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Performance Evaluation of *CNF* and *ZMC*s as Fluid Loss Control Additive in Water Based Mud

Anthony Kerunwa[1], Goodness James Akoma[1], Rachael Onyeka Okoronkwo[1], Ndubuisi U. Okereke[1], Stephen G. Udeagbara[2]

[1] *Department of Petroleum Engineering, Federal University of Techno0logy, Owerri, Nigeria*
[2] *Department of Chemical and Petroleum Engineering, Afe Babalola University, Ado-Ekiti, Nigeria*

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Abstract

The frequently imported chemicals used for fluid loss control are not just considered environmentally unsafe but also exorbitant in price which impact on the drilling cost and have ripple effect on the nation's economy. Thus, the quest for several experiments on use of local additives which are not only cheap but also environmentally safe. This study is intended to investigate the suitability of locally sourced materials viz: cocos nucifera (coconut) fibre (CNF) and zea mays (corn) cobs (ZMCs) as fluid loss control agents in water based drilling mud. The local additives were subjected to several mud tests in order to ascertain if they can compete with the imported additive, to wit: carboxymethyl cellulose (CMC). Results obtained confirmed that muds formulated with a combination of local additives (CNF + ZMCs) had better yield stress at concentration of 5g, 10g and 15g in comparison to CMC. At 10g and above, muds formulated with CNF + ZMCs additive had fluid loss volumes which were within the API specification and competitive to CMC while CNF and ZMCs did not meet the API standard at tested concentrations. Also CNF+ZMCs additive had filter cake thickness that is comparable to CMC and within API specification. From the result, CNF+ZMCs additive will not have any problem associated with fluid loss likes oil productivity reduction. As such the combined local additives can be used to substitute the imported CMC for fluid loss control.

Keywords: *Drilling mud; Local materials; Mud properties; Biodegradable; Weighing materials; Cutting transport.*

1. Introduction

The drilling fluid (DF) or otherwise drilling mud (DM) is said to be "blood" of all operations that involve drilling in the petroleum industry [1]. The drilling process is therefore not complete without the DF which is an integral component of any drilling operation [2]. A DF is a combination of clay, dirt, and chemical additives which forms a mixture that is pumped down hole [3-4] to carry cuttings which the drill bit produces (i.e. from the hole bottom to the surface) as it bores into different sediments it comes in contact with [3, 5-6]. The DF is usually a mixture of oil or water, weighing materials, and some chemicals to give it certain desirable properties. DF has so many functions regardless of the type of formation [7-8]. These functions are: To efficiently clean the wellbore by carrying and transporting cuttings, Maintain bottom hole pressure, cooling and lubricating of the bit and drill string, transmission of hydraulic power to bit nozzle, corrosion control, formation damage control, aid in cementing operation, maintain wellbore stability and prevents loss circulation, and seal permeable zones. Hence, for any successful drilling operation, the circulating DF is required to have a high performance rate. Classification of DF is dependent on the base fluid used to prepare the mud [9]. They are: (a) Water base drilling mud (WBDM) with water as continuous phase (b) Oil base mud (OBM) with oil as the continuous phase (c) Pneumatic fluids with gas or gas liquid mixtures as their continuous phase. During the process of selecting DF, some factors must be considered and they are: (i) how friendly is the DF to the environment? (ii) Environmentally friendly DM and its additives are mostly used in the exploration and exploitation of hydrocarbons both on offshore and onshore so as to avoid aquatic bodies such as fishes, ocean and pollution of coastal areas and terrestrial environment from being destroyed. Therefore the use of WBDM is highly encouraged by environmental regulations [10] (iii) the cost of fluid (iv) the fluids technical performance. The choice of the DF and the application of these factors therefore define the success of drilling operation [2, 11]. WBDM has the advantage of being environmentally friendlier and cheaper than oil base mud [12]. Understanding the DF properties is very important to combat and eliminate any drilling problem [13]. These properties which include viscosity, density, pH, fluid loss etc. are variables that should be checked for to ensure good drilling condition of the well. Fluid loss control is a property of DF that plays various important functions in well construction process. Various researches have been conducted on the use of fluid loss control agents to reduce fluid volume that sips into the formation during drilling [14-15]. The addition of materials into the DM for drilling operation to reduce filtration rate [16] or otherwise minimize the filtrate volume that *is lost* to the permeable medium as a result of filtration process [17] and improve the characteristic of the mud cake is known as filtration control [16-17] or fluid loss [17]. The liquid portion of the system that passes through the filter cake into the formation as a result of hydrostatic pressure of the mud column and formation pressure is the drilling fluid filtrate [5]. Minimum fluid loss volume is one of the desired properties for mud and it can be achieved by formation of a low permeability filter cake on the wellbore [18]. The drilling fluid should be made in such a way that they will help reduce filtrate loss, form thin filter cake that cements the bore hole walls as to ensure reduced fluid loss and promote stability of the well drilled [19]. Damage of reservoirs and reduction in productivity can be due to constant fluid invasion into porous formation thereby blocking hydrocarbon exit flow path or causing formation collapse, pipe sticking, drag and torque as a result of thick mud cake formation [20]. Several chemicals are utilized as fluid loss additives in the oil and gas industry and these chemicals are usually imported at an unduly high price which takes a huge part of drilling cost and has serious effect on the economy of the nation. Additives that are locally sourced are readily available and should be recommended to the drilling industry to address the huge cost required for importation of chemicals for DF formulation and the impact the imported harmful chemicals have on the ecosystem [21]. This study intends to evaluate CNF, ZMCs and CNF + ZMCs at 50-50% concentration as fluid loss control additive in water based drilling mud. This is carried out by establishing their filtration capabilities. Thereafter, comparison is made with conventional fluid loss additive - carboxyl methyl cellulose (CMC) and the local materials utilized for water based DF formulation.

2. Literature review

Agwu *et al.* [19] carried out a study on rice husk and saw dust as filter loss control agent for water based mud. In their work, experiments were conducted to assess the filter cake formed by both rice husk and saw dust when they were employed as filter loss control agents. They observed that their existed an inversely proportional relationship between the filter loss and filtrate thickness for the local additives. Results from filter loss test showed that ground rice husk prevented fluid loss by an average of 77% and the filtration control for ground saw dust was 63%. They finally concluded that rice husk and saw dust were promising fluid loss control additives for water based mud. Okon *et al.* [25] evaluated locally sourced materials namely rice husk, *Detarium microcarpum* and *Brachystegia eurycoma* as fluid loss control additives in water based drilling fluid. They posited that mud cake permeability depended on the fluid loss additive contents in the drilling mud, fluid loss volume and filter cake thickness depended on mud permeability. Results showed that the filter cake thickness and fluid loss volume of rice husk and *Detarium microcarpum* were comparable with CMC from additive content of 10g while *Brachystegia eurycoma* was comparable with 15g CMC .They concluded that the local fluid loss control additives have the potential to be compared with conventional CMC and PAC-R. Ghazali *et al.* [23] carried out an investigation on the potential of natural polymer corn starch as fluid loss control agent. Results showed that corn starch can be employed as a fluid loss control agent during the process of drilling because it meets the basic condition of drilling fluid rheological properties with optimal range and it was observed that higher concentration of corn starch gave good fluid loss control behaviour. Okon *et al.* [24] carried out an investigation on rice husk and concluded that a considerable concentration of rice husk can be used as a viable fluid loss control additive replacement for convectional polymers (CMC and PAC R) since rice husk exhibits good filtration and control potential. Idress and Hasan [25] carried out an investigation on different environmentally friendly waste materials namely: orange peel and sun flower as loss circulation agent. Orange peel and sun flower were said to be able to serve as alternative loss circulation material (LCM) in DF and they were environmentally friendly. They reached the conclusion that the mud performance in terms of filtration control can be improved upon by combining different sizes of the LCM. Dagde, and Nmegbu, [26] carried out a study on DF formulation using cellulose generated from groundnut husk. Results showed that cellulose from the groundnut husk can significantly reduce fluid loss control agent. Conclusions made were as follows: cellulose from processed groundnut husk can control fluid loss in DF effectively when in high concentration, groundnut husk can be used to replace polyanionic cellulose (PAC) in drilling mud preparation, pH value of prepared mud is comparable with standard mud and groundnut husk is accessible and low in cost which accounts for reduced well cost. Al-Hameedi *et al.* [27] carried out an experimental investigation using mandarin peels powder (MPP) as a local additive as well as a bio enhancer in water based drilling mud. Results showed that MPP gave tangible improvement in the filtration characteristics through the reduction of fluid loss and thickness of mud cake at the concentrations of 3% and 4% and this suggests that MPP can be utilized as additive for fluid loss control. They opined that because MPP excellently minimized the filter cake in comparison to the base mud, it can also be utilized for filter cake enhancement before the hole is been secured with casing string in order to eliminate any possibility of mechanical stuck pipe as a result of thick mud cake. They suggested that when drilling through cement, MPP can be deployed as pH reducer at higher concentrations, since it has shown capacity to pH effectively reduce and cause precipitation of calcium content, since PAC-LV did not much influence the pH in comparison with MPP. They concluded that MPP as a local drilling additive can replace or support other conventional chemical additive which has served the same purpose and cost minimization of DF can be achieved using MPP. Azizi *et al.* [28] conducted a research on Agarwood waste as new fluid loss control agent in water based DF. They concluded that agar wood could be used as a substitute for the conventional fluid loss control agent in water base DF since it is environmentally safe, largely available, and relatively cheaper compared to conventional fluid loss control agent.

2.1 *Cocos nucifera* fibre

Coconut fruit has its botanical name as cocos nucifera and its tree is one amongst the palm tree family. Cocos nucifera fruit has three layers and they include; the exocarp, the mesocarp, and the endocarp. The exocarp and mesocarp is what makes for the CNF. The produce of a cocos nucifera fruit has at least 40% of CNF. CNF is extracted from the outer shell of the cocos nucifera by manual process. The CNF is chemically composed of cellulose, pyroligeneous acid, ligin, gas, charcoal, tannin and potassium. The physical properties of the CNF are: density– 1.40g/cc, length – 6-8inches, breaking elongation – 30%, swelling in water– 5% [29].

2.2. *Zea mays* cob

Corn has its botanical name as *Zea mays*. It is found on the central core of an ear of a zea mays plant. It is the part of the ear on which the kernels (Zea mays grains) grow. The cobs of the Zea mays were manually extracted and prepared. ZMCs is a natural additive that contains 44.96 % - carbon, 6.10 % hydrogen, 2.42 % - nitrogen, 44.77 % - oxygen, 0.29 % - chlorine, 1.46 % - ash, 0.55 % - moisture [30]. ZMC's cellulose is a natural, biodegradable and renewable polymer that can be turned into a drilling mud additive as fluid loss control agent. The advantage of ZMCs is its flaky nature, and due to this, it can seal off porous formations when employed in a drilling mud as a fluid loss control additive. This local additives is environmentally friendly, cheap and readily available, and has no adverse effect on the formation [31].

3. Materials and method

3.1. Materials

The following are the materials used for this study: Bentonite**,** Low pressure low temperature filter press (LPLT), barite, mud balance, water, rotary viscometer, CNF, weighing balance, ZMCs, agitator, carboxymethyl cellulose (cmc), measuring cylinder**,** caustic soda (NaOH)**,** water bottle**,** ph meter**,** grinding machine**,** stop watch.

3.2. Method

The method that was used for this research work was experimental. Fluid loss experiment: This was carried out to determine the local additives (CNF and *ZMC*s) ability in controlling fluid loss when compared to the conventional carboxymethyl cellulose (CMC).

3.2.1. Preparation of the samples

The fluid loss and pH additives used for this work were sourced locally. The local fluid loss and pH additives are: cocos nucifera (coconut) fibre, zea mays (corn) cobs and cocos nucifera ash respectively. The fibre of cocos nucifera and the grains of the cobs of zea mays were extracted manually. After the extraction, the fibre of the cocos nucifera and the cobs from the zea mays were sundried till no moisture was left in them. The CNF and the ZMCs were later ground into fine powder using a grinding machine. The ground CNF and ground ZMCs were sieved using a sieve of mesh size 20 microns until finer particles were obtained. The sieved particles of the ground CNF and the ground ZMCs were weighed. Some quantities of the CNF were burnt in an oven until and the entire quantity of CNF were burnt into ash and the burnt ash was used as pH enhancing additive. Fig.1 shows CNF and ZMCs while figure 2 shows Ground CNF and Ground ZMCs utilized for the study respectively

Fig. 1(a) Cocos nucifera (Coconut) fibre

Fig 1(b) Zea mays (Corn) cobs

Fig. 2(a) Ground CNFa.

Fig. 2(b) Ground ZMCs

3.2.2. Formulation of fluid loss mud samples

For the fluid loss experiment, four (4) different mud samples namely: sample A, sample B, sample C and sample D were formulated while the concentration of the fluid loss additives were varied in 2g, 4g, and 6g respectively in equal proportions. Sample A is the mud sample with CMC as fluid loss additive while samples B is mud sample with CNF as fluid loss additive, C is mud sample with ZMCs as fluid loss additive while D is mud sample with CNF + ZMCs as fluid loss additive. The composition of the different mud samples are shown in table 1. The composition was then repeated for 4g and 6g concentrations.

Table 1. Composition of water based mud samples with 2g of fluid loss additives

Additives	Sample A A CMC	Sample B B Ground CNF	Sample C C Ground ZMCs	Sample D Ground CNF + (ZMCs
Bentonite(g)	25	25	25	25
Barite(g)	10	10	10	10
Water(mL)	350	350	350	350
CMC(g)	2	Nil	Nil	Nil
Ground CNF(g)	Nil	2	Nil	Nil
Ground ZMCs(g)	Nil	Nil	2	Nil
Ground Cocos nucifera fibre + ZMCs(g)	Nil	Nil	Nil	2

3.2.3. Mixing procedure of fluid loss mud samples

The various quantity of materials used were weighed using a weighing balance. Distilled water of 350mL was measured using a graduated cylinder and then poured into a cup. 25g of bentonite was added to the distilled water and agitated for five minutes. 0.25g of NaOH was added to the slurry and mixed for two minutes. Thereafter, 2g of CMC was added and mixed for three minutes. 10g of barite was added and agitated for fifteen minutes. The procedure above was repeated for 4g and 6g of CMC. The Hamilton beach mixer was used to mix the slurry at medium speed and the total mixing time was thirty minutes. The same mixing procedure for CMC mud (sample A) was also used for CNF (samples B), ZMCs (sample C) and CNF + ZMCs (sample D) but in this case, CNF, ZMCs, and CNF + ZMCs were added respectively in each of the mud prepared instead of CMC.

3.2.4. Determination of mud density

The calibration of the Baroid mud balance was first checked by using the calibration mark provided on the scale and then mud balance was standardized using distilled water. The mud cup was cleaned, dried and filled to the brim with the mud sample to be measured. The lid was placed on the cup and some mud allowed flow out of the hole on the lid to ensure that there was no trapped air in the cup. The cup and lid were wiped to dry off any mud on the surface in order to obtain accurate measurement as the knife edge was placed on the fulcrum with the rider was adjusted until the cup content and the rider were at equilibrium (balance) which was indicated by the bubble. At equilibrium, the density of the mud sample was read on the calibrated arm of the mud balance.

3.2.5. Rheology test

The rheological properties of the mud were measured with the Fan rotational viscometer. The determination of mud rheological properties was done with Fann viscometer with R1-B1-F1 installation configuration (model 35). Viscometer's calibration was first achieved before mud rheological properties were determined

3.2.5.1. Determination of mud viscosity and yield stress

The mud sample was poured into the rotary viscometer's mud cup with the immersion of rotor sleeve exactly to the fill line on the sleeve by raising the platform. The platform's lock knot was then tightened with the power switch on the viscometer's back panel turned on. The speed knob was rotated to the stir setting, so as to stir the mud for some seconds, and the further rotated to 600RPM. when steady reading was reached by the dial, 600 RPM reading was thereafter recorded. A repetition of the process was carried out for 300RPM, 200RPM, 100RPM, 60RPM, 30RPM and 6RPM. The PV (plastic viscosity), AV (apparent viscosity) and YP (yield point) were determined with the equations respectively stated:

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

$$AV = \frac{\theta_{600}}{2} \quad (2)$$

$$YP = \theta_{300} - PV \quad (3)$$

WBDM, especially those formulated with local agro materials fit Herschel-Buckley equation perfectly than Bingham plastic model or even the power law equation [8] and is expressed as [8,32-33]:

$$\tau = \tau_0 + Ky^n \quad (4)$$

where: K = consistency index; y = velocity gradient or shear rate; n = flow behavior index; τ == shear stress; τ_0= yield stress of the fluid when τ = 0. If n = 0, fluid is Newtonian, with n > 1, fluid is is dilatants and with n< 1, fluid is pseudoplastic [8,32]. The yield stress of the fluid (τ_0) can be calculated as recommended by API for the rheological parameters of Herschel Buckley model using $^{R6}/_{R3}$ [33]:

$$\tau_0 = 2\tau_3 - \tau_6 \quad (5)$$

where: τ_6 and $\tau_3$are shear stress at 6rpm and 3rpm respectively

3.2.5.2. Determination of gel strength of the mud

The gel strength describes the mud's attractive forces when it is at static condition. It is the mud's capability to ensure the suspension of the drilled cuttings is maintained in case circulation stopped. It is the stress required for the mud to be kept in motion. The gel strength were taken at 10 seconds and 10 minutes. The speed selector knob was rotated to stir the mud sample for a 10 seconds, then immediately shut off. As soon as the sleeve stopped rotating, the knob was turned to the gel reading after 10 seconds and then at 10 minutes. The maximum dial was then recorded for each case.

3.2.6. Mud filtration test

The four filter cells were cleaned, dried with the rubber gaskets checked. The cells were assembled as follows: base cap, rubber gasket, screen, filter paper, rubber gasket, and cell body. A freshly stirred sample of each mud was poured into the cells respectively to 0.5 inch (13 mL) and to the top to ensure that filtrate contamination is highly minimized. The top cap was checked to ensure that the rubber gasket was in place and seats completely around the assembly. The cell assembly was placed into the frame and secured with the T-screw. Clean dry graduated glass cylinder was then placed under the filtrate exit tube of each cell. The regulator T-screw was turned counter-clockwise until the screw was in the right position and the diaphragm pressure was relieved. The safety bleeder valve on the regulator was put in the closed position. The air hose was connected to the designated pressure source; the valve on the pressure source opened to initiate pressurization into the air hose. The regulator was adjusted by turning the T-screw clockwise so that pressure was applied to the cell in 30 seconds or less. At the end of 15 minutes, the volume of filtrate collected was measured. The air flow through the pressure regulator was shut off by turning the T-screw in a counter clockwise direction. The valve on the pressure source was then closed and the relief valve was carefully opened. The assembly was then dismantled with the mud removed from the cup. The filter cake for each mud sample was measured using a ruler and the measurements were recorded.

4. Results and discussions

The various mud samples containing CMC, cocos nucifera fiber, ZMCs, and cocos nucifera ash were tested in this work for density, rheology, and filtration.

4.1. Density of mud samples

Figure 3 depicts Density of the various mud samples at different concentration. From the results of figure 3, the local additives – CNF, ZMCs and CNF+ZMCs had mud densities of 8.85ppg, 8.91ppg, and 9.15ppg respectively at the concentration of 5g each. The mud densities gotten from the local additives at 5g concentration falls within the recommended API specification (8.65ppg - 9.60ppg) for water based mud as stated by [34]. However, increasing the concentration of each of the additives from 5g to 10g shows that CNF, ZMCs and CNF+ZMCs had mud densities of 8.84ppg, 8.91ppg, and 9.16ppg respectively. At 10g concentration, the local additives also had mud density which were within the recommended API specification. Furthermore, when the concentration of the additives were increased from 10g to 15g, it was observed that the local additives - CNF, ZMCs and CNF + ZMCs had mud densities of 8.85ppg, 8.91ppg and 9.16ppg respectively. This shows that increasing the concentration of the additives did not increase the mud densities of the formulated mud with the additives. CNF + ZMCs mud had density that was close to that of CMC - 9.25ppg at 2g, 9.24ppg at 4g and 9.25ppg at 6g respectively, as such CNF + ZMCs can compete with CMC. From Figure 3, the required mud density was maintained for the formulated muds. A benefit of the required mud density obtained from CNF, ZMCs and CNF + ZMCs muds as compared to CMC mud is that less barite would be used, reducing the cost of mud formulation. It is important that the required mud density be maintained because the formation hydrostatic pressure is countered through this means. Inadequate mud density means the mud does not have the ability to withstand formation pressure and thus potential disaster are bound to occur like kick which can consequently lead to blowout. However, if the mud weight or density is too high, there will be increased tendency of mud filtrate penetrating the porous formation thereby worsening fluid loss problem.

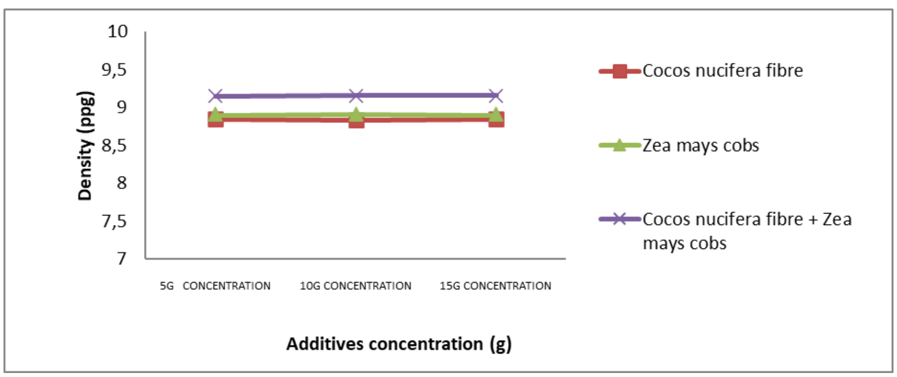

Fig. 3. Density of the various mud samples at different concentration

4.2. Rheology of mud samples

Table 2. Yield stress for the various mud samples

Yield stress for various mud samples (lbs/100ft^2)			
Mud samples	Additives Concentrations (g)		
	2g	4g	6g
Mud with CMC additive	30	35	40
Mud samples	Additives Concentrations (g)		
	5g	10g	15g
Mud with CNF additive	6	13	25
Mud with ZMCs additive	17	23	34
Mud with CNF + ZMCs additive	27	30	38

Yield stress (YS) evaluates the ability of mud to lift cuttings out of the annulus. A higher YS indicates that drilling fluid has the ability to carry out cuttings efficiently. Table 2 depicts the YS for the various mud samples viz: mud with CMC additive, mud with CNF additive, mud with

ZMCs additive and mud with CNF+ZMCs additive. From Table 2, 2g concentration of CMC in the mud gave a YS of 30lbs/100ft^2 which is within the API limit (25lbs/100ft^2-45lbs/100ft^2) while the local additives – CNF, ZMCs and CNF+ZMCs gave a YS of 6lbs/100ft^2, 17lbs/100ft^2 and 27lbs/100ft^2 respectively at the concentration of 5g each. The YS gotten from CNF and ZMCs at 5g concentration falls below the recommended API specification while that of CNF+ZMCs falls within the API boundary of 25lbs/100ft^2-45lbs/100ft^2 as stated by [8]. Therefore, the local additives at 5g concentration will have poor cuttings transportation and poor hole cleaning. As the CMC additive was increased to a concentration of 4g, it was observed that CMC had the highest YS of 35lbs/100ft^2 while the local additives - CNF, ZMCs and CNF+ZMCs had yield points of 13lbs/100ft^2, 23lbs/100ft^2, and 30lbs/100ft^2 respectively at an increment of 10g. At 10g concentration, CNF and ZMCs does not fall within the API specification but CNF + ZMCs had a better yield stress of 30lbs/100ft^2 which falls within the required API specification. However, at 15g concentration, the local additives additives - CNF, ZMCs and CNF + ZMCs had yield stress of 25 lbs/100ft^2, 34lbs/100ft^2, and 38lbs/100ft^2 respectively. This shows that at higher concentration, the YS increases significantly and the local additives can compete with CMC as they fall within the API specified range of 25lbs/100ft^2-45lbs/100ft^2 as stated by [8]. Therefore, comparing the local additives to CMC shows that mud with CNF + ZMCs additive gave the best cuttings carrying tendency, while mud with ZMCs and mud with CNF additives will only have a good cuttings carrying capacity at 15g concentration and above. The gel strength as well is\ a vital parameter for the evaluation of DF performance. There is no much difference between the formulated mud samples' gel strength; all the mud samples had good gel structure. Excessive gel strength causes a whole lot of drilling problems and as such should be discouraged. Proper gel strength allows solids to be well suspended in the hole which settle out on the surface.

4.3. Fluid loss of various mud samples

Table 3. API specification for fluid loss control additive

Fluid loss control additive	API fluid loss requirement	Filter cake thickness
Carboxylmethyl cellulose (CMC)	1.0 x 10^{-5} m^3, max. [19,35]	<2mm [19,36]

Fig. 4 shows the fluid loss volume results that were obtained from the various mud samples. From fig. 4, 2g concentration of CMC in the mud gave a fluid loss volume of 9.6x10^{-6}m^3, 4g concentration gave a fluid loss volume of 9.2x10^{-6}m^3, while 6g concentration gave a fluid loss volume of 8.6x10^{-6}m^3. This shows CMC at 2g with a fluid loss of 9.6x10^{-6}m^3 was nearly close to the maximum though still within the API recommended specification for fluid loss of 1.0 x 10^{-5} m^3 but as the concentration increased to 4g and 6g, the fluid loss volume decreased and very much within the API specification of 1.0 x 10^{-5} m^3 as given in Table 3 and stated by [19,35]. 5g concentration of CNF additive in the mud yielded an extremely high fluid loss volume of 19x10^{-6}m^3 and further increase in the concentration of CNF from 5g to 10g and 15g still yielded high fluid loss volume of 16x10^{-6}m^3 and 14x10^{-6}m^3 respectively. Therefore, CNF is poor fluid loss control additive and cannot compete with CMC because it does not fall within the API recommended specification for fluid loss. ZMCs at 5g concentration gave a high fluid loss volume of 18x10^{-6}m^3. Further increase in the concentration of ZMCs to 10g and 15g decreased tremendously and resulted to a fluid loss volume of 14x10^{-6}m^3 and 10.2x10^{-6}m^3 respectively. The fluid loss values of ZMCs though with a tremendous decrease from 14x10^{-6}m^3 and 10.2x10^{-6}m^3 still falls above the API recommended specification for fluid loss of 1x10^{-5}m^3 given in Table 3. This shows that ZMCs is a poor fluid loss control additive at the stated concentrations but can be a potential fluid loss control additive if employed in higher concentration. The combination of cocos nucifera fiber + ZMCs at 5g concentration gave a fluid loss volume of 12x10^{-6}m^3 and a further increase in concentration to 10g resulted to a significant decrease in fluid loss volume from 12x10^{-6}m^3 to 9.6x10^{-6}m^3 and falls within the API recommended specification for fluid loss. At 15g concentration, the combination of CNF + ZMCs gave a fluid loss volume of $8x10^{-6}m^3$ which also falls within the API recommended specification for fluid loss of $1.0x10^{-5}m^3$ as by stated by [19,35]. This shows that increase in concentration of CNF + ZMCs gave a significant decrease in the fluid loss volume and as such CNF + ZMCs at concentration of 10g and above is a good fluid loss control additive. Therefore, CNF + ZMCs can compete favorably with CMC at concentration of 10g and above.

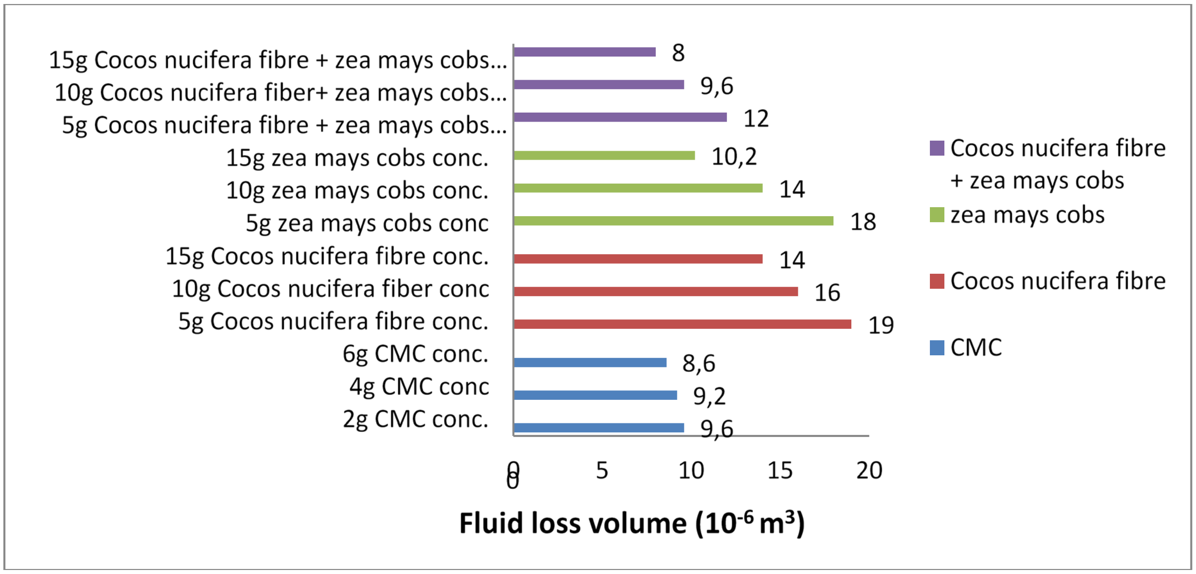

Fig. 4. Fluid loss volume of the various mud samples at different concentrations

4.4. Filter cake thickness of the mud samples

Fig. 5 depicts the filter cake thickness results of the various formulated mud samples while fig. 6, 7, 8 and 9 depict the individual filter cake thickness of mud with CNF additive, mud with ZMCs additive, mud with CNF + ZMCs and mud with CMC additive respectively. From Fig. 5, 2g, 4g and 6g concentration of CMC in the mud gave filter cake thickness of 1.2mm, 1.5mm and 1.8mm respectively. This shows that the filter cake thickness of CMC at 2g, 4g and 6g concentrations fall within the API specification for filter cake thickness as shown in Table 3 (<2mm as stated by [19,36]). However, 5g, 10g and 15g concentrations of CNF in the mud yielded higher filter cake thickness of 2.4mm, 2.7mm, and 3.0mm respectively. The filter cake thickness of CNF in the mud did not fall within the API recommended specification for filter cake thickness. This shows that CNF is a poor fluid loss control additive and cannot compete with CMC at the stated concentrations. On the other hand, ZMCs at a concentration 5g, gave filter cake thickness of 1.9mm, but at 10g and 15g concentrations, 2.3mm, and 2.9mm filter cake thickness were respectively obtained. This also shows that ZMCs mud at 5g concentration falls within the API specification for filter cake thickness as shown in table 3 while at 10g and 15g concentrations failed to fall within the API recommended specification. Cocos nucifera fiber + ZMCs in the mud at 5g, 10g and 15g concentration gave filter cake thickness of 1.5mm, 1.7mm, and 1.9mm respectively. This shows that the filter cake thickness of cocos nucifera fiber + ZMCs at 5g, 10g and 15g concentrations fall within the API specification for filter cake thickness as shown in Table 3 (<2mm as stated by [19,36]. Therefore, CNF + ZMCs additive can again compete reasonably with CMC additive at concentrations of 5g, 10g and 15g. The results show that as the fluid loss volume decreases, the filter cake thickness increases and it was observed that the filter cake thickness increased with increasing concentration of additives in the mud samples. The problems associated with fluid loss include reduction in oil productivity and damage to the formation [19-20]. Therefore it is imperative to state that CNF + ZMCs additive haven reasonably shown excellent qualities like CMC, will not have any problem associated with fluid loss such as reduction in oil productivity and damage to the formation.

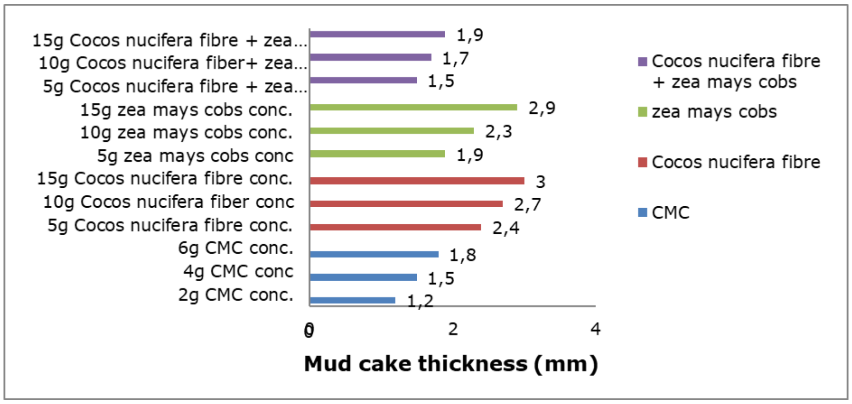

Fig. 5. Filter cake thickness for the various mud samples at different concentration

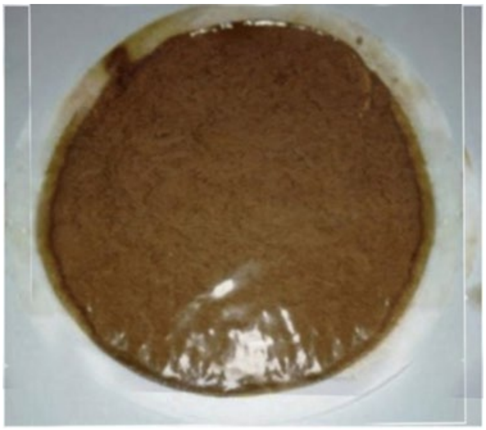

Fig. 6. CNF mud filter cake

Fig. 7. ZMCs mud filter cake

Fig. 8: CNF + Zea may cobs mud filter cake

Fig. 9: CMC mud filter cake

4.5. Permeability of mud cake

Table 4. Mud cake permeability of WBDM formulated with CNF, ZMCs and CNF + ZMCs.

Fluid loss control material concentration (g)	Mud cake permeability (mD)		
	CNF	ZMC	CNF+ZMC
	$X10^{-3}$	$X10^{-3}$	$X10^{-3}$
5	4,018	3,061	1,611
10	3,866	2,882	1,461
15	3,759	2,647	1,360

The permeability of the mud cake of CNF, ZMCs and CNF + ZMCs formulated muds were determined using by [37]'s model, given in equation 6.

$$k = Q_f * \varepsilon * \mu * 8.95 * 10^{-5} \quad (6)$$

where: k = cake permeability (mD); Q_f = fluid loss (mL); ε = cake thickness (mm) and μ = mud's liquid phase viscosity (cP).

With the Equation (4), the calculated permeability of mud cake at various concentrations of CNF, ZMCs and CNF + ZMCs is depicted in Table 4. Result from table 4, show that CNF mud has the highest cake permeability followed by ZMCs mud with CNF + ZMCs mud as the least. This explains the reason why CNF mud had the highest fluid loss volumes, followed by ZMCs mud and finally zocos nucifera fibre + ZMCs mud with the least volume of fluid loss at the respective concentrations as depicted in Fig. 4.

5. Conclusions

The intent of this study is to evaluate the performance of CNF, ZMCs and a combination of CNF with ZMCs as fluid loss control material in WBDM. To achieve the result that will be consistent with the reality of the field, the API general direction for DF field testing was followed consistently. From the results of the research conducted, conclusions drawn are:

i The agro-waste materials utilized in this study– CNF and ZMCs are promising control additives for fluid loss in WBDMs due to their renewability and abundance.

ii The characteristics of a combination of CNF and ZMCs as fluid loss control material was excellent and compared favourably with CMC

iii From the yield stress result, mud with CNF + ZMCs in all the concentrations tested had yield stress that fell within the API specification, and will be able to carry cuttings far better than mud with CNF and mud with ZMCs alone.

iv The characteristics of the filter cake of the local agro additives, to wt: CNF + ZMCs are acceptably good for mud cake requirements

v The local additives are just waste materials and have the advantage of not only being cheap but also easy to access, biodegradable and environmentally friendly. The utilization of these waste materials will convert waste to wealth.

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To whom correspondence should be addressed: Dr. Anthony Kerunwa, Department of Petroleum Engineering, Federal University of Techno0logy, Owerri, Nigeria, E-mail: anthonykerunwa@rocketmail.com