	Mud Weight (ppg)	pH	300rpm	600rpm	Plastic Viscosity (cp)	Yield Point	Apparent Viscosity (cp)	Time (hrs)
Omoku-1	1.18	9.90	7.00	62	84	22	40	42.0	144
Lobia-1	1.18	9.82	6.40	75	93	18	57	46.5	144
Ughelli-1	1.17	9.75	6.82	46	78	32	14	39.0	144

TABLE 12: Effects of *Serretia* on Drilling Mud Samples

Clay Samples	Specific Gravity	Mud Weight (ppg)	pH	300rpm	600rpm	Plastic Viscosity (cp)	Yield Point	Apparent Viscosity (cp)	Time (hrs)
Omoku-2	1.18	9.85	6.89	58.5	70.50	12.00	46.5	35.25	144
Lobia-2	1.17	9.80	6.81	67.5	88.75	21.25	46.25	44.38	144
Ughelli-2	1.16	9.70	6.90	45.0	75.00	30.00	15.00	37.50	144

TABLE 13: Effects of *Pseudomonas Aeruginosa* on Drilling Mud Samples

Clay Samples	Specific Gravity	Mud Weight (ppg)	pH	300rpm	600rpm	Plastic Viscosity(cp)	Yield Point	Apparent Viscosity (cp)	Time (hrs)
Omoku-3	1.18	9.85	6.89	43.5	59.0	16.0	27.0	29.50	144
Lobia-3	1.19	9.90	6.97	73.5	93.0	19.5	54.0	46.50	144
Ughelli-3	1.16	9.70	7.00	46.3	75.5	29.2	17.1	37.75	144

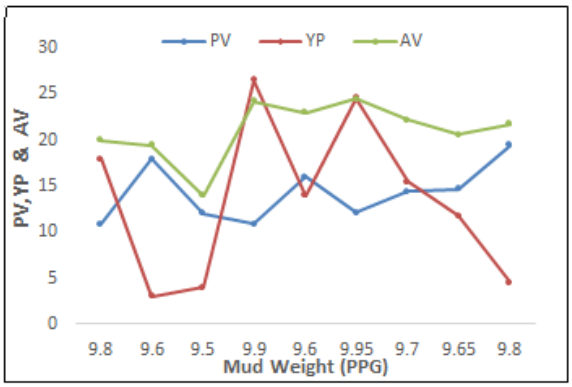

Fig 1: Variation in PV, YP & AV with Mud Weight in Mud Samples without Microorganisms.

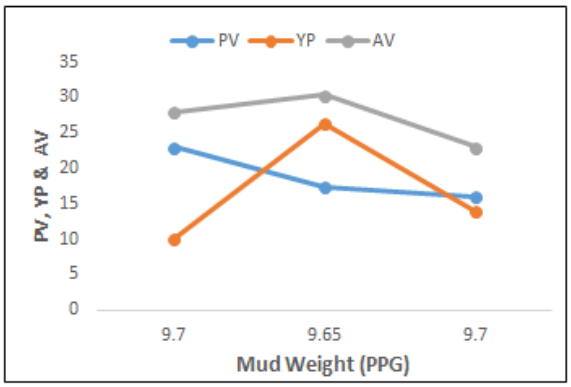

Fig 3. Variation in PV, YP & AV with Mud Weight in Mud Samples after 48Hrs of Microbial Action (*Serretia*)

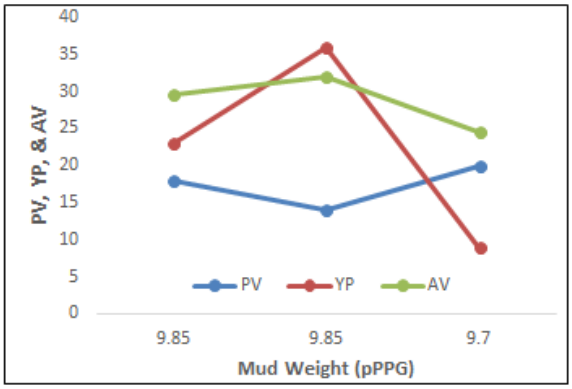

Fig 2. Variation in PV, YP & AV with Mud Weight in Mud Samples after 48Hrs of Microbial Action (*Shigella*)

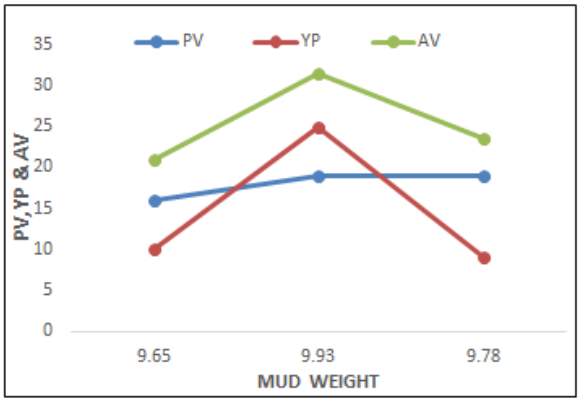

Fig 4. Variation in PV, YP & AV with Mud Weight in Mud Samples after 48Hrs of Microbial Action (*Pseudomonas Aeruginosa*)

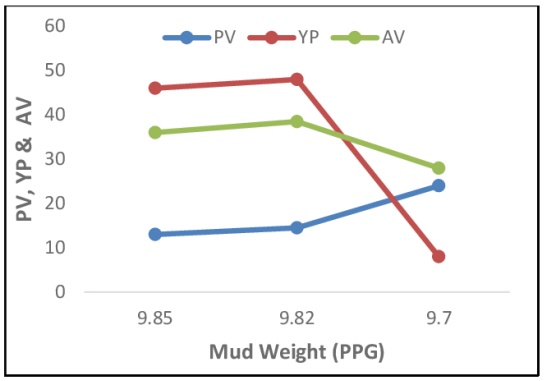

Fig 5. Variation in PV, YP & AV with Mud Weight in Mud Samples after 96Hrs of Microbial Action (Shigella)

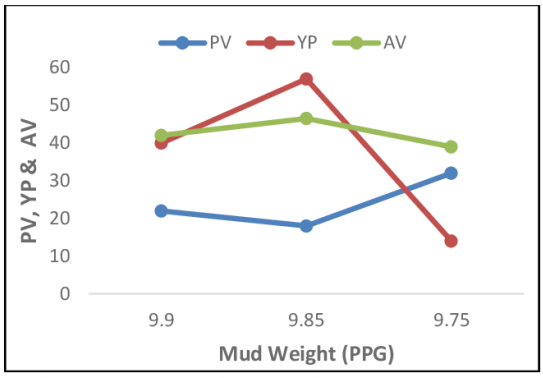

Fig 8. Variation in PV, YP & AV with Mud Weight in Mud Samples after 144Hrs of Microbial Action (Shigella)

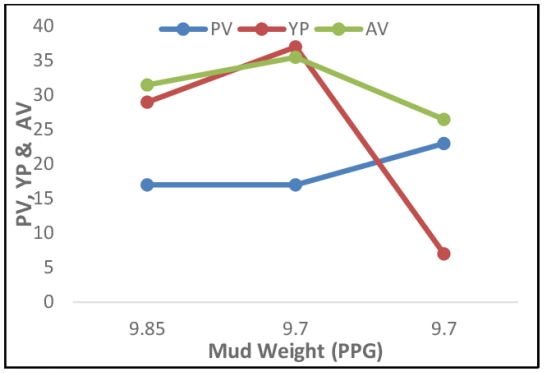

Fig 6. Variation in PV, YP & AV with Mud Weight in Mud Samples after 96Hrs of Microbial Action (Serretia).

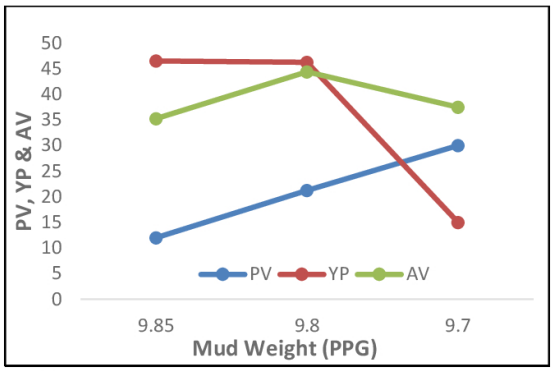

Fig 9. Variation in PV, YP & AV with Mud Weight in Mud Samples after 144Hrs of Microbial Action (Serretia)

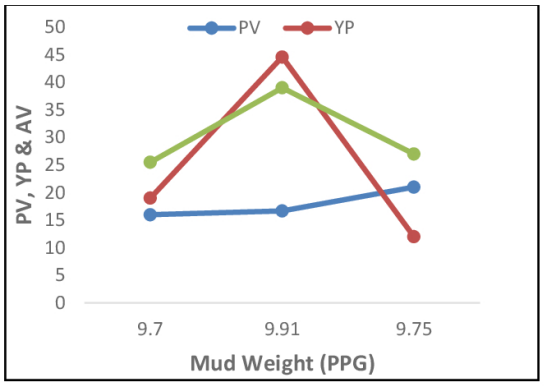

Fig 7. Variation in PV, YP & AV with Mud Weight in Mud Samples after 48Hrs of Microbial Action (Pseudomonas Aeruginosa)

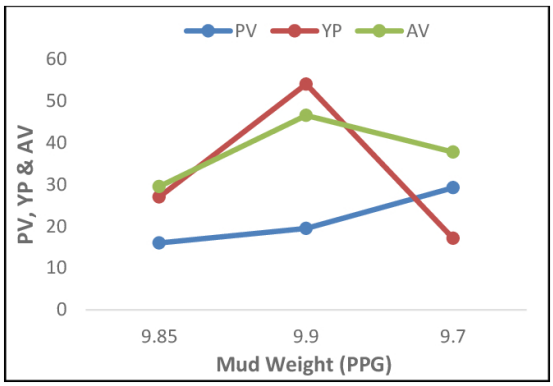

Fig 10. Variation in PV, YP & AV with Mud Weight in Mud Samples after 144Hrs of Microbial Action (Pseudomonas Aeruginosa)

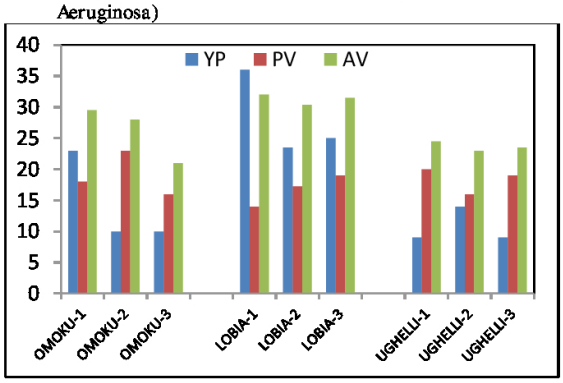

Fig 11. Effect of Microorganisms (Shigella, Serretia and Pseudomonas Aeruginosa) on Drilling Mud Samples for after 48Hrs of Investigation

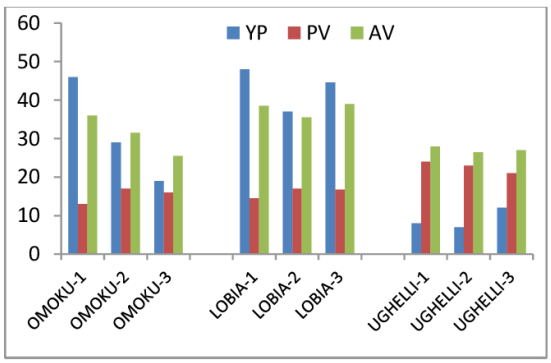

Fig 12. Effect of Microorganisms (Shigella, Serretia and Pseudomonas Aeruginosa) on Drilling Mud Samples for after 96Hrs of Investigation.

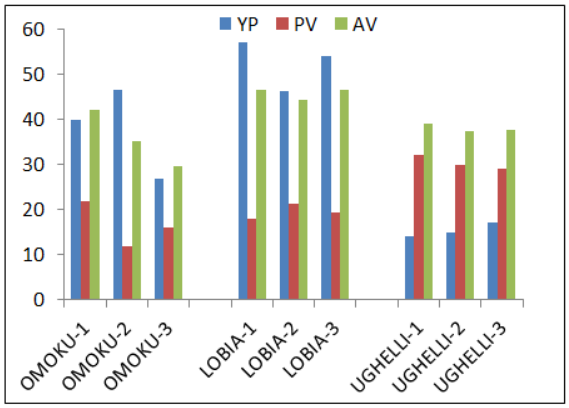

Fig 13. Effect of Microorganisms (*Shigella, Serretia* and *Pseudomonas Aeruginosa*) on Drilling Mud Samples for after 144Hrs of Investigation.

3.5 Effects of *Shigella* on Drilling Mud Samples

Experimental observations showed that mud samples prepared from Omoku clays reduced in weight after 48 hours of *Shigella* action. This mud weight was maintained until about 96 hours when a slight increase from 9.80 ppg to about 9.85 ppg was noticed. After 144 hours, the Omoku-1 was observed to have increased by in mud weight, recording about 9.90 ppg.Lobia-1 slightly decreased from an initial mud weight of 9.90 ppg to 9.85 ppg after 48 hours of microbial action. It further decreased to 9.82 ppg after 96 hours but remain almost the same after 144 hours. Ughelli-1 maintained its 9.70 ppg mud weight through the entire period of investigation though increased slightly by 0.52% after 144 hours. For pH tests on the action of *Shigella* on mud samples, Omoku-1 and Lobia-1 indicated that this microorganism possesses the ability of considerably increasing the acidity of these mud samples with time. However, the reverse was observed for the action of *Shigella* onUghelli-1. It was noticed that sample Ughelli-1 with an initial pH indication of 6.62 recorded a test of neutrality (pH =7.00) after 144 hours of investigation. All other rheological properties of mud samples Omoku-1, Lobia-1 and Ughelli-1 such as apparent viscosity and plastic viscosity did not vary significantly. Conversely, variations in yielding of the mud samples were found to be significant for all 3 *Shigella* subjected samples. This may be traceable to produced metabolites by this microorganism which possess the ability to significantly alter the yielding capacity of drilling muds.

3.6 Effects of *Serretia* on Drilling Mud Samples

It was observed that the mud weight of sample Omoku-2 increases from 9.60 ppg to 9.70 ppg after 48 hours and to 9.85 ppg after 96 hours on application of *Serratia*. The mud weight remained the same after 144 hours of microbial action. At this point, it can be inferred that the metabolites produced after 96 days of action had no significant effect on mud weight for this sample. The pH investigation on this mud sample revealed that this microorganism (*Serretia*) can significantly increase the acidity of the drilling mud. This can be traceable to the production of bio-acids as one of the major metabolites of this organism. This trend was also observed for Lobia-2 mud sample as pH value decreased from 7.25 to 6.81 after 144 hours. The Ughelli-2 sample however showed a different pH behavior. On application of *Serretia*, the acidity of the mud reduced with time. This could have no doubt been as a result of the clay chemistry.

The mud weight of samples Lobia-2 and Ughelli-2 both increased over the 144 hours period of investigation, although Ughelli-2 slightly increased by 0.52% from 9.65 ppg to 9.70 ppg. This mud weight was maintained through 144 hours of observation for the Ughelli-2 mud sample. Other rheological properties such as yield point, plastic viscosity and apparent viscosity were found to be greatly altered by this microorganism for all 3 mud samples (Omoku-2, Lobia-2 and Ughelli-2), with the most significant variation in the yielding capacity of the mud.

3.7 Effects of *Pseudomonas Aeruginosa* on Mud Samples

Pseudomonas Aeruginosa increased the mud weight of mud sample Omoku-3 from 9.50 ppg to 9.85 ppg after 144 hours. This was not so for the other mud samples with Lobia-3 having an initial mud weight of 9.95 ppg and a final measured mud weight of 9.90 ppg after 144hours of *Pseudomonas Aeruginosa* action**.** Ughelli-3 mud sample also showed a reduction in mud weight from initial mud weight of 9.80 ppg to 9.70 ppg, possibly as a result of solvents produced by metabolic processes of the microorganism.The action of *Pseudomonas Aeruginosa* on mud samples Omoku-3 and Lobia-3 changed their pH indications from being basic to acidic. Omoku-3 having a pH of 7.41 was altered to 6.89 and Lobia-3 with pH 7.25 was changed to 6.97 after 144 hours.

However, Ughelli-3 mud behaved differently from all other *Pseudomonas Aeruginosa* subjected samples. While others like Lobia-3 and Omoku-3 changed from being alkaline to acidic, Ughelli-3 mud sample changed from being acidic to being neutral (pH = 7.00) after 144 hours of investigation. It can be projected that a continuous examination of *Pseudomonas Aeruginosa*, the Ughelli mud can considerably increase its alkalinity. It could possibly be inferred that the clay chemistry of Ughelli muds amongst other factors may be responsible for this as it deviates from Lobia-3 and

Omoku-3 responses to *Pseudomonas Aeruginosa* with respect to pH indication

IV. CONCLUSION

This study has proven that rheological properties of clay samples when considered for drilling mud preparation, regardless of their location can be altered upon subjection to microbial action. Drilling mud preparation entails a thorough evaluation of mud constituents in their right proportions. When these constituents do not meet certain design criterion, the muds become less effective. From a biological stand point, the non-conservative nature of this study reveals that if already prepared mud samples are exposed to these microorganisms, they can significantly distort the plastic and rheological behavior of the already designed mud. Drilling muds are designed for specific application, when there is a distortion in a particular mud property, maximum deliverability may not be achieved during drilling operations. For example, this study have shown that the pH of a mud can be altered regardless of the clay composition when subjected to *Shigella*, *Serretia* or *Pseudomonas Aeruginosa*, it also revealed that there can be high fluctuations in the yielding capacity of these clay materials when exposed to these microorganisms. It is however imperative that detailed analysis on clay chemistry as well as microbial reaction kinetic to clay materials is understudied. Also, a sound and comprehensive examination of the morphology of candidate microorganisms to be used for mud preparation be conducted for optimum performance.

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Appendix

Shear rate, γ (sec^{-1}) = Rheometer speed x 1.703
Shear stress, τ (dynes/cm^2) =Viscosity x shear rate
Plastic viscosity, PV (cp) = θ600 - θ300
Yield point, (YP) = θ300 - PV
Viscosity, μ (cp)= $\frac{300 \text{ x dial reading}}{\text{Rheometer speed}}$
Apparent viscosity, AV (cp) =$\frac{\theta 600}{2}$

Fig 14. 8-RPM Rorary Viscometer

Fig 15. pH Meter used

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