Evaluation of the Impacts of Locally Sourced Lost Circulation Materials on Drilling Muds Properties

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Abstract- Lost circulation is one of the most troublesome and costly problems encountered in drilling. Lost circulation often results to excessive and expensive loss of muds and may lead to a blowout, stuck pipe, or formation damage. There are numerous materials which are used to prevent loss circulation. Regrettably most of the materials that are used in Nigerian Oil and Gas fields are imported. The usual argument is that locally sourced materials will adversely affect drilling mud properties. The purpose of the research was to evaluate the impacts of locally sourced loss circulation materials on drilling muds properties. Locally sourced lost circulation materials from agricultural wastes (Rice Husks, Corn Cobs and Walnut shells) were used to formulate drilling mud and the properties evaluated and compared with the drilling formulated using imported lost circulation materials. The muds formulated using lost circulation materials produced from agricultural wastes in most cases have lower viscosity and higher yield points than muds formulated using conventional / commercial lost circulation material. Therefore, they have good prospect for drilling in the sense that their low viscosity will offer less resistance to fluid flow and their higher yield points will enable them carry cuttings better. Muds formulated using Rice Husks as lost circulation materials has better gel strength. Results showed that all the mud samples have desirable mud density and mud cake thickness, but the muds formulated using Corn Cobs has lowest fluid loss value.

Index Terms- Lost Circulation, Locally Sourced, Agricultural Wastes, Drilling mud Properties

I. INTRODUCTION

One of the most common, troublesome and costly problems encountered during drilling and or cementing operations is lost circulation. Lost circulation is best defined as the uncontrolled flow of whole mud into a formation (Bourgoyne et al, 1991; Rabia, 2001; Baroid-Halliburton, 2006). This can occur in naturally cavernous, fissured, or coarsely permeable beds, or can be artificially induced by hydraulically or mechanically fracturing the rock, thereby giving the fluid a channel in which to travel.

According to Baroid-Halliburton, (2006) and Osisanya, (2011), the major conditions that cause lost circulation to occur down hole are:

(a) The pressure in the well bore must exceed the pore pressure (i.e. when the formation fracture resistance is exceeded by the pressure in the wellbore).
(b) There must be a flow pathway for the losses to occur.

According to Baroid-Halliburton, (2006); Mitchell and Miska, (2011) subsurface pathways that cause, or leads to lost circulation include:

(a) Natural fractures
(b) Induced or created fractures (fast tripping or underground blow-outs)
(c) Cavernous formations (crevices and channels)
(d) Unconsolidated or highly permeable formations Natural fractures present in the rock formations (including non-sealing faults)

The rate of losses is indicative of the lost pathways and can also give the treatment method to be used to combat the losses.

The severity of lost circulation can be grouped into the following categories (Abbas et al. 2004):

(a) Seepage losses: up to 10 bbl/hr lost while circulating
(b) Partial losses: 10 – 500 bbl/hr lost while circulating
(c) Severe losses: more than 500 bbl/hr lost while circulating

Extensive loss of whole mud to a cavernous, vugular, fissured, or coarsely permeable formation is expensive and may lead to a blowout, stuck pipe, or formation damage. This problem is magnified when expensive muds are used. Lost circulation control is therefore a significant concern for the oilfield industry. If lost-circulation zones are anticipated, preventive measures should be taken by treating the mud with Loss Circulation Materials (LCMs). Lost Lost circulation materials are used to plug zones of formation loss (Pal, 2012). Lost circulation control materials can be divided into three groups (Neal, 1985; Bourgoyne et al, 1991; Nayberg and Petty, 1986; Ali and Singh, 1991; Rabia, 2001; Pilehvari and Nyshadham, 2002; Growcock, and Harvey, 2005; Azar, and Robello, 2007).

(a) Fibers (rice hulls, peanut hulls, wood, cane etc.)
(b) Flakes (ground mica, plastic laminate, cellophane, and polyethylene plastic chips etc.)
(c) Granules (ground walnut shells, pecan shells, almond shells, plastic, and calcium carbonate etc.).

These are materials that can easily be sourced locally, in facts some of them are regarded as wastes. Regrettably most of the loss circulation materials used in Nigerian oil and gas fields are imported. The usual argument is that locally sourced materials will adversely affect drilling fluids properties. However, the use of locally sourced materials as lost circulation materials can drastically reduce the drilling cost as well as contribute immensely to the local content development initiative. The purpose of this study is therefore to evaluate the impacts of locally sourced loss circulation materials on the properties of drilling muds.

II. MATERIALS AND METHODS

A. Materials

These comprise:

(a) Principal components of water based mud (Table 1)
(b) Lost Circulation Materials to be Investigated (Table 2)
(c) Apparatus and equipment (Table 2)

Table.1: Principal components of water-based mud

SN	BASED MATERIALS	REMARKS
1	Water	Base Fluid
2	Bentonite	Rheological and Filtration control
3	Barite	weighting materials
4	Xanthan Gum	Viscosifiers
5	Potassium Chloride	Shale Hydration Inhibitor
6	Caustic Soda (NaOH)	pH control additive
7	Lignite	Filtrate reducers /Thinning agents

Table 2: Lost Circulation Materials to be investigated

SN	Lost Circulation Materials	Sources	Category
1	Rice Husks	Agricultural Wastes	Fibrous
2	Corn Cobs	Agricultural Wastes	Flakes
3	Walnut shells	Agricultural Wastes	Granular
4	Calcium Carbonate (limestone)	Conventional and Commercial (Imported)	Granular

Table 3: Mud Properties and Major Testing Equipment

MUD PROPERTIES TESTS	MAJOR EQUIPMENT
Mud Weight	Baroid Mud Balance Model 140
Viscosity	Fann Viscometer (rheometer), Model 35 FANN®
Gel Strength	Fann Viscometer (rheometer), Model 35 FANN®
pH	Universal pH indicators, pH meter-Hach Model H260

Filtrate Rate and Mud Cake Thickness	Filter Press (API LTLP Model 300 and HTHP Model MB, 4 Unit, Vernier Caliper

Other include Spatula, Sieve, Triple Beam balance, Mortar grinder RM 200, Cutting mills SM 100, Jaw Crushers BB 50, Muffle furnace BST/MF/900 Electric multi mixer (blender), Measuring cup, Filter paper, Weighing Balance, Beakers, Flasks, and Sample containers, Pulverizer, sieve, spatula, digital weighing machine, rotary viscometer, graduated cylinder, multi-rate mixer.

B. Methods

A laboratory study was undertaken to compare the performance of conventional or LCM's with t in both oil- and water-based drilling muds

These entailed:

(a) Preparations of Samples of Lost Circulation Materials.
(b) Drilling Mud Formulations using:
  - Agricultural wastes as lost circulation materials
  - Imported Materials as lost circulation materials.
(c) Mud Properties Testing:
  - Conventional Drilling Mud Properties Tests.
  - Lost Circulation Tests.
  - Pore Plugging Tests

Preparation of Samples of Lost Circulation Materials

All the agricultural wastes were sourced from Edo State, Nigeria.

The following simple processes were carried out to produce lost circulation materials from the Agricultural wastes:

(a) Cutting and chopping of the wastes into small chips
(b) Cleaned Rice Husks, Corn Cobs and Walnut shells were dried at 60 °C for about 3–4 h. The dried materials were then ground and sieved.

Mud Samples Formulation

The drilling muds were formulated to optimize its functions as well to ensure minimal hole problems. Consequently, six drilling muds samples were formulated in accordance to the API (2009) standard.

Table 4: Composition of Water Based Drilling Muds

	A1	A2	B1	B2	C1	C2	D1	D2	E
Water (mls)	350	350	350	350	350	350	350	350	350
Bentonite	21g	21g	21g	21g	21g	21g	21g	21g	21g
Barite	12g	12g	12g	12g	12g	12g	12g	12g	12g
Xanthan Gum	1.5g	1.5g	1.5g	1.5g	1.5g	1.5g	1.5g	1.5g	1.5g
Potassium Chloride (KCl)	25g	25g	25g	25g	25g	25g	25g	25g	25g
Lignite	2.5g	2.5g	2.5g	2.5g	2.5g	2.5g	2.5g	2.5g	2.5g
Caustic Soda	0.5g	0.5g	0.5g	0.5g	0.5g	0.5g	0.5g	0.5g	0.5g
Lost Circulation Materials	3g Grinded Rice Husks	6g Grinded Rice Husks	3g Grinded Corn Cobs	6g Grinded Corn Cobs	3g Grinded Walnut shells	6g Grinded Walnut shells	3g $CaCO_3$	6g $CaCO_3$	Blank

Mud Properties Determination

The muds properties were determined in accordance with methods as described by Baroid, 1998; Baker Hughes Inteq, 1999; Amoco, 2002; ANSI/API, 2017.

(1) Rheological Properties Determination

The following were determined; Plastic viscosity (PV), Yield point (YP), Gel strength, Apparent viscosity (AV), Consistency index (K), Yield stress (YS), Flow index (n), Tau(τ),

The Equipment and apparatus used include Calibrated FANN concentric cylinder rotational viscometer, thermostatically controlled viscometer heater cup, Thermometer: 32 to 220°F (0 to 104°C).

Procedure

Fluid sample was collected and placed in a thermostatically controlled viscometer cup leaving enough empty volume for the displacement of the bob and sleeve. The viscometer rotor sleeve was immersed exactly to the scribed line. The fluid sample was heated up to the selected temperature.

The viscometer sleeve was rotated at 600 rpm until a steady dial reading was obtained and recorded. The viscometer sleeve was also rotated at 300 rpm until a steady dial reading was obtained and recorded.

The sample was stirred for 10 to 15 seconds at 600 rpm, the mud left to stand undisturbed for 10 seconds. The viscometer sleeve was then rotated at 6 rpm until the maximum dial reading was obtained and recorded. This was done also for 3 rpm. The maximum dial reading obtained as the 10-second gel strength, lbf/100 ft^2 was also recorded.

(2) Gel Strength

The speed selector knob was then rotated to stir the mud sample for a few seconds, then it was rotated to gel setting and the power was immediately shut off. As soon as the sleeve stopped rotating, the power was turned on after 10 seconds and 10 minutes respectively. The maximum dial was recorded for each case. Gel strength, lbf/100 ft^2 = Max. dial reading at 3 rpm.

Weight (Density) Determination

The Equipment and apparatus used include Baroid mud balance, graduated mud cup, Thermometer: 32 to 220°F (0 to 104°C).

The Equipment was calibrated as follows:

The lid was removed from the cup completely filled with water. The lid was replaced and wipe dry. The balance arm was replaced on the base with knife-edge resting on the fulcrum. The level dial was being centered when the rider is set on 8.33.

Test Procedure

The lid was removed from the cup, and then completely filled the cup with the tested mud. The lid was replaced and rotated until firmly seated; making sure some mud were expelled through the hole in the cup. The mud from the outside of the cup was washed or wiped. The balance arm on the base was placed, with the knife-edge resting on the fulcrum. The rider was moved until the graduated arm is level, as indicated by the level vial on the beam. At the left-hand edge of the rider, the density on either side of the lever in all desired units was read without disturbing the rider.

Filtration Rate and Mud Cake Thickness Determination

The Equipment and apparatus used include: Filter press (API LTLP and HTHP), Filter paper, Stop-watch, graduated cylinder, Thermometer up to 500°F (260°C), High-speed mixer

(a) Filtration Rate

The mud cell from filter press frame was detached. The bottom of filter cell was removed; the right size filter paper was placed in the bottom of the cell. The tested mud was poured into cup assembly, putting filter paper and screen on top of mud tighten screw clamp. With the air pressure valve closed, the mud cup assembly was clamped to the frame while holding the filtrate outlet end finger tight. A graduated cylinder was placed underneath to collect filtrate. Air pressure valve was opened and timing started at the same time. The filtrate was collected and report $cm^3$for specified intervals up to 30 minutes. 8. The results were recorded and tabulated.

(b) Mud Cake Thickness

Vernier caliper was used to measure the thickness (32nd of an inch or cm)

III. RESULT AND DISCUSSIONS

(1) Rheological properties

According to Darley and Gray (1988), Alderman et al (1989), Baker Hughes (2006) and Azar and Robello (2007) good drilling fluids for oil well drilling are those capable of sustaining sufficiently large stress to maintain cuttings in suspension, particularly when fluid circulation is stopped, while having a low viscosity for efficient pumping. These requirements are determined by Plastic viscosity (PV), Yield point (YP), Gel strength, Apparent viscosity (AV), Consistency index (K) Yield stress (YS), Flow index (n), Tau(τ).

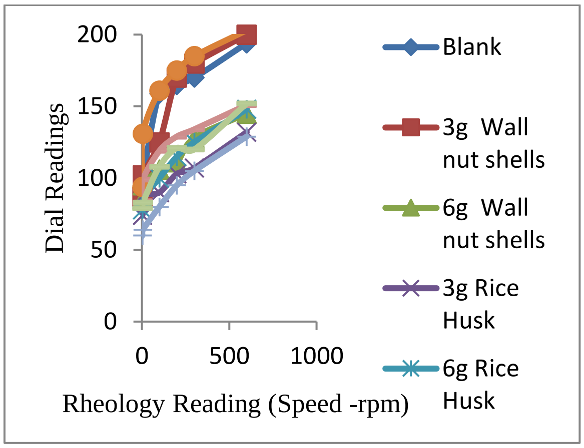

Figure 1: Comparison of the Rheology Reading (shear stress and shear rate)

Figure 1 showed the relationship between shear stress, and shear rate of drilling fluids indicating non-Newtonian.

(A) Plastic Viscosity- The muds formulated using conventional / commercial lost circulation materials (Calcium Carbonate) and those without lost circulation materials (blank) have a higher plastic viscosity compared to the muds formulated using lost circulation materials produced from agricultural wastes (Rice Husks , Corn Cobs and Walnut shells) (Figure 2). This indicates that muds formulated using conventional / commercial lost circulation materials (Calcium Carbonate) and those without lost circulation materials (blank) have higher viscosity, which would offer a greater resistance to fluid flow that will result in increased circulating pressures that can cause loss of circulation and increased pumping costs. Thus, muds formulated using lost circulation materials produced from agricultural wastes (Rice Husks, Corn Cobs and Walnut shells) with low viscosity have good prospect for drilling in the sense that their low viscosity will offer less resistance to fluid flow and therefore would lead to a turbulent flow at low pump pressure which would result in good hole cleaning.

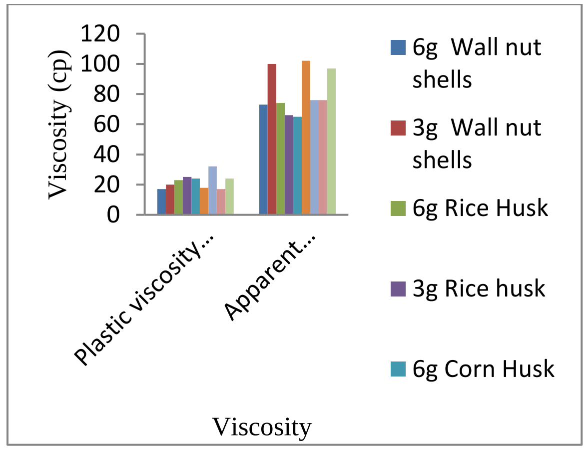

Figure 2: Comparison of the Viscosity

(B) The yield point (YP)

The yield point (YP) is used to evaluate the ability of a mud to lift cuttings out of the annulus. A high YP implies a non-Newtonian fluid; one that carries cuttings better than a fluid of similar density but lower YP. Additionally, frictional pressure loss is directly related to the YP. It is important to state here that excessively high YP leads to high pressure losses while the drilling mud is being circulated. The muds formulated using lost circulation materials produced from agricultural Wastes (Rice Husks , Corn Cobs and Walnut shells) in most cases have higher yield points as compared to muds formulated using conventional / commercial lost circulation materials (Calcium Carbonate) and those without lost circulation materials (blank) (Figure 3).

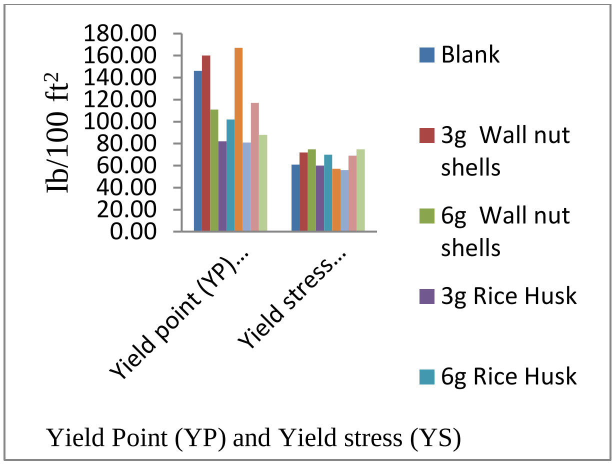

Figure 3: Comparison of the Yield Point (YP) and Yield stress (YS)

(C) Flow index (n) and Consistency index (K)

Figure 4 showed that showed that muds with commercial lost circulation materials a higher flow index compared to those lost circulation materials produced from agricultural Wastes (Rice Husks, Corn Cobs and Walnut shells) however, the consistency index is lower (Figure 5).

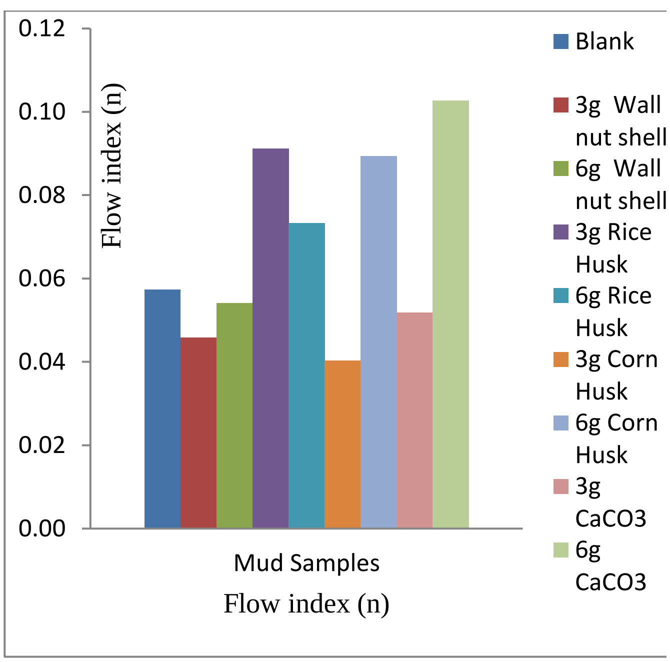

Figure 4 Comparison of the Flow index (n)

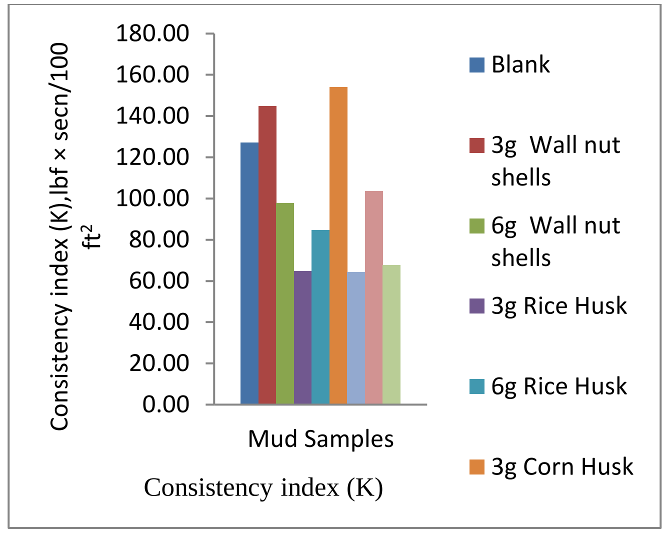

Figure 5: Comparison of the Consistency index (K)

(D) Gel Strength

The gel strength is another important drilling fluid property, as it demonstrates the ability of the drilling mud to suspend drill solid (drilled cuttings) and weighting material when mud circulation is ceased. Figure 6 indicate that muds formulated using Rice Husks as lost circulation materials has lowest gel strength values at both 10 seconds and 10 minutes compared to other. Thus, the gel strength values of the muds formulated using Rice Husks show that the mud exhibits a flat gel structure, meaning that the mud will remain pumpable with time if left static in the hole. Conversely, the gel strength values of the muds formulated using conventional / commercial lost circulation materials (Calcium Carbonate) and those without lost circulation materials (blank) were much higher, indicating that the diesel mud exhibits a progressive gel structure. This is an indication that the gelation of muds formulated using conventional / commercial lost circulation materials (Calcium Carbonate) and those without lost circulation materials (blank) rapidly gained strength with time, which generally is an undesirable feature of a drilling mud. Therefore, the weak gel/fragile property of the muds formulated using Rice Husks as lost circulation materials is desirable during drilling operation as the gel can be broken easily with lower pump pressure to make circulation. On the other hand, the high value of muds formulated using conventional / commercial lost circulation materials (Calcium Carbonate) and those without lost circulation materials (blank) gel strength would lead to high circulation breakdown pressure and increased pumping costs as high pump power is required to overcome these gelling potentials.

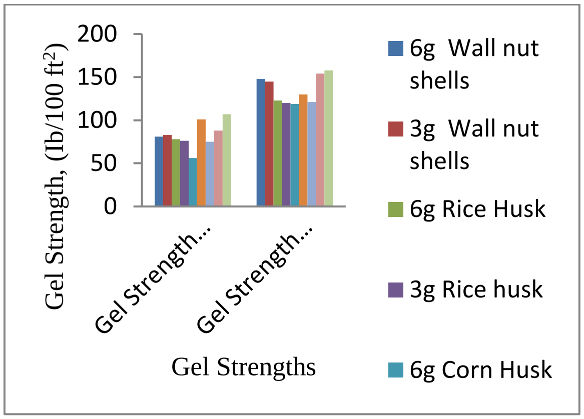

Figure 6: Comparison of the Gel Strengths

(E) Mud Density

Mud density of drilling fluid system is mainly necessary for the control of formation pressures. Additionally, an increase in mud density increases the capacity of the mud to carry drilled cuttings as the suspending fluid has an associated buoyancy effect on the cuttings. Figure 8 showed that all the mud samples have desirable mud density of 8.45 to 8.5Ib/gal as compared to standard mud.

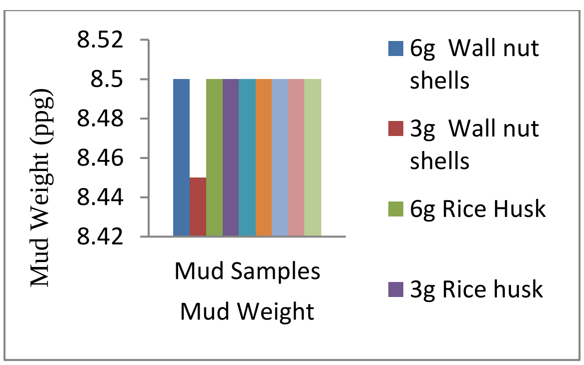

Figure 7: Comparison of Mud Weight

(F) Filtration Loss

Filtration rate is often the most important property of a drilling fluid, particularly when drilling permeable formations where the hydrostatic pressure exceeds the formation pressure. Proper control of filtration can prevent or minimize wall sticking and drag and in some areas improve borehole stability. Figure 8 show filtrate volume from the formulated muds collected after 30 minutes. The results depict that the water volume collected from muds formulated using Corn Cobs as lost circulation materials are lower and thus better (5.6 ml for 6g and 6.4 for 3g).

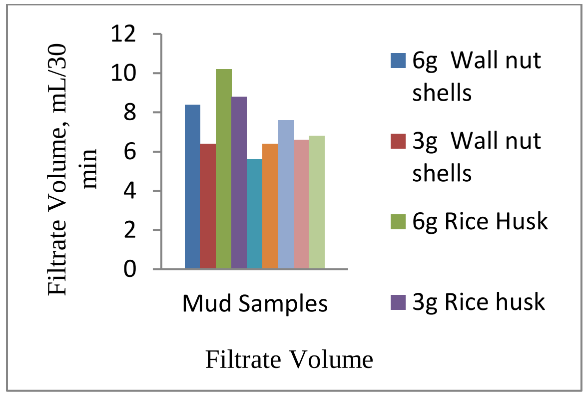

Figure 8: Comparison of the Filtrate Volume

(G) Mud Cake Thickness

Generally, high filtrate volumes are associated with thick filter cake because the cake is formed by deposition of clay particles on the walls of the hole during filtrate loss to the formation. The higher the filter volume, the thicker the filter cake and the less efficient the drilling mud. The effect of this is that a thick mud cake reduces the effective diameter of the drilled wellbore thereby increasing the area of contact between the drill pipe and the cake leading to increased risk of stuck pipe incidents. Based on the results of the study (Figure 9) ,muds formulated using Walnut shells as lost circulation materials have lowest mud cake thickness of the agricultural wastes (0.65 mm for 3g and 0.8mm for 3g).

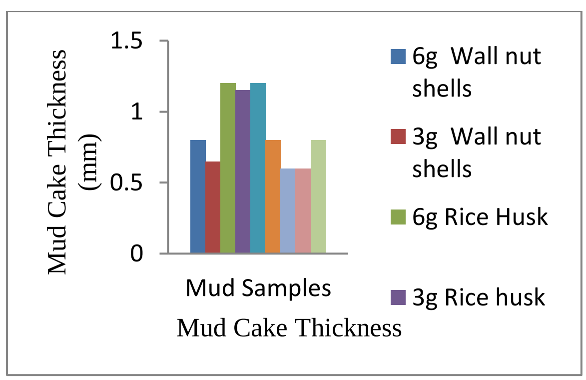

Figure 9: Comparison of the Mud Cake Thickness

IV. CONCLUSION

Locally sourced lost circulation materials from agricultural wastes were used to develop drilling mud and the properties evaluated. Based on the experimental, it can be concluded that lost circulation materials from agricultural wastes (Rice Husks, Corn Cobs and Walnut shells) can suitably be used as drilling fluids in place of the conventional materials. The muds formulated using lost circulation materials produced from agricultural wastes (Rice Husks , Corn Cobs and Walnut shells) in most cases have higher yield points as compared to muds formulated using conventional / commercial lost circulation materials (Calcium Carbonate) and those without lost circulation materials (blank). A high YP implies a non-Newtonian fluid; one that carries cuttings better than a fluid of similar density but lower YP.
Muds formulated using lost circulation materials produced from agricultural wastes (Rice Husks, Corn Cobs and Walnut shells) with low viscosity have good prospect for drilling in the sense that their low viscosity will offer less resistance to fluid flow and therefore would lead to a turbulent flow at low pump pressure which would result in good hole cleaning.

The gel strength is another important drilling fluid property, as it demonstrates the ability of the drilling mud to suspend drill solid (drilled cuttings) and weighting material when mud circulation is ceased. Muds formulated using Rice Husks as lost circulation materials has lowest gel strength values at both 10 seconds and 10 minutes compared to other.

Results showed that all the mud samples have desirable mud density of 8.45 to 8.5Ib/gal.
The results showed that the water volume collected from muds formulated using Corn Cobs as lost circulation materials are lower and thus better (5.6 ml for 6g and 6.4 for 3g). Besides, mud cake thickness of the muds formulated using Agricultural as using lost circulation materials are compare favourably with the conventional/ commercial ones.

REFERENCES

[1] Bourgoyne Jr., A.T., Millheim, K.K., Chenevert, M.E., and Young Jr., F.S., ― Applied Drilling Engineering (2nd Printing). SPE, Richardson, Texas, 1991, pp 101.

[2] Rabia, Hussain ―Well Engineering and Construction". Entrac Consulting,. 2001, pp. 609–618.

[3] Baroid-Halliburton―Lost Circulation and Wellbore Stress Management- DS-Baroid Fluid Services Fluids Handbook-Halliburton-2006 9-1 to 9-15

[4] Osisanya, S. ―Course Notes on Drilling and Production Laboratory". Mewbourne School of Petroleum and Geological Engineering, University of Oklahoma, Oklahoma (Spring), 2002.

[5] Mitchell, R. F. and Miska, S. Z. ― Fundamentals of drilling engineering,. 2011, SPE Textbook Series, Vol. 12. Society of Petroleum Engineers, Richardson,Texas.

[6] Abbas, R., Jarouj, H., Dole, S., Effendhly, Junaidi, H., El-Hassan, H., Francis, L., Hornsby, L., McCaith, S., Shuttleworth, N., van der Plas, K., Messier, E., Munk, T., Nadland, N., Svendsen, R.K., Therond, E., and Taoutaou, S. ― A Safety Net for Controlling Lost Circulation, 2004; Oilfield Review (winter, 2003/2004).

[7] Pal Skalle ― Drilling Fluid Engineering 3rd Edition Ventus Publishing Aps.2012, pp 30.

[8] Neal, J. Adam.Drilling Engineering - A Complete Well Planning Approach, PennWell Publishing Company, 1985. Tulsa, Oklahoma

[9] Nayberg T.M. and Petty B.A. ―Laboratory Study of Lost Circulation Materials for Use in Oil-Sase Drilling Muds. Copyright 1986, Society of Petroleum Engineers Paper presentation at the Deep Drilling and Production Symposium of the Society of Petroleum Engineer

[10] Ali, A., Kalloo, C. L., and Singh, U. B., ''A Practical Approach for Preventing Lost Circulation in Severely Depleted Unconsolidated Sandstone Reservoirs,'' SPE/IADC 21917, SPE/IADC Conference, Amsterdam, March 11–14, 1991.

[11] Pilehvari, A.A., and Nyshadham, V.R―Effect of Material Type and Size Distribution on Performance of Loss/Seepage Control Material, paper SPE 73791 presented at the 2002 SPE International Symposium and Exhibition on

Formation Damage Control held in Lafayette, Louisiana, 20-21 February.

[12] Growcock, F., and Harvey, T. — *Drilling Fluids Processing Handbook*. Gulf Professional Publishing, Elsevier, 2005, pp 620-621.

[13] Azar, J. J. and Robello Samuel, G—Drilling Engineering, Penn Well Corporation, Tulsa, Oklahoma 2007.

[14] Baroid — Baroid Fluids Handbook, 1998, Baroid Drilling Fluids Inc, Houston, Texas.pp. 5-3 - to 5-96.

[15] Baker Hughes Inteq — Fluid Engineering Handbook, 1999; Technical Communications Group, Houston, TX 77267-0968 USA, pp 1-12 to 1-26.

[16] Amoco —Drilling Fluids Manual, Amoco Production Company Drilling Fluids Manual, 2002, pp 3-1 to 3-41.

[17] ANSI/API —Recommended Practice13B-1 for Field Testing Water-based Drilling Fluids, 2017.

[18] Darley, H.C.H. and Gray, G.R. — Composition and Properties of Drilling and Completion Fluids, Fifth Edition, 1988, Gulf Publishing Company. pp 1-27.

[19] Alderman Neil John, Babu Ram D, Hughes T.L and Maitland Geoffrey —The Rheological Properties of Water-Based Drilling Fluids, 1989, Assessed Research Gate 2018.

[20] Baker Hughes —Drilling Fluids Reference Manual, Baker Hughes Drilling Fluids, Revised 2006, Chapter 1.

APPENDIX

Figure A1: Sources of Locally Prepared Lost Circulation Materials