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Laboratory Investigation of Palm Kernel Fiber as an Additive to Optimize the Performance of Locally Produced Drilling Fluid

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Abstract
The oil industry was one of many industries badly hit by COVID 19, as the drastic drop in demand ultimately led to a price shock and sharp oil price reduction. The industry is faced with the need to develop strategies to survive even in unprecedented times. Adaptation measures at this point mostly circle around cost reduction and drilling mud being an integral part of CAPEX is not left out in the drive to optimize cost. In this work, extensive investigation was done to identify a local material such as palm kernel fiber (PFA) as an efficient mud additive. Four mud samples (two WBM's and OBM's) were formulated and analyzed at different PFA concentrations with the results compared to standard mud formulation. Experimental results indicated that while the PFA may enhance the fluid loss behavior of the mud samples, its effect on other rheological parameters requires further investigation, to avoid detrimental decisions that are based on a single observation parameter. Further observations from the findings in this work show that the locally modified mud samples are comparatively good alternatives with less environmental impacts. From the cumulative findings, recommendations are presented for field usage of locally formulated mud for drilling.

Keywords: *drilling fluids, local materials, cost optimization, palm kernel fiber, waste management, lost circulation, mud additives, and fluid loss.*

I. INTRODUCTION

Statistics from 2011 showed that the value of the drilling fluids market on a global scale was about 7.2 billion US dollars and this increased by 71% in the span of seven years to be valued at 12.3 billion US dollars as at 2018. Its use for offshore purposes accounted for 30% of the total market in 2012 and the global industry analysis report published by Transparency Market Research showed that North America has always been the leading market for drilling fluids with over 55 % of the global share Markets & Markets, [4, 5].

Some challenges which the oil and gas industry is continuously faced with include: *the ever-rising energy demand in the form of fossil fuels and the increasing operational cost caused by the depletion of conventional hydrocarbon reserves*; a recent unprecedented challenge is the Corona virus which rocked global industries. As such, it behooves on the industry to adopt sustainable measures to buffer the effect of sharp market downturns by ensuring optimal running cost (of which drilling mud cost is an integral part). As a rule, optimized cost is often a major prospect indicator for the rapidly evolving drilling and exploration activities across the globe.

Since the cost of drilling mud could be approximately 15 to 18% of the overall cost of drilling the well, (Kruse, 1975) it therefore implies that significant cost cutting could be achieved by identifying new prospects in drilling fluid formulations using locally sourced additives. However, the operational efficiency must not be compromised as this could lead to severe economic losses and major safety issues such as well kick/blow out, excessive mud loss in the porous media (leading to well damage and difficulty in interpreting well log data), well-bore integrity issues and other issues associated with drilling through difficult geological locations (swelling Clay and Shale).

In the work of Akinade, *et al*., a study was done to investigate ways of improving the gel strength of locally produced drilling mud for use in Nigeria, since gel strength has been identified by authors as the major limitation to the wide application of locally produced drilling fluids. In their study, guar gum and ginger mix was used to formulate one sample of drilling mud, serving as a viscosifier – thereby improving the rheological properties of locally produced mud, as well as its gel strength. From the results of their experiment, it was observed that the guar gum-ginger mix additive achieved the purpose of improving the gel strength and other rheological properties of the locally produced mud. By comparison, it competed favorably when compared to the mud sample formulated with API standard gel strength additive (Kassab, Ismail, & Elessawi, 2011; Kruse, 1975).

In another study by Peretomode, 2018, powder from plantain peels (PPP) and burnt palm head sponge (BPHSP) as well as sodium hydroxide (NaOH) were shown to be usable as good additives for local drilling fluid production. However, in this case, water-based muds (WBM) samples were formulated such that BPHSP, PPP and NaOH were varied in amounts of 1.0 to 5.0 g. The results from the analyses done in that study revealed that the pH and rheological properties (i.e., apparent viscosity, plastic viscosity and yield point) of water-based mud samples formulated were relatively enhanced with respective to the commercial NaOH, BPHSP and PPP quantities added. The aforementioned rheological properties were enhanced with increase in the quantity of each of the utilized additives. The commercial NaOH had the highest percentage of improvement on the mud pH with 22.2 – 50%, followed by that of BPHSP (16.7 – 44.4%) and PPP (11.1 – 33.3%), respectively. It is thus obvious from the results that commercial sodium hydroxide, burnt palm head sponge ash powder and plantain peels powder can respectively be used as additives to enhance or improve the pH and rheological properties (viscosity and yield point) of water-based mud.

In this study, an investigation is presented for using palm kernel fiber to enhance the performance of a locally produced drilling mud at the PVT/Core Analysis Laboratory, Department of Petroleum, Rivers State University, Port-Harcourt.

II. LITERATURE REVIEW

2.1 The Composition of Drilling Fluids

The requirements of a particular drilling operation and environmental regulations are the major determinant of the composition of a drilling mud. The most common drilling muds are those with liquid as the continuous phase. A typical drilling mud is typically made up of:

- **i.** Water or Oil as the Continuous Phase: This may either be water based or oil (i.e. vegetable or mineral oil) based.
- **ii.** Reactive Solids Phase (Colloidal Phase): Commercial clays such as; bentonite and attapulgite as well as hydrated clays and shales native to the drilled formation and suspended in the continuous phase. The suspended solids are chemically treated to control mud properties. The colloidal phase helps to give viscosity to the drilling fluid as well as to sealing the walls of the hole so in order to avoid the problem of lost circulation (Hossain & Al-Majed, 2015).

iii. Inert Solids Phase**:** There are also chemically inert solids in suspension. These may be derived either from drill cuttings such as limestone, dolomites, or sand. Barium sulfate (barite) is also added to the drilling fluid to increase the fluids density, and it is also an inert solid

iv. Various Chemical Additives Necessary to Control Properties within Desired Limits: The additives include various thickeners used to influence the viscosity of the fluid, example, xanthan gum, guar gum, glycol, carboxymethylcellulose, polyanionic cellulose (PAC), or starch. In turn, deflocculants are used to reduce viscosity of clay-based muds; anionic polyelectrolyte (example acrylates, polyphosphates, lignosulphonates or tannic acid derivatives such as quebracho) are frequently used (Kassab, Ismail, & Elessawi, 2011).

2.2 Mud Additives used in Oil Well Drilling

The philosophy of the drilling operation and the environmental impact assessment (EIA) results greatly influenced the choice of drilling fluid type. For some special consideration in some applications, the desired drilling mud characteristics can be realized by the use of special additives. The method of mud formulation is derived from practical experience and research. It is often challenging to study the effects of drilling waste discharges because drilling fluids are comprised of a wide range of additives; many of them are known, but many times confusing due to different trade names, generic descriptions, chemical formulae and regional or industry slang words. Even a mud engineer in one company would not really know what another company calls the same product (Kruse, 1975). Usually, the controls of drilling fluids always present two problems namely:

i. Determination of required drilling mud properties such as; density, viscosity, gel strength and filtration in order to effectively perform the drilling operation.

ii. Selecting the mud type and additives for formulating mud with desired properties (Melton, et al., 2004).

The properties of drilling muds can be adjusted to meet any reasonable set of conditions, thereby overcoming most drilling problems such as abnormal pressures, lost circulation and sloughing shale. The selection of the proper mud additives for certain conditions is sometimes confusing, however because of the large number of mud dealers and the wide variety of trade names. A wide range of chemical additives are used in the formulation of drilling mud and these additives include: Weighting agents, viscousifiers, thinners, filter-loss control agents, pH control additives, surfactants, loss circulation agents, de-foamers, lubricants and corrosion inhibitors (Peretomode, 2018).

III. METHOD & MATERIAL

3.1 Equipment and Preparation of Drilling Fluid

The following were used in the preparation of mud samples and subsequent analysis:

1. Sieve
2. Electronic Weighing Balance
3. Multi-Mixer
4. Mud Balance
5. Rheometer (8 SPEED VISCOMETER)
6. Marsh Funnel

3.2 Low Pressure Low Temperature Filtration Test

This test was done to measure the static filtration behaviour of WBM, OBM and emulsion at ambient (room) temperature as well as 100-psi differential pressure, performed in accordance with API specifications, using a static filter press. Understanding the fluid loss characteristics of the mud is essential to identify mud that has a high-filtration loss characteristics and reformulate, to avoid high fluid invasion and also thick mud cake.

3.3 Description of the Samples

This research adopted water-based mud, oil-based mud and emulsion as the drilling fluid.

3.3.1 Water-Based Mud

The selection of water-based mud was driven by several advantages such as being;

- **i.** relatively cheaper
- **ii.** more environmentally friendly
- **iii.** characteristic of less complexity
- **iv.** easier to prepare/less time consuming and
- **v.** can be formulated to overcome drilling problems

3.3.2 Oil-Based Mud

The selection of oil-based mud in this project was driven by several advantages such as being;

- **i.** thermally stable in deep, HPHT wells
- **ii.** characteristic of increased lubricity in deviated offshore wells and
- **iii.** hole stability in thick, water-sensitive shales

3.3.3 Summary of Mud Composition Used in the Work

In summary;

- **i.** Fluid phase- water, oil and emulsion were used as the continuous phase.
- **ii.** Solids (used as additives).
  - a. Inert solids - these do not react within mud (e.g., barite used as weighting agent)
  - b. Active solid – these clays are reactive (e.g., bentonite used as viscousifier)
- **iii.** There are some other additives (e.g., like Caustic soda, soda ash, xanthan gum, borax, KCl and palm kernel fibre as PAC

  For accurate composition of drilling fluid, the petroleum engineering laboratory was chosen for the practical. During this practical, the mud weight was kept constant. Drilling fluid composition for the samples of water and oil based muds were such that 76.8g of barite was added to water and oil and kept for over 24 hours for good consistency. After mixing, fluid loss test is done for 10 minutes the results are presented on Table 1 below.

Table 1: Mud Sample Formulation with PFA

Samples	Description
Sample 1: WBM1	WBM + 2.0%PFA
Sample 2: WBM2	WBM + 4.0%PFA
Sample 3: OBM1	OBM + 2.0%PFA
Sample 4: OBM2	OBM + 4.0%PFA
Standard	0.0% PFA

IV. RESULT & DISCUSSION

4.1 Analysis of Sample Composition

The study analyzes four different mud samples; two water-based muds (WMB1 and WBM2) and oil-based muds (OBM1 and OBM2) with continuous phase as water and oil respectively. The muds were formulated by adding solids (both inactive and active solids) in similar

proportion to each of the four samples and other additives (such as caustic soda, soda ash, xanthan gum, borax, KCl).
Both the formulation of the mud samples from base fluids and its subsequent laboratory analysis were wholly done at the Department of Petroleum Engineering Laboratory, Rivers State University.

4.2 The Rheological Properties of Samples

The data Table (2) shows the result of sample dial readings at different rpm. The results show a remarkable difference in the estimated values for the OBM and the WBM with the WBM1 sample closest to the reference standard. The indicated result in this table can help to reach a conclusion that the WBM's has better rheological properties than the OBM's. However, this is only at the specified test conditions and base formulations of the mud samples.

Table 2A: Sample Dial Readings at Different RPM

RPM	WBM1	WBM2	OBM1	OBM2	Standard
600	123	116	94	83	141
300	98	92	75	64	111
200	85	83	60	49	99
100	54	64	38	30	72
60	44	54	29	21	59
30	29	42	18	19	37
6	26	29	9	10	31

From the values in the table above, the PV/YP of the mud samples were calculated using the rheological relationships in Equations (1) and (2) below. Cumulative observations in Tables (2A) and (2B) show that as PFA (palm-kernel fibre additive) increases, both the YP and the YP reduces. Hence, for each type, a remarkable variance exists between the two mud samples and the reference standard. For the WBM, the difference was 1.00cp for PV and 5lb/100ft2 for YP while those of OBM were 0cp and lb/100ft2 for PV and YP respectively. By comparing with the standard reference mud, it could be again seen that the WBM sample used in this study is comparably better than the OBM's at the current test conditions (near ambient condition)

Table 2B: Plastic Viscosity and Yield Point Value of the Mud Samples

PV/YP	WBM 1	WBM 2	OBM 1	OBM 2	Standard
PV (cp)	25	24	19	19	30
YP (lb/100ft2)	73	68	56	45	81
YP/PV (lb/100ft2/cp)	2.92	2.83	2.94	2.37	2.7

$$\boldsymbol{PV} = \emptyset_{600} - \emptyset_{300} \quad (1)$$

$$\boldsymbol{YP} = \emptyset_{300} - \boldsymbol{PV} \quad (2)$$

A remarkable feature of the YP/PV parameter is that it shows the mud with better hole cleaning efficiency. Therefore, it could be said that the OBM's have better hole cleaning efficiency which were generally enhanced in each case of mud sample by increasing PFA concentration. Generally, YP/PV is considered as the best indicator for mud rheology. It is used as a cutting transportation index. However, the opinion on the optimal choice of YP/PV value remains a debate in both the industry and the academia.

4.3 Effect of Additive Concentration on Mud Density and Specific Gravity

Table 3: Sample Specific Gravity

Mud Samples	WBM 1	WBM 2	OBM 1	OBM2	Standard
SPECIFIC GRAVITY	0.97	0.98	0.95	0.97	0.94

The results in Table (3) and (4) were the results of mud density and specific gravity recorded using the Baroid Mud Balance. A quick observation of the result shows that there was relative increment in the values of the mud specific gravity and density (given in different field units) with increasing PFA concentration.

Table 4: Mud Sample Density

MUD DENSITY	WBM1	WBM2	OBM1	OBM2	Standard
Lb/gal	7.88	7.90	7.59	7.71	7.80
Lb/ft3	59.80	58.90	59.50	59.10	59.30
Psi/100ft2	411.3	410.7	409.7	409.9	409.4

a. Effect of Additive Concentration on Gel Strength and Sand Content

Gel strength of a mud characteristically defines its ability to suspend solids. It is also closely associated with good and efficient hole cleaning processes. The values of the 10-sec and 10-min gel shown in Table (5) below indicate that increasing the PFA concentration may not necessarily increase the gel strength to remarkable extent. From the percentage increase in gel strength for the OBM's, it could be said that they are more susceptible to be influenced by PFA concentration unlike the WBM samples. Notwithstanding, the argument supported by this study shows that the PFA concentration will have minimal or no effect on the gel strength and vice versa.

Table 5: Gel Strength Results

GEL STRENGTH	WBM1	WBM2	OBM1	OBM2	Standard
10-sec	25	24	6	5	12
10-min	25	25	6	5	12

Table 6: Sand Content of the Samples

Mud Samples	WBM1	WBM2	OBM1	OBM2	Standard
Sand Content	0.04%	0.04%	0.05%	0.06%	0.05%

The result in Table 6 above is also an important one to consider as it can observed from this table that coarse-classified PFA materials are quite undesirable due to the tendency to result in increased solid content.

4.5 Effects of Local Additives on Fluid Loss Behavior of Samples

The actual motivation for this study is based on the empirical findings that local materials such as palm kernel fiber could be used a fluid loss material for both OBM's and WBM's.

The value in Table (7) provides interesting findings on how the fluid loss parameter is affected by PFA concentration for both mud types considered in this analysis.

Table 7: Fluid Loss Behavior

TIME (Minutes)	WBM1 Ml	WBM2 Ml	OBM1 Ml	OBM2 Ml
5	3	1.51	1.77	1.48
10	6	3.0	2.71	3
15	8	4.9	3.40	5
20	11	5.8	4.9	6
25	12.5	6.4	5.9	8
30	13	7.1	7	8.7
35	13	7.8	8	9.4
40	13	8.3	8	10.3
50	14	8.7	8.9	10.5

From the results gotten, it is observed that as time advances, increase in the PFA additive concentration consequently leads to an increase in the fluid loss performance for the mud samples. Although, the OBMs comparatively performed better than the WBMs as lower fluid loss was recorded for the former. The plots in Figures (1) to (4) represent each sample fluid loss behavioral trend.

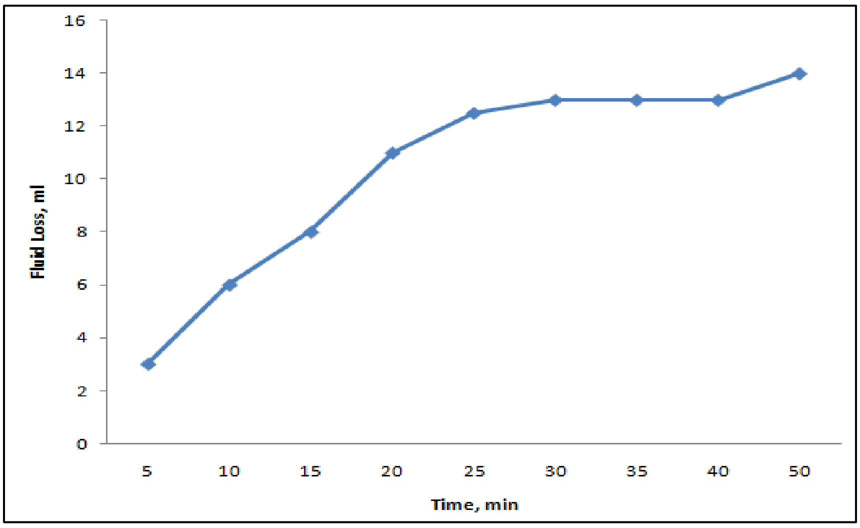

Figure 1: Fluid Loss versus Time for WBM1-Sample

From the plot for the samples, it is observed that after about 20 minutes, a pseudo-steady state was reached due to higher mud filtration tendencies which can be attributed to porous filling during the initial stage of filtration that results to the formation of mud filter cake. The differences in the trend path of Figures (1) to (4) show that different mud samples have its unique characteristic fluid loss behavior even though a rule of thumb may exist. Hence, it is always recommended to perform fresh laboratory analysis during mud programming of any drilling and completions job.

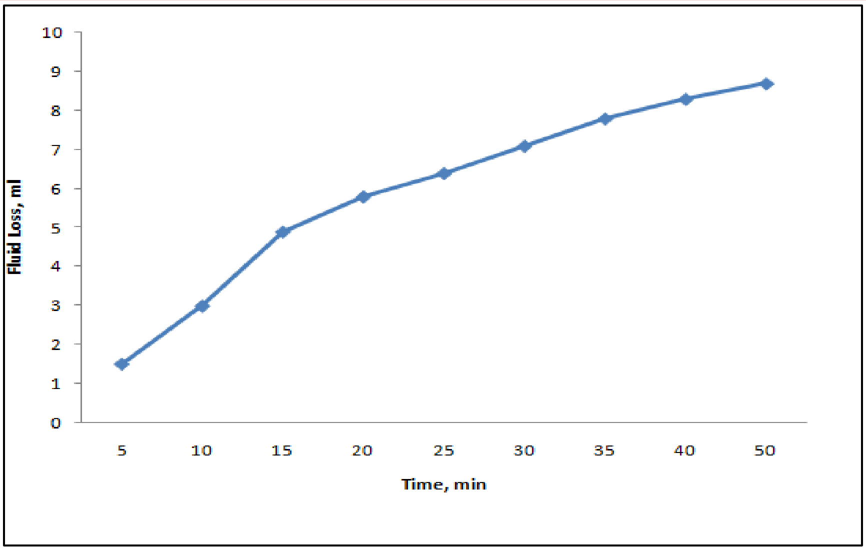

Figure 2: Fluid Loss versus Time for WBM2-Sample

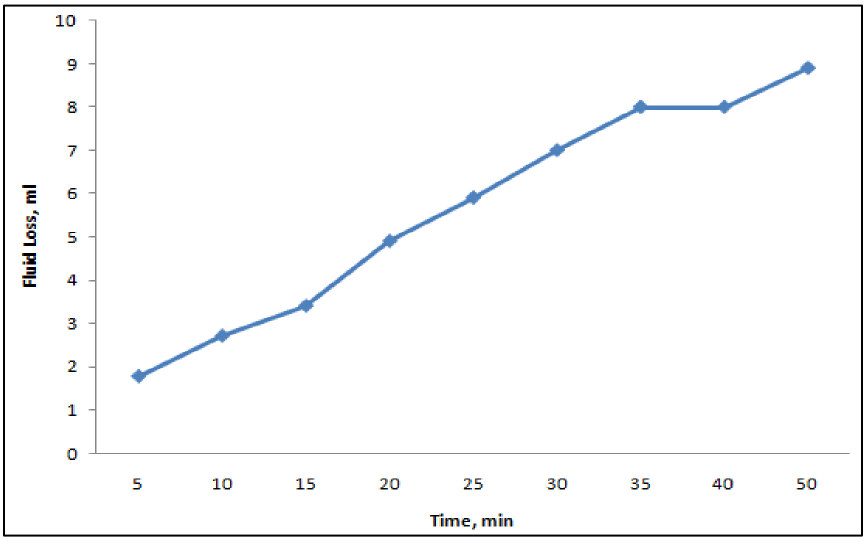

Figure 3: Fluid Loss versus Time for OBM1-Sample

It must be pointed out that while higher PFA at earlier stages may be suitable for better fluid loss control in OBM's, reducing the PFA concentration may be highly recommendable during the later stage. This analysis is clearly supported by the findings in the Table (6) above.

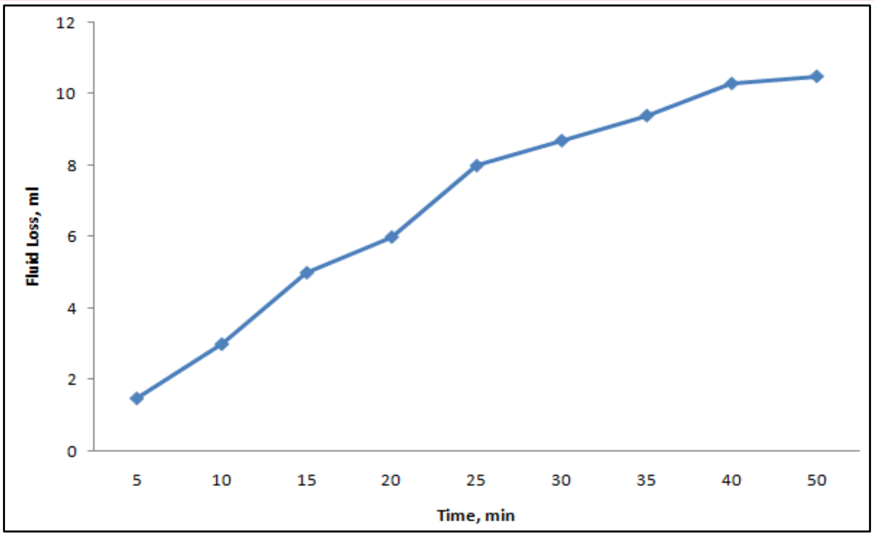

Figure 4: Fluid Loss versus Time for OBM2-Sample

On Figure (5) below, a better comparative analysis could be made with respect to each mud sample. In this case, it could be seen that WBM2 and OBM1 has better fluid loss performance than the rest. Hence, we may say that while higher PFA may be suitable for a WBM, lower concentration could be better for an OBM.

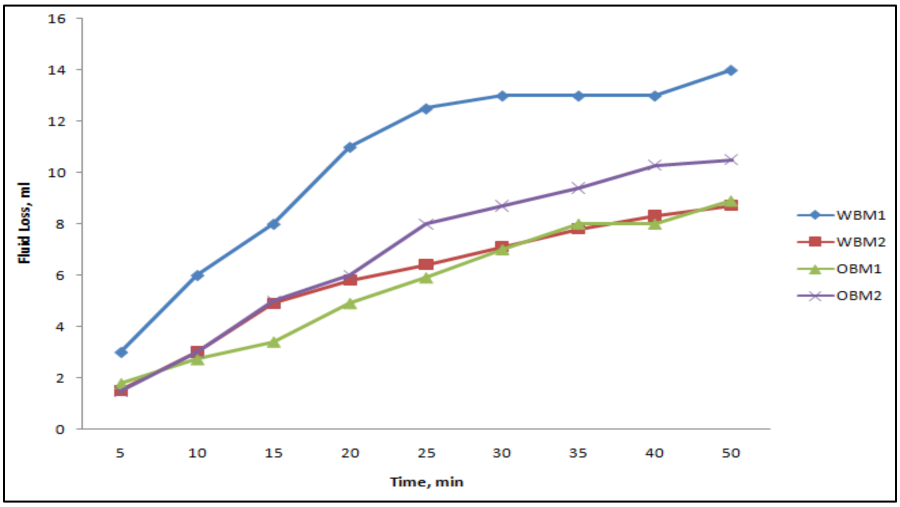

Figure 5: Comparative Plot of the Fluid Loss versus Time for Each Sample

V. CONCLUSION

This research has provided insights into identifying the potentials of using local materials (such as palm kernel fibre) as a mud additive. Analyses were conducted on four mud samples - *two WBM's and OBM's*. These were formulated with different PFA concentrations and results compared to a standard mud formulation.

The results clearly indicated that the local material (PFA) improved the fluid loss behavior of the mud samples, but its effect on other rheological parameters is yet to be fully understood. Generally, observations from the findings in this work show that the locally modified mud samples are comparably good alternatives with less environmental impacts.

VI. RECOMMENDATION

The following recommendations have been made from the findings in this work:

- **i.** Extensive laboratory investigation should be made before using a particular mud sample. This is because each mud sample has its unique rheological characteristics.
- **ii.** In alignment with SDGs (sustainable development goals) 9 and 13, the findings in this work support the use of local waste materials such as palm kernel fibres as fluid loss control agents.
- **iii.** Further investigations are highly recommended at other possible PFA concentrations.
- **iv.** Further studies should be dedicated to investigating the sensitivity of other additives on the performance of the locally sourced PFA's.

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