

# Use of Coconut Fibre as a Suitable pH and Rheology Enhancer

Dune, Kingdom K.<sup>1,\*</sup>, Vipene, Kale Kelvin<sup>2</sup>

## Abstract

*This paper studied the use of coconut fibre as a substitute for caustic soda in drilling fluids for the improvement of pH in a water-based mud. The coconut coir was dried in the sun for 7 hours and ground into very fine particles, after which it was placed in an electronic oven at a temperature of 105°C for 1 hour to remove any remaining moisture. Sieving using a 200 mm sieve was then done. Eleven mud samples were formulated, varying the concentrations of coconut fibre in each sample and various tests, including mud density, viscosity and pH, were carried out on them. The pH of all mud samples falls in the range 9.2 to 9.5 as compared to the control sample (A) of pH 9.0, which is a good range for water-based muds to minimize corrosion of the in-hole metal components. It means that the addition of coconut fibres improved the pH of the muds, which shows their viability as suitable replacements for sodium hydroxide. A plot of the true Bingham yield point (TBYP) versus mass concentration of coconut fibre was done to optimize the quantity of the coconut fibre to be added to the mud to produce a minimum yield point of 20 Lb/100ft<sup>2</sup> required to initiate flow and improve the pH, which was estimated to be 3.5 gram. The results showed that coconut fibre is a good substitute for caustic soda (NaOH). They also act as good fluid loss and help improve the performance of polymers in the mud.*

**Keywords:** Coconut fibre, drilling fluid, fluid, pH enhancer and rheological properties, water-based mud

## INTRODUCTION

Oil, water, clays, and other substances are combined to create drilling fluids, often known as drilling muds, which facilitate drilling. It is circulated downhole through the drill string and performs many functions such as stabilize formation pressure, cooling and lubrication of the drill bit and drill string and removal of rock cuttings from the hole. The three primary categories of drilling fluids are gaseous, water-based, and oil-based, with gaseous drilling fluids being less widely utilized than water- or oil-based fluids (Ahmed and Ekrem, 2019) [2].

Chemicals in drilling muds are commonly known as additives. The mud additives should be adequately tested before use to prevent common drilling problems “since the success of drilling operations depends on the proper selection of drilling fluid system” (Bourgoyne et al., 1991), [6] The utilization of local materials has dated a while back in a bid to conserve foreign exchange and utilize local materials for cost effectiveness.

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The viscosity of a mud is a crucial mud flow attribute; a high viscosity typically translates into better hole cleaning since cuttings will settle more quickly if the fluid viscosity is low. The ability of a drilling fluid to transport drill cuttings from the bit up the annulus to the surface is one of its most important roles, according to Igwilo (2000) [8]. Another very important function of the mud is its ability to suspend cuttings when there is no circulation due to the thixotropic nature (Ahmadi 2008).

Drilling activities started in the middle of the 1950s, and local clay and additives were utilized

until the early 1960s, when they were replaced by imported ones, according to Bindei (1987) [5]. Igwilo *et. al* (2020) in his work “beneficiated local bentonite using snail shell and mucuna solanine” found out that Nigerian bentonite could compete favorably with imported bentonite [9]. Ololade *et. al* (2020) in their work discovered that “medium coarse coconut fibre in the combination ratio of 60:40” gave good rheological properties and had the least fluid loss making it suitable as a lost circulation material [11]. Amanullah & Yu (2004), in their experimental work, used corn-based starch as mud viscosifier and reported that “some of the starches have better filtration control properties than that of the imported mud starch been the second most abundant biomass found in nature [3]”. Biliamino & Ibrahim (2010) demonstrated that “calcium bentonite can easily be upgraded to sodium bentonite” [4].

In the exploration and production phase of the petroleum industry, innovations are constantly being sought after on ways to reduce the enormous costs of the importation of drilling fluid additives especially given the high rate of foreign exchange and the impact on the economy. Wami *et al.* (2015) conducted a research on “the use of potato starch as a viscosifier and fluid loss control agent in a water-based mud” and results showed the efficiency of potato starch as a viscosifier and fluid loss reducing agent. Igwe and Kinate (2015) “proved the efficacy of periwinkle shell ash as a filtration loss control agent in water-based drilling mud and found out that 2g of periwinkle shell ash gave minimal filtrate volume of 6.7ml after 30 minutes of filtration” [7]. The pH of a drilling fluid is important for certain polymers to function properly and to prevent the mud from losing its properties so pH should be kept in the range of 8.0 to 10.5 (Petromode, 2018) [12]. Abdumaliq *et. al* (2020) studied “the use of banana peels ash and plantain peels ash as pH and viscosity enhancers in water-based drilling fluids.” They found out that these additives improved the mud pH and also improved its viscosity. The aim of this study is to use coconut fibre as an additive to enhance pH and rheology of drilling muds.

## MATERIALS AND METHODS

### Materials

The materials used for the experiments include: coconut fibre, beakers, spatula, measuring cylinder, electronic weighing balance, electronic oven, sieves, oven, blender/mixer, rheometer, mud balance, pH paper, thermometer, stop watch and API Filter Press. The coconut fibres were obtained from International Institute for Tropical Agriculture (IITA), Onne, some few kilometers from Port Harcourt, Nigeria. In this study, an experimental work was carried out in the Petroleum Engineering laboratory, RSU, Port Harcourt in order to evaluate the effect of coconut fibre on the drilling mud with respect to its pH and rheological properties. Eleven mud samples were prepared with different concentrations of coconut fibre, where sample A (the control) contained 0.2g of caustic soda while gradually replacing it with the coconut fibre in subsequent samples. The results from the formulated drilling mud samples were compared with the standard drilling mud formulated with caustic soda.

### Preparation of Coconut Fibre

The coconut coir (Figure 1) was dried in the sun for 7 hours and ground into very fine particles, after which it was placed in an electronic oven for 1 hour at a temperature of 105°C to remove any remaining moisture. Sieving using a 200µm sieve was then done.



**Figure 1.** Coconut fibre.

### Formulation of Mud Samples

Eleven different mud samples were formulated using different concentrations of the drilling mud additives. The drilling fluid additives used for the mud formulation include: Caustic soda, Soda ash, Polyanionic Cellulose (PAC), coconut fibre, Xanthan gum, Potassium chloride, barite, borax and bentonite. The control sample was labelled Sample A. The experimental samples were labelled B to K. The mixture was agitated (stirred) thoroughly using a mixer/blender. The other additives were introduced into the mixture and agitated at five-minute intervals one after the other until the last additive was added. Table 1 shows Mud Composition for Sample A (Control Sample). The other additives were kept constant while the variant was coconut fibre in the mud samples. Caustic soda was replaced with coconut fibre in samples B, C, D, E, F, G, H, I, J and K. Coconut fibre was added in gradual increments of 0.5g, 1g, 1.5g up to 5g in each mud sample as shown in Table 2.

**Table 1.** Mud Composition for Sample A (Control Sample).

Composition	Concentration	Function
Water	350ml	Base fluid
Caustic soda	2g	Alkalinity control
Soda Ash	0.2g	Calcium ion removal
PAC	2.0g	Fluid loss control
Xanthan gum	2.8g	Viscosifier
Potassium chloride	18g	Inhibitor
Barite	76.8g	Weighting material
Borax	2g	Preservative
Bentonite	2.8g	Viscosifier
Coconut fibre	0.5 to 5g	pH enhancer

**Table 2.** Sample Preparation

Sample	Coconut Fiber in Grams
B	0.5
C	1.0
D	1.5
E	2.0
F	2.5
G	3.0
H	3.5
I	4.0
J	4.5
K	5.0

### Mud Properties Determination

The mud weight was measured using a Baroid mud balance at room temperature of about 25°C after adding coconut fibre. A constant volume cup with a lever arm rider calibrated to read the mud density in pounds per gallon (ppg) directly is part of the device. Once the lid is removed, the cup is fully filled with the mud to be tested. After replacing the lid, the mud that had been ejected from the cup's hole was cleaned off. With the knife edge resting on the fulcrum, the balancing arm was positioned on the base (Manual of Drilling Fluids and Hydraulics, 1998) [10].

The 8-speed rotational rheometer (Ofite model 800) was utilized to measure the rheological properties of the formulated mud samples. The formulated mud samples were placed under rheometer's arm set at the various predetermined speeds of 600, 300, 200, 100 rpm, etc and the force or torque the rotating bob exerts on the fluid was measured. These measurements were converted to the fluid's flow properties such as plastic viscosity (PV), apparent viscosity (AV), shear stress and shear

rate. These fluids' rheological properties were determined using the following formulas:

$$\text{Apparent Viscosity in cP, } \mu_a = \frac{\theta 600}{2} \quad (1)$$

$$\text{Plastic Viscosity in cP, } \mu_p = \theta 600 - \phi 300 \quad (2)$$

$$\text{Effective Viscosity in cP, } \mu_e = \frac{300 \times \theta}{\omega} \quad (3)$$

$$\text{Yield Point (Lb/100 ft}^2\text{), } Y_p = \theta 300 - \mu_p \quad (4)$$

$$\text{Shear Stress (Lb/100 ft}^2\text{), } \tau = 1.0678 * \theta \quad (5)$$

$$\text{Shear Rate (sec}^{-1}\text{), } \gamma = 1.703 * \omega \quad (6)$$

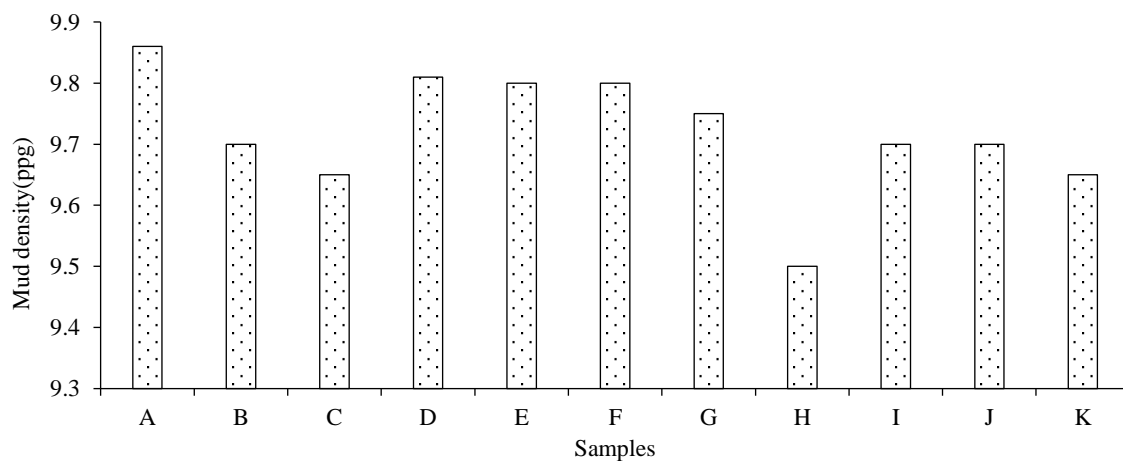
where  $\phi$  is the dial reading and  $\omega$  is the rotor speed, rpm.

## RESULTS AND DISCUSSION

Rheological properties of the drilling fluid samples are displayed in Table 3 while the mud weight measured for the various samples (A-K) are displayed in Figure 2. The results in Table 3 were used to calculate the shear stress and shear rates, using Equations 5 and 6, which were plotted in Figures 4-7 for the various mud samples.

### Mud Weight

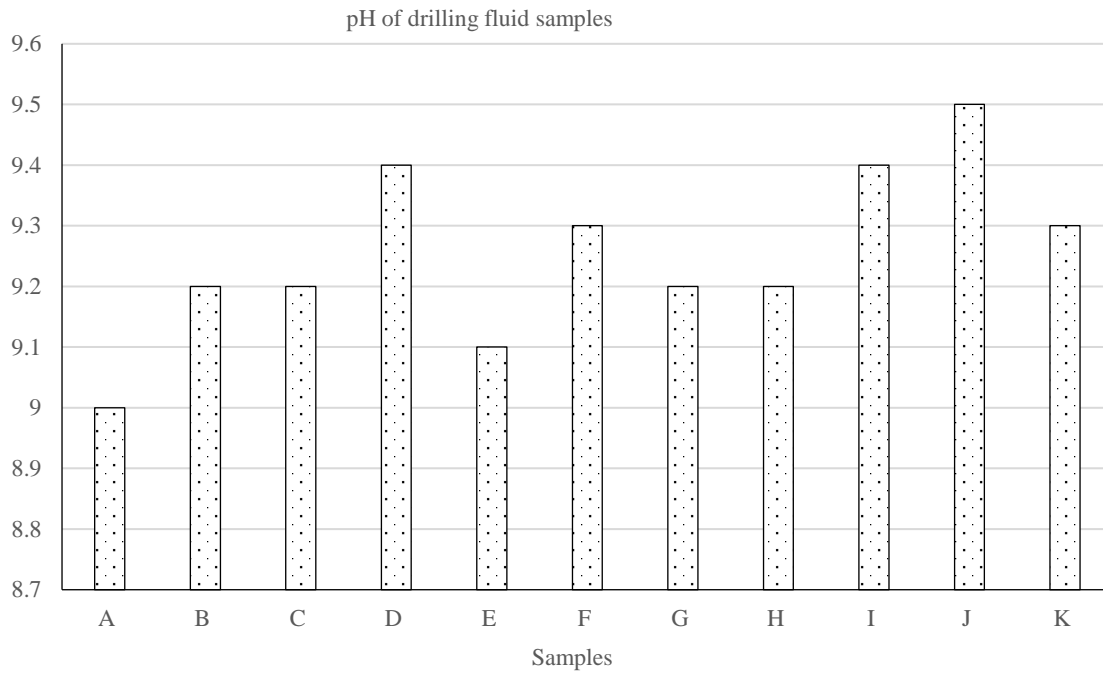
Generally, weighting materials are computed and added to mud formulations for the purpose of combating and balancing formation pressure. Some reservoirs require a heavier mud than others depending on the subsurface pressures encountered. The result in Figure 2 shows that coconut fibre does not significantly increase mud weight.



**Figure 2.** Mud Density of Drilling mud Samples.

### Hydrogen Ion Concentration (pH)

The pH of the drilling mud samples (A-K) is shown in the Figure 3, with all Samples displaying pH in the range 9.0 to 9.5 which is a good range for water-based muds. "The mud pH affects viscosity; bentonite is least influenced when the pH is between 7 and 9.5. Above this point, the viscosity will increase, perhaps resulting in viscosities that are out of proportion for acceptable drilling qualities. To minimize shale difficulties, a pH of 8.5 to 9.5 appears to provide the optimum hole stability and mud property control. A high pH (10+) appears to produce shale issues. Metal corrosion increases when it comes into contact with an acidic fluid, hence a higher pH is preferable for pipe and casing protection" (Abdulmalik et al., 2020) [1].



**Figure 3.** pH of mud samples.

The results show that coconut fibre in Sample J gave the highest pH of 9.5, followed by Samples D and I having a pH of 9.4. The pH of all mud samples falls in the range 9.2 to 9.5 as compared to the control sample (A) pH of 9.0, which is a good range for water-based muds to minimize corrosion of the in-hole metal components. It means that the addition of coconut fibres improved the pH of the muds, which shows their viability as suitable replacements for sodium hydroxide.

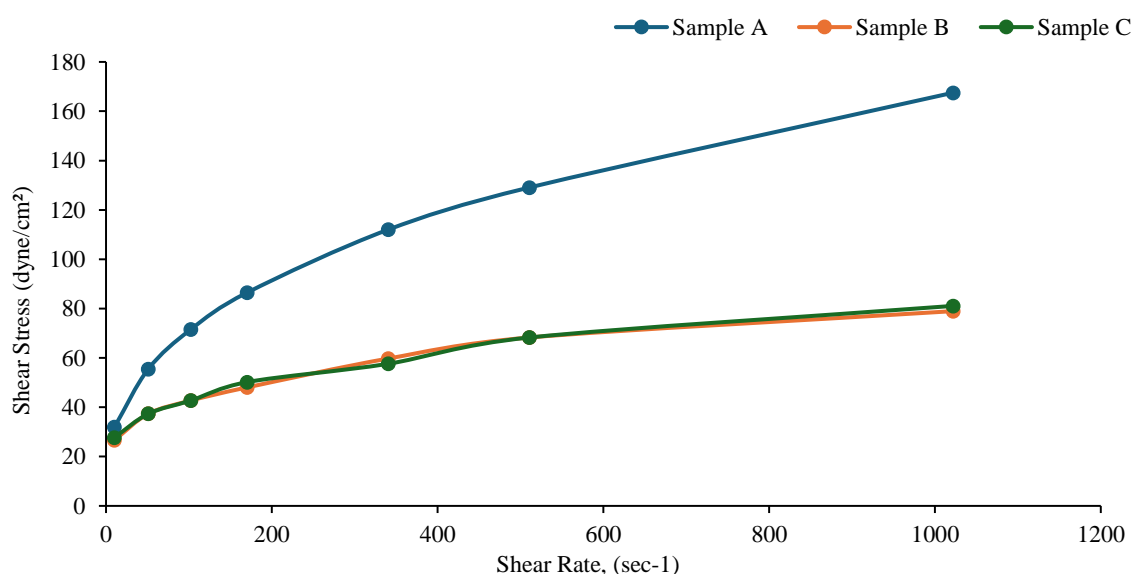
**Table 3.** Rheological properties of the drilling fluid samples.

Sample	Ø600	Ø300	Ø200	Ø100	Ø60	Ø30	Ø6	Pv (Ø600-Ø300)	Yp (Ø600-PV)	AV Ø600/2	10 mins gel strength	pH	Mud Weight (ppg)	10 sec gel strength
A	157	121	105	81	67	52	30	36	85	78.5	28	9.0	9.86	28
B	74	64	56	45	40	35	25	10	54	37	23	9.2	9.7	24
C	76	64	54	47	40	35	26	12	52	38	24	9.2	9.65	24
D	135	110	94	74	61	50	32	25	85	67.5	25	9.4	9.81	27
E	132	100	95	77	66	53	40	32	68	66	30	9.1	9.8	33
F	114	90	80	65	54	44	29	24	66	57	25	9.3	9.8	27
G	112	88	78	63	52	42	27	24	56	64	25	9.2	9.75	25
H	65	53	45	35	33	26	19	12	41	32.5	16	9.2	9.5	16
I	102	76	65	52	50	41	26	26	50	51	25	9.4	9.7	25
J	120	92	85	76	65	50	28	32	60	60	24	9.5	9.7	24
K	108	83	72	56	51	42	27	25	58	54	21	9.3	9.65	23

### Shear Stress and Shear Rate Plots for the Mud Samples

Figures 4-7 show an observable relationship between shear stress and shear rate of the drilling fluid produced from water-based drilling mud formulated with local additives (coconut fibre). The muds exhibit behavior that is close to Bingham plastic model which translates to marked deviation from the Newtonian fluid model since the curves do not pass through the origin as observed in the plots. Table 4 shows the Bingham plastic yield point values read from Shear stress-shear rate plots (Figures 4-7) and plotted in Figure 8 to show the trend of the yield point and the true Bingham yield point (TBYP) for the various Samples, which are essential for the evaluation of the right, optimum quantity of the local material under investigation. The term yield point refers to "a measure of the electrochemical or

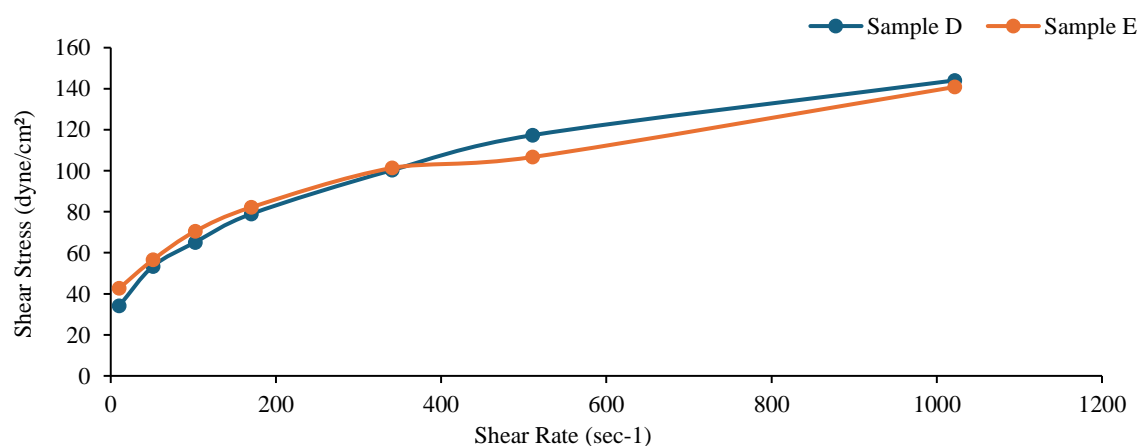
chemical attractive forces in the mud" (Drilling Fluids and Hydraulics Manual, 1998). Figure 4 shows the plots of shear stress versus shear rate for Samples A, B and C.



**Figure 4.** Shear Stress vs Shear Rate Plots for Samples A, B and C

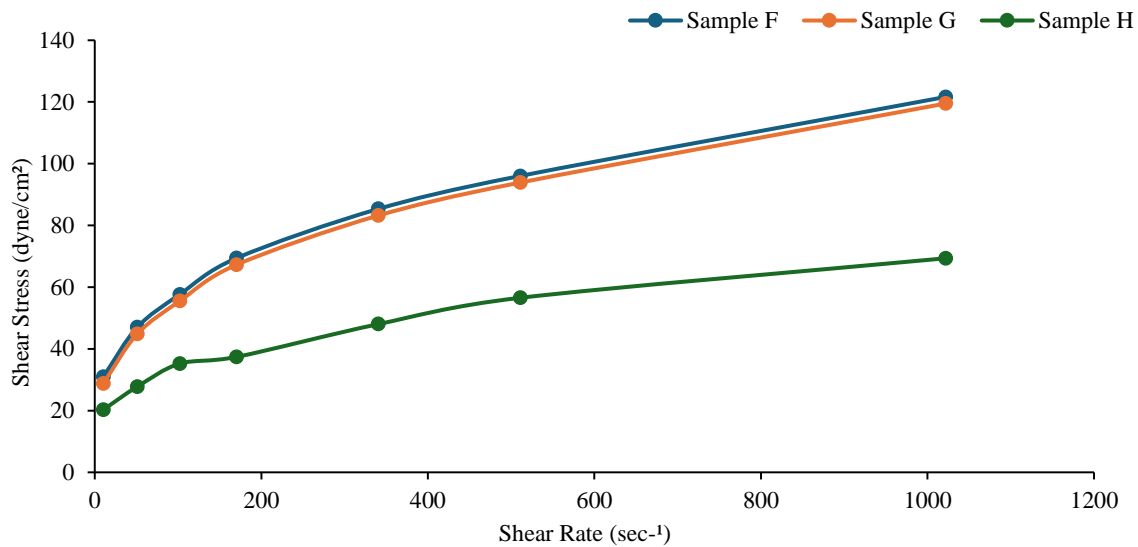
Sample A is the control sample which contains only caustic soda of 2g. Sample B and C contain coconut fiber of 0.5g and 1g respectively. Caustic soda can help stabilize the clay particles and prevent the breakdown of polymers used as viscosifiers, which are essential for controlling the rheology of the fluid. In water-based muds, the addition of caustic soda can lead to changes in clay behaviour by dispersing or flocculating clay particles which directly affects the rheology. Sample A requires a shear stress of about 32 dyne/cm<sup>2</sup> to initiate a flow while samples B and C require 26dyne/cm<sup>2</sup> and 27dyne/cm<sup>2</sup> respectively.

In Figure 5, sample D and E both contain 1.5g and 2g of coconut fiber, respectively. They both require a shear stress of 34.16 and 42.7dynes/cm<sup>2</sup> to initiate flow. At a shear stress of 100 dynes/cm<sup>2</sup> the two curves overlap at a shear rate of 370 sec<sup>-1</sup>. Coconut fiber can impact the shear stress and shear rate of water-based drilling fluids by increasing their viscosity and rheological properties. This mainly depends on their ratio and concentration. This is because fibers increase the internal friction within the fluid by introducing a network structure that resists deformation enhancing the carrying capacity of the fluid and providing better support for drill cuttings.



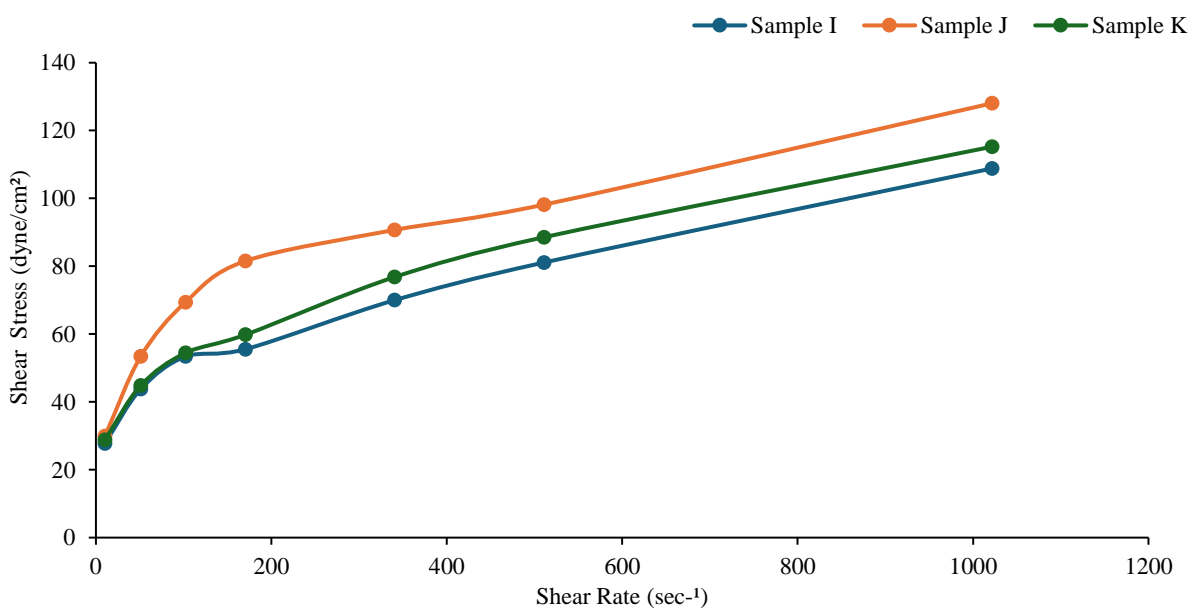
**Figure 5.** Shear Stress vs Shear Rate Plots for Samples D and E.

Figure 6 is the plots of shear stress vs shear rate for Samples F, G and H. At optimal point, a certain fibre concentration, the fluid reaches its maximum effective viscosity. The fibres have sufficiently interconnected to create a dense network that resists flow. Beyond the optimal concentration, adding fibers can lead to overcrowding. Fibres may clump reducing their effectiveness in increasing viscosity.



**Figure 6.** Shear Stress vs Shear Rate Plots for Samples F, G and H.

In Figure 7, a plot for Samples I, J and K, with further increase in the additives, the shear stress did not necessarily increase. This implies that the additive may have reached its optimum point. But the fluid still maintained a Bingham plastic model. The fluid will now flow until a minimum shear stress is given to it. Once the true Bingham yield point (TBYP) is exceeded, the fluid begins to flow. This phenomenon is also known as thixotropy.

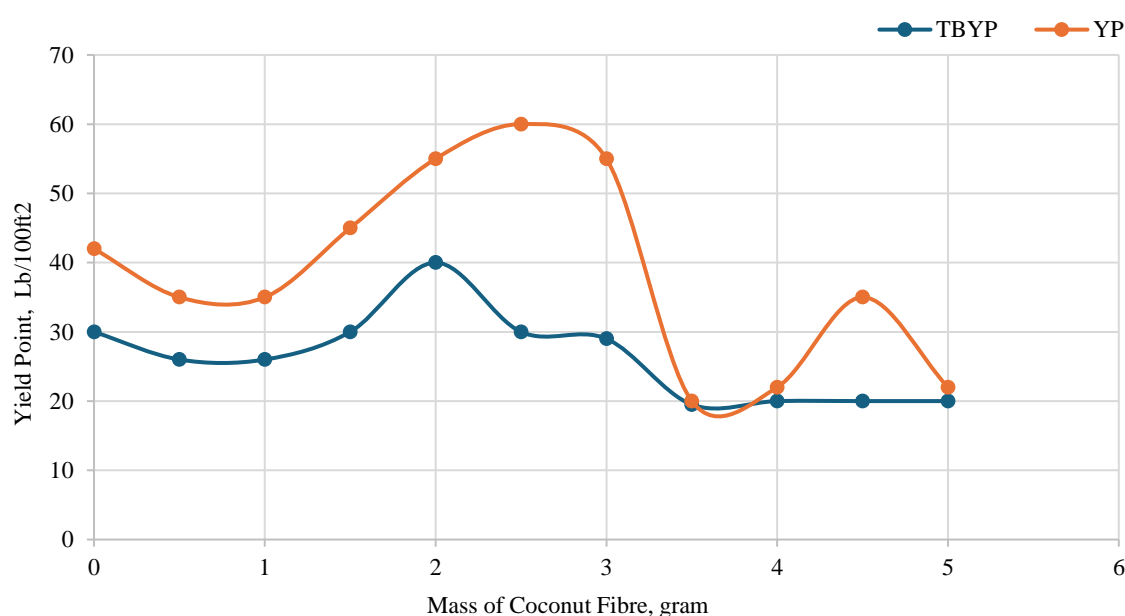


**Figure 7.** Shear Stress vs Shear Rate Plots for Samples I, J and K.

A very interesting trend was observed when values of yield point (YP) and the true Bingham yield point (TBYP) for the various samples were collated, displayed in Table 4 and plotted in Figure 8. Initially, TBYP increased to a maximum of 40 Lb/100ft<sup>2</sup> on addition of 2g of coconut fibre, and then

decreased steadily to 20 Lb/100ft<sup>2</sup> on further addition. The overall effect of the replacement of the coconut fibre in the mud samples was a decrease in the true Bingham yield point until a constant, optimum value of 20 Lb/100ft<sup>2</sup> was attained. From Figure 8, the trend of the yield point and the true Bingham yield point (TBYP) for the various Samples depicts that the quantity of local material added to the mud was able to modify their rheological and flow properties, especially the yield point.

The YP is decreased as the mass concentration of coconut fibre is gradually increased. This means a decrease in the apparent viscosity. This plot (Figure 8) is important because it helps in the optimization of the quantity of the material for economic reasons. Since the yield point/stress must be exceeded for flow to be initiated, the optimum quantity of the coconut fibre to be added to the mud to produce a minimum true Bingham yield point of 20Lb/100ft<sup>2</sup> required to improve the pH is 3.5 gram as can be seen in Figure 8.



**Figure 8.** A plot of the Yield Points of the Mud Samples.

**Table 4.** True Bingham Yield Point (TBYP) for various Mud Samples

Table 4: True Bingham Yield Point (TBYP) for various Mud Samples				
Sample	Coconut Fibre, Grams	TBYP, (Lb/100ft <sup>2</sup> )	YP, (Lb/100ft <sup>2</sup> )	Figure
A	0	30	42	4
B	0.5	26	35	4
C	1.0	26	35	4
D	1.5	30	45	5
E	2.0	40	55	5
F	2.5	30	60	6
G	3.0	29	55	6
H	3.5	19	20	6
I	4.0	20	22	7
J	4.5	20	40	7
K	5.0	20	22	7

Results obtained for the drilling fluid Samples in this study fall within the API standard specifications with respect to rheology, fluid loss, density and pH as compiled by Darly and Gray (1988) shown in Table 5.

**Table 5.** API specification of drilling mud properties (Darly and Gray 1988)

Drilling Mud Properties	API Specification
Viscometer dial at 600rpm	Min. 30
Viscometer dial at 300rpm	Min 23
PV (cp)	Min 7
YP (Lb/100ft <sup>3</sup> )	Max 50
Apparent viscosity (cp)	Min 15
Fluid loss	Max 12
pH	9 – 11

## CONCLUSION

Coconut fibre, which is a waste product, could be useful in the drilling industry to reduce costs. The properties considered in this study include pH (mud alkalinity), viscosity and yield point. The pH of all mud samples falls in the range 9.2 to 9.5 as compared to the control sample (A) of pH 9.0. A plot of the true Bigham yield point (TBYP) versus mass concentration of coconut fibre was done to optimize the quantity of the material to be added to the mud to produce a minimum yield point of 20 Lb/100ft<sup>2</sup> required to initiated flow and improve the pH, which was estimated to be 3.5 gram. The results showed that coconut fibre is a good substitute for caustic soda (NaOH), acting as good pH enhancers, fluid loss agent and help improve the performance of polymers in the mud.

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