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Rice husk and saw dust as filter loss control agents for water-based muds

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A R T I C L E I N F O

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A B S T R A C T

When drilling with water based muds (WBM), significant fluid loss volumes from the mud into the formation can have adverse effects not just on the mud and its properties but also on the stability of the wellbore. Prevention of mud filter loss is one way of assessing the performance of a drilling mud. However, evaluation of the effectiveness or otherwise of a fluid loss control additive can be made by characterizing the mud cake formed. Interestingly, the mud cake characterization is one area that has been somewhat neglected in drilling fluid formulation with agro waste materials. Two cellulosic materials - rice husk and saw dust were chosen for the experimental study. The specie of the rice husk used was the African rice *(Oryza glaberrima)* while the dust from the saw milling of *Oxystigma manni* was utilized for this study. To ensure result acceptability, the rice husk and saw dust were ground and the resulting products were sieved to 1.25×10^{-4} m. The filtration characteristics of the formulated mud samples were tested using the American Petroleum Institute (API) filter press and in accordance to the API recommended practice for field testing WBMs. From the filter loss tests, it was observed that the ground rice husk prevented filter loss by an average of 77% compared to ground saw dust filtration control of 63%. In addition, it was observed that at higher concentrations, ground saw dust and rice husk prevented fluid loss to the minimum acceptable API standard. For the filter cake thickness measured in millimetres, ground rice husk exhibited thicker mud cakes when compared with the saw dust by an average amount of 14%. For the mud cake characteristics, the rice husk mud exhibited smooth and slippery cakes while the saw dust mud exhibited rough texture, sticky and firm cakes.

1. Introduction

The numerous roles demanded of and played by the drilling mud is the kernel of a successful and conclusive drilling operation. One of these roles is to consolidate the walls of the wellbore being drilled. One qualification instrumental to get the license for consolidation is to contrive a drilling fluid with low filtrate loss, low permeability and thin mud cake (Awele, 2014). The basic mechanism behind the mud's consolidation property is this: mud filtrate filters into the formation while the mud's solid components remain behind and forms the mud cake which essentially acts as a plaster to the walls of the borehole (Feng et al., 2018; Liu and Santamarina, 2018). The initial filtrate loss is referred to as spurt loss (Kumar, 2010) while subsequent losses after spurt loss is referred to as continuous fluid loss and is highly undesirable (Azar and Samuel, 2007). Kosynkin et al. (2011) mentions one of these undesirable effects to include formation damage and oil productivity reduction. In Annis and Smith (1996) assessment of the problem, they render filtrate invasion as impeding more of formation evaluation efforts and well completion practices than they do on drilling operations. Citing the advantage of a thin filter cake, Baroid Industrial Drilling Products (2017) remarks that it minimizes the incidence of differential pipe sticking, torque and drag issues among others. These problems almost always lead to non-productive time. Beyond the thickness of the filter cake, a description of the quality and texture of the filter cake formed is important since a mud engineer reports them alongside other parameters on the API mud report form (Schlumberger, 2017). A gritty texture in comparison with a smooth slick cake leads to high torque and drag (Baroid Industrial Drilling Products, 2017). Generally, polymers are used for filtration loss control in drilling muds. Caenn and Chillingar (1996), reports that polyanionic cellulose, carboxyl methyl cellulose, hydroxyethyl cellulose and other polymers are conventional filter loss control additives. The need to do more with less has spawned so many ideas such as the replacement of conventional mud additives with cellulosic agrowastes and now a shift towards the use of nanostructures of these agrowaste materials. Harping on this transition, Chauhan and Chauhan (2013) and Malik et al. (2016) pointed to the advantages of cellulosic materials to include being cheap

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and abundant. Interestingly, success stories abound in the use of nanoparticles as drilling mud additives (Guan et al., 2018; Hoelscher et al., 2012). The basic reason for this shift is due to the fact that most of the conventional mud filter loss control materials are thermally unstable and degrade at high temperatures (Igwe and Kinate, 2015; Thomas, 1982); whereas nanomaterials materials have the potential to overcome this challenge due to their excellent physiochemical, hydrodynamic and high stability at elevated temperatures (Dejtaradon et al., 2019; Perween et al., 2019). Beyond this, the very fine nature (in terms of size) of nanomaterials and their high specific surface area implies that very low concentrations of nanomaterials can cause great enhancement in mud properties (Amanullah and Ramasamy, 2018). This would ultimately lead to an overall reduction in the cost of the mud. In a specific instances, mud fluid loss decreases with addition of the nanomaterials such as ZnO, CuO and Nanosilica in WBMs (Mikhienkova et al., 2018; Dejtaradon et al., 2019; Katende et al., 2019) A good summation of existing works and the cumulative evidence gleaned from literature on using agro materials as filter loss control agents in drilling muds has greatly underscored the strength of agro materials being useful as fluid loss control agents in drilling muds (Agwu and Akpabio, 2018). However, many questions arise as to the effectiveness of these agro materials as filter loss control agents in the field. At the heart of this questioning is the need to have holistic explanation system in place to look at the entire picture (filter loss control capacity, filter cake characteristics, effect of high downhole temperatures, salinity effects) etc. Collectively, the review by Agwu and Akpabio (2018) indicates that tests to which these agro materials are subjected are few and far between; with only about 9% of studies underpinned by the cake characteristics descriptions. They added that the tests mainly revolve around fluid loss and mud rheology etc. leaving out cake characteristic descriptions and a host of others. In addition, to rely solely on the filter loss volumes as a yardstick to measuring the efficiency of a filter loss control material is an attempt to indulge in misdirecting the current away from that which is more important to drilling operations – the filter cake to less important ones – the filtrate volume (Annis and Smith, 1996). It must also be added that when wellbore processes such as cementing are to be carried out, the mud cake is always removed. Hence, the characterization of mud cakes enables mud engineers know the appropriate cake removal recipe that would be efficient (Bageri et al., 2013). This work therefore intends to fill the gap of describing the filter cake characteristics of muds formulated with rice husk and saw dust as filter loss control materials while also looking at their fluid loss control capacities. To achieve this, API based static filtration experiment would be used to determine the filter loss and filter cake characteristics. This paper would be organized as follows: first, the basis for choosing the two materials would be presented, then the materials and methods used during the tests would come thereafter. This would be followed by a discussion of the results obtained in the course of the study while the paper would climax with some concluding remarks.

1.1. Basis of choice of saw dust and rice husk for the study

Three parameters were used as yardsticks for choosing rice husk and saw dust for this study. They include the following:

(a) ***Cellulose content***: Both rice husk and saw dust contain a reasonable amount of cellulose which is the target component as seen in the percentages in Table 1.

(b) ***Availability***: Rice husk is one of the most widely available agricultural wastes in many rice producing countries around the world (Katsuki et al., 2005). In Nigeria, according to the International Rice Research Institute (2018) approximately 6 × 10^9 kg of rice was produced in 2018. For every grain of rice produced, there is a corresponding rice husk generated. According to the International Rice Research Institute (2016), each kilogram of rice results in approximately 0.28 kg of rice husk as a by-product during the milling process. Thus, if the record of Nigeria's paddy rice production in 2018 according to United States Department of Agriculture is anything to go by, then approximately 1.7 × 10^9 kg of rice husk was produced that year. The states in Nigeria where rice is produced include: Benue, Kaduna, Kebbi, Niger, Taraba, Ogun, Enugu, Cross River, Akwa Ibom, Ebonyi and Anambra. On the other hand, woods from which saw dust is produced are found in forest vegetation zones in Nigeria. According to Paulrud et al. (2002), about 10–13% of the total volume of a wood log is reduced to sawdust during milling operations.

(c) ***Cost***: Table 2 shows the costs of different cellulosic materials that can act as filter loss agents in drilling fluids. The costs are ranked from lowest to highest as seen in the table with rice husk powder having the least cost and polyanionic cellulose having the greatest cost. On the basis that rice husk and saw dust had low costs compared to the other cellulosic materials, this made them rank tops in the list of choice for this study. It must be stated that these costs are subject to change over time; however, the consolation is that the availability of the rice husk and saw dust offsets this.

Table 1
Cellulose content of rice husk and woods for saw dust.

Material	Cellulose (%)	Hemicellulose (%)	Lignin (%)	Ash (%)	Source
Soft wood	30–60	20–30	21–37	<1	Tsoumis (1991)
Hard wood	31–64	25–40	14–34	<1	Tsoumis (1991)
Rice husk	43.8	31.6	NA	NA	Kristensen (1996); Nakbanpote et al.(2000) and Raveendran et al. (1995)

2. Materials and methods

This study is divided into four parts namely: (a) Collection of the rice husk and saw dust, (b) physical pre-treatment of the rice husk and saw dust, (c) mud formulation and (d) evaluation of the API filter loss and filter cake characteristics of the mud formulated with rice husk and saw dust as filter loss control agents. The reagents used for the study were fresh water, sodium hydroxide, barite, bentonite, rice husk and saw dust while the apparatus used were Oven (Type 48 BE Apex Tray Drier), weighing balance, measuring cylinder, beakers, Hamilton beach mixer and cup, pH indicator strip, thermometer, sieving mesh, bucket, bowl and stop watch, Fann viscometer, API filter press, a sieve and a spatula.

2.1. Collection of the rice husk and saw dust

The dust from the saw milling of *Oxystigma manni,* -Ntufiak (local name in Akwa Ibom State, Nigeria) was utilized for this study and was obtained from a sawmill at Ufan-abasi timber market, Ibesikpo Asutan local government area of Akwa Ibom State, Nigeria. The rice husk sample was obtained from a local rice mill in Ini local government area of Akwa Ibom State, Nigeria. The specie of rice husk used was the African rice *(Oryza glaberrima).*

2.2. Physical pre-treatment of the rice husk and saw dust

The samples (rice husk and saw dust) were cleaned manually in order to remove foreign materials. Then they were oven dried in an oven for about 3–4 hours. After this period, the samples were again cleaned manually and chopped into small pieces. Finally, each of the rice husk and saw dust sample was milled using a hammer mill. To ensure sample homogeneity and reduce uncertainty of particle size, the rice husk and saw dust were sieved to a particle size of 1.25 × 10^{-4} m (see Figs. 1a, 1b, 2a and 2b). The reason for using this particle size is because the smaller

(a) Before sieving **(b)** After pulverization

Fig. 1. Rice husk used for the study.

(a) Before sieving **(b)** After pulverization

Fig. 2. Saw dust used for the study.

Table 2
Cost of filter loss control materials.

Material	Cost/kg (USD)	Source
Rice husk powder	0.08	Shreenidhi Bio Agric Extracts (2017)
Saw dust powder	0.12	Hardik Enterprises (2017)
Carboxymethyl cellulose	4.96	Okoro et al. (2018)
Polyanionic cellulose	6.00	Okoro et al. (2018)

Table 3
Materials used for mud formulation.

Mud material	Amount	Mixing order	Mixing time (seconds)	Function of material
Water	3.5×10^{-4} m^3	1	—	Base liquid
Bentonite	0.0225 kg	2	900	Viscosifier
NaOH	0.00025 kg	3	600	pH control
Rice Husk (RH 1)	0.005 kg	4a	600	Fluid loss control agent
Rice Husk (RH 2)	0.01 kg			
Rice Husk (RH 3)	0.015 kg			
Rice Husk (RH 4)	0.02 kg			
Saw Dust (SD 1)	0.005 kg	4b	600	Fluid loss control agent
Saw Dust (SD 2)	0.01 kg			
Saw Dust (SD 3)	0.015 kg			
Saw Dust (SD 4)	0.02 kg			
Barite	0.01 kg	5	600	Densifier

the particles size of a drilling fluid additive, the lower filtrate volume of the mud (Ghazali et al., 2014; Perlmutter, 2005). Then the pulverized saw dust and rice husk was subsequently stored at room temperature.

2.3. Mud mixing and drilling fluid preparation

Both the rice husk ash and saw dust samples were used to formulate water-based drilling mud based on American Petroleum Institute (API) standard of 0.0225 kg of treated bentonite to 3.5×10^{-4} m^3 of water; with addition of sodium hydroxide and barite. Each sample was mixed using a standard Hamilton Beach Commercial high-speed mixer (Model 550) and a bottom mixer cup. Each solid additive to the mud was weighed, and gently introduced into 3.5×10^{-4} m^3 of fresh water while the impeller was mixing. To forestall fluid loss, each sample was mixed for 600 seconds at a low speed in the mixing order as shown in Table 3. Nine portions were made out of the formulated mud. To the first portion, no rice husk or saw dust was added. This was used as the control mud and was code named CTRL MUD. To four portions out of the remaining eight portions, varying amounts of rice husk in increments of 0.005 kg up to a maximum of 0.02 kg were added. Mud formulated with 0.005 kg rice husk would be named 0.005 kg rice husk mud. The same applies to muds formulated with 0.01 kg rice husk (0.01 kg rice husk mud) and so on. The same was done to the last four portions of mud. Varying amounts of saw dust in increments of 0.005 kg up to a maximum of 0.02 kg were added. They were named 0.005 kg saw dust mud for mud formulated with 0.005 kg saw dust and same applies for muds formulated with 0.01 kg saw dust mud etc. Hence, a total of 9 mud systems namely: CTRL MUD, 0.005 kg rice husk mud, 0.01 kg rice husk mud, 0.015 kg rice husk mud, 0.02 kg rice husk mud, 0.005 kg saw dust mud, 0.01 kg saw dust mud, 0.015 kg saw dust mud and 0.02 kg saw dust mud were formulated. The formulated drilling muds were allowed to age for 24 hours at room temperature before carrying out further tests. The API specifications for the conventional fluid loss control additives are as shown in Table 4.

2.4. *Filtration test (low pressure, low temperature test)*

The API recommended practice for field testing water based drilling fluids, API RP 13B-1 (American Petroleum Institute, 2003), was used as the guide for carrying out the filtration experiment. This test was carried out at room temperature for a period of 1800 seconds. The low temperature, low pressure (LTLP) filter press was used and it consists of a cell cylindrical in shape with an internal diameter and height 0.0762 m and 0.127 m respectively as shown in Fig. 3. This cylindrical cell holds the mud to be measured. The bottom of the cylindrical cell is fitted with a filter paper (Whatman No. 50). When all the connections on the filter press are set, a pressure of 6.89×10^5 Pascals is supplied to the cell's top from an air compressor pump using a back pressure regulator attached to a nitrogen tank. The filtrate after 1800 seconds is collected in a 5×10^{-5} m^3 graduated cylinder placed beneath the cell. In half an hour, the volume of filtrate in cubic metres (m^3) collected is reported as the API filtrate loss. After this time, the cell is disassembled in order to get out the filter paper. The filter paper contains a layer of mud cake. The thickness of the filter cake is then measured to the nearest millimetre using a ruler.

2.5. *Filter cake characteristics measurements*

Obviously, the modalities for describing the cake characteristics differ from author to author due to the dearth of a universal approach to the descriptions (Amanullah and Tan, 2001). Nevertheless, the API qualitative conceptions of thin, thick, firm, rubbery, smooth, sticky etc. would form the basis for the cake descriptions. Hence, the following cake characteristics: slickness and texture were determined subjectively while thickness was measured quantitatively. First, the texture and slickness were determined by physical examination while the thickness was measured by using a ruler and reported in millimetres.

3. Results and discussions

3.1. *Filtration test results*

The result of the filtration experiment is presented in Fig. 4. It is discernible from the figure that the rice husk and saw dust failed as a fluid loss control additive when added in low concentrations but the filtrate loss kept decreasing for all the mud samples as the concentration of rice husk and sawdust cellulose increased. Only when more than 0.01 kg of rice husk is added to the water based mud, do we observe a comparable performance to the required API standard as shown in the case of high viscosity API polyanionic cellulose (PAC) as seen in Fig. 4. Additionally, from Fig. 4, it is observed that only when 0.015 kg and more of saw dust is added to the mud that we find a comparable filter loss control to the high viscosity API polyanionic cellulose. However, from this figure, it can be said that neither the saw dust nor the rice husk based on the range of the concentration of the materials – rice husk and saw dust chosen (i.e. 0.005 kg–0.02 kg) was able to compare with the fluid loss control capability of the API high viscosity carboxymethyl cellulose (CMC).

Table 4
API Specifications for fluid loss additives.

Parameter	API Specification
API Filter loss	API CMC (Hi vis) = 1×10^{-5} m^3 max., API PAC (Hi vis) = 2.3×10^{-5} m^3 max. (American Petroleum Institute, 2010)
Filter cake thickness	<2mm (Drilling Formulas, 2016)

3.1.1. *Effect of concentration of rice husk and saw dust on mud spurt loss*

The spurt loss was measured at the third second of time. At this time, there was a rapid, almost instantaneous "spurt" of the drilling mud filtrate through the filter paper and the volume was measured. Comparing the spurt loss volumes with the API filter loss after 1800 seconds, it is observed that the spurt loss takes a large percentage of the API filter loss. This is seen when Figs. 4 and 5 are compared. In practical terms, large spurt loss volumes indicate that the filter cake is slow in being formed and vice versa. Fig. 5 is a plot of spurt loss against concentration of rice husk and saw dust. From the figure, it is seen that the spurt loss is dependent on the concentration of rice husk and saw dust added to the mud. However, rice husk concentration has a marked effect has on spurt loss; with a rapid drop in spurt volume from 1.4×10^{-5} m^3 with 0.005 kg of rice husk added to 1×10^{-5} m^3 with 0.01 kg of rice husk added and then a linear decrease upon further additions. In general, for the rice husk mud there was a general trend for the spurt volume to decrease with increasing rice husk concentration. Similar results are recorded for the influence of saw dust concentration on spurt loss volumes with stepwise decreases by approximately the same factor as saw dust concentration increased. Comparing the spurt loss volumes for the rice husk muds and saw dust muds, it is observed that for equal concentrations of rice husk and saw dust, the spurt loss volumes recorded for the rice husk was lower than that of saw dust muds at lower concentrations. However, at higher concentrations, both the rice husk and sawdust muds levelled off at equal spurt loss volumes. It could then be said that high concentrations of these two additives in muds would not have any significant effect on spurt loss volumes.

3.2. *Filter cake results*

3.2.1. *Slickness of the mud cake*

From a physical examination of Fig. 6b, it is seen that the rice husk mud cake is smooth and slippery, a characteristic required of good filter cakes as opposed to the near dry, solid cake formed by the saw dust mud in Fig. 6a. This goes to show that the rice husk mud would prevent differential pipe sticking due to its slick nature compared to the saw dust mud.

3.2.2. *Texture of the mud cake*

Since no direct test can be run to determine the texture of a mud cake, then subjective judgement was used. A physical examination of the filter cakes indicates that the texture of the filter cake prepared from sawdust was somewhat rough, sticky, and firm as observed in Fig. 6a, while the texture for the filter cake prepared from rice husk was soft, smooth, slippery and not solid enough as seen in Fig. 6b.

The sticky texture of the mud formulated from the ground saw dust points to the fact that there would be more frictional drag on the drill pipe when it contacts the walls of the borehole than the smooth, slippery texture of the mud formulated with rice husk.

3.2.3. *Mud cake thickness*

The results of the thickness of filter cake of the drilling fluid

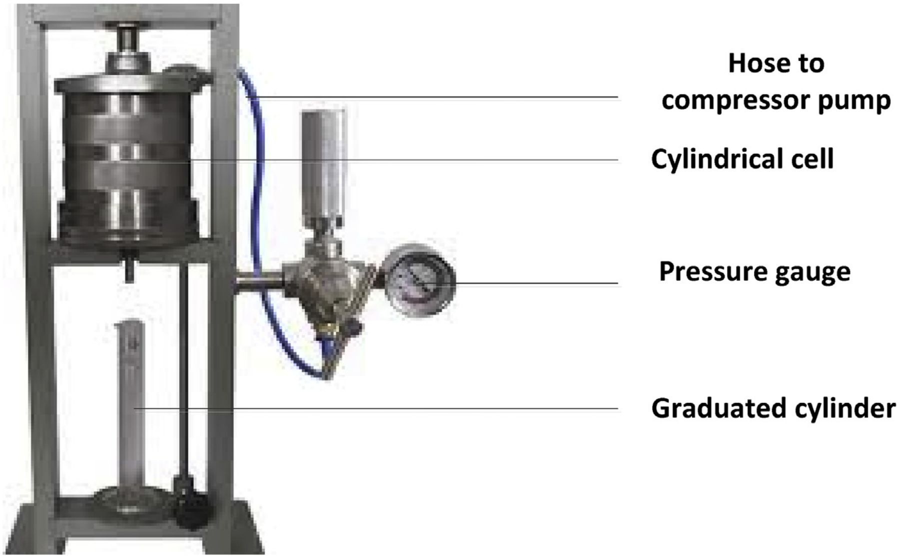


Fig. 3. API LTLP filter press used for the experiment (Source: Rig China group, 2019).

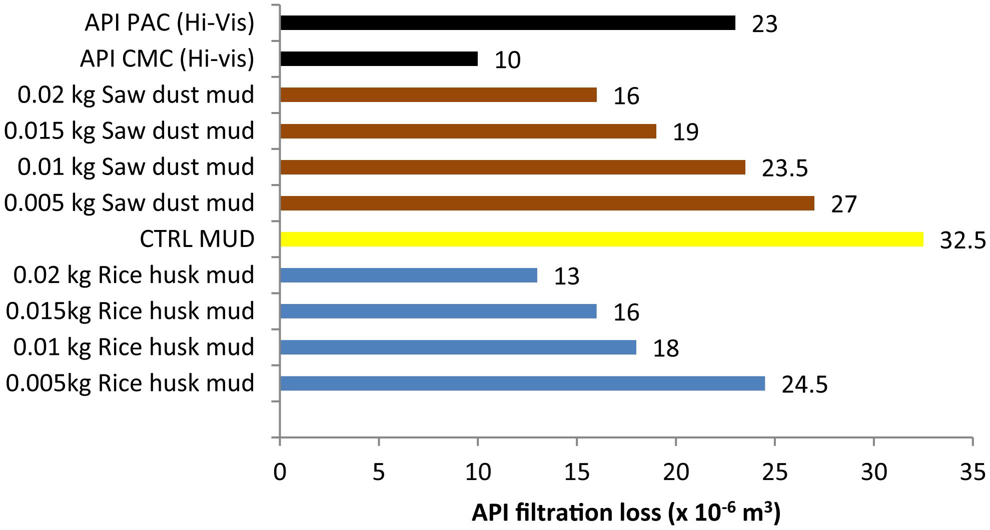


Fig. 4. API filtration loss after 1800 seconds for the formulated water based muds with different concentrations of rice husk and saw dust.

formulated with rice husk and saw dust in varying quantities is displayed in Fig. 7. The insert in Figs. 6a and 6b shows the cake thickness. The thickness was measured and it ranged from 2.8 mm to 3.8 mm for rice husk mud and 2.6 mm–3.3 mm for saw dust mud. It was observed that there was an increase in the thickness of the filter cake of the drilling fluid as rice husk and saw dust concentration increased. From the mud cake thickness as shown for both rice husk and saw dust in Fig. 7, it can be said that the cakes formed for both the saw dust and rice husk for failed to meet the 2 mm API standard since API states that a thin cake has less than 2 mm thickness while a thick cake has thickness ranging between 4 and 6 mm. However, it could be safely said that since the test for the filter loss was a static filtration test, the cake keeps growing with time. But in dynamic filtration tests where the hydrodynamic erosion of the circulating fluid comes to play, then its growth would be limited.

3.2.4. *Mud cake permeability*

To determine the mud cake permeability for both the rice husk and saw dust formulated muds, the model developed by Lomba (2010) shown in Eq. (1) is used.

$$k = Q_f * \varepsilon * \mu * 8.95 * 10^{-5} \tag{1}$$

The definitions of the parameters of Eq. (1) are as follows: k represents the cake permeability in millidarcy (mD), Q_f represents the fluid loss in mL, ε represents the cake thickness measured in millimetres (mm) while μ represents the viscosity of the liquid phase of the mud in centipoise.

Using Eq. (1), the cake permeability at different rice husk and saw dust concentrations is as shown in Table 5. From the table, the values of cake permeability for the saw dust mud are higher than those formulated with rice husk. This offers the explanation for why the filter loss volumes in the case of the saw dust were relatively higher than those of its rice husk counterpart. These filter loss volumes are shown in Fig. 4. Additionally, since the cakes formed from the rice husk show low cake permeabilities, this offers the explanation for why the thickness of the cakes in the rice husk mud are higher than those of its saw dust counterpart.

4. Conclusions

The thrust of this study has been to holistically assess the filter cake formed when rice husk and saw dust are used as filter loss control agents

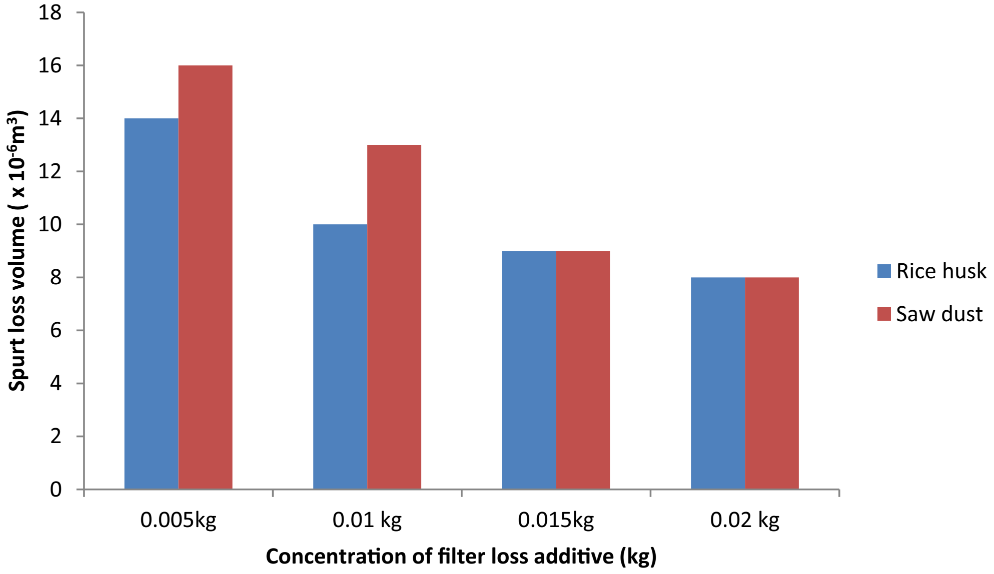
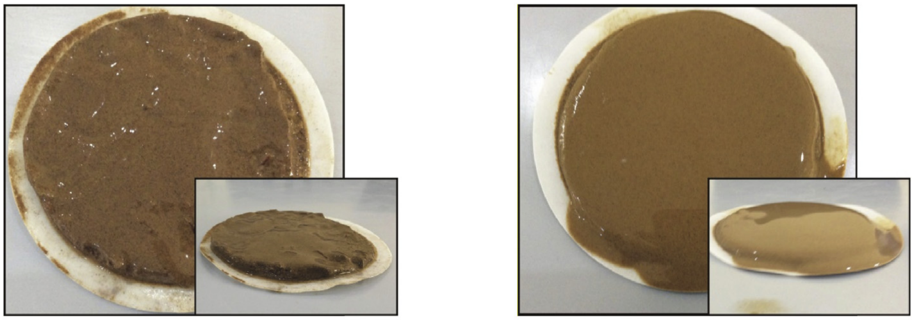


Fig. 5. Effect of concentration of rice husk and saw dust on spurt loss.



(a) Saw dust **(b)** Rice husk

Fig. 6. Filter cake from two pulverized agrowaste materials.

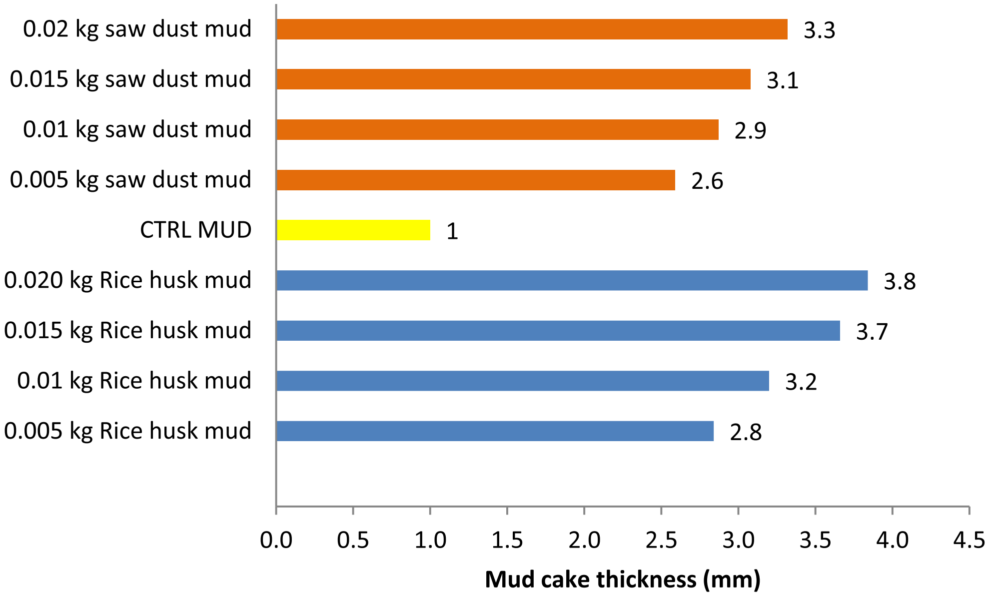


Fig. 7. Mud cake thickness for water based muds with varying concentrations of rice husk and saw dust.

Table 5
Cake permeability for WBM formulated with rice husk and saw dust.

Concentration fluid loss control material (kg)	Cake permeability (mD)	
	Saw dust (x 10^{-3})	Rice husk (x 10^{-3})
0.005	6.283	6.14
0.01	6.099	5.155
0.015	5.272	5.298
0.02	4.726	4.421

in water based muds. In order to make the results of the work consistent with field reality, the general direction by API for field testing of drilling muds was consistently followed. Based on the results, the following conclusions are drawn:

1. The use of commercial organic polymers as fluid loss control agents in drilling muds leads to increase in the cost of the fluids; hence, researchers focus on the use of feasible agro-waste cellulosic low-cost materials for drilling fluid loss control is not misplaced.
2. The cellulosic waste materials studied in this work – rice husk and saw dust are promising filtration loss control additives for water based drilling muds because of their abundance and renewability.
3. The fluid loss control characteristics of the rice husk and saw dust was noticeably influenced as their amounts in the mud increased.
4. It is observed that an inversely proportional relationship exists between the filter loss and the filtrate thickness for both the rice husk and saw dust muds. As filter loss decreased, the filter cake thickness increased.
5. Saw dust mud cakes had appreciable rough texture due to its sticky characteristic and may have a high sticking coefficient as opposed to the slippery and smooth mud cakes formed by the rice husk.

Declarations

Author contribution statement

Okorie Agwu: Conceived and designed the experiments; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Glory Archibong: Performed the experiments.

Julius Akpabio: Analyzed and interpreted the data; Wrote the paper.

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Competing interest statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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