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Experimental Study of the Possible use of Locally Derived Plantain Peelings and Rice Husk as Additives for Oil Based Mud at High Temperature - High Pressure Conditions

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Abstract

Drilling in HT/HP wells has adverse effects on drilling fluids. At high temperatures and pressures, the chemical additives used in drilling fluid formulations experience thermal degradation above 107°C (225°F) leading to strong variations (reduction) in rheological and filtration characteristics. Locally derived Rice-Husk and grounded Plantain peels were used to improve the rheology and filtration properties of back-loaded oil based mud at HT/HP behavior, and the results were compared to industrial additives like Sodium Carbooxymethylcellulosics (CMC), Polyanionic Cellulosics (PAC), and Sodium Polyacrylates (SPA). This research was centered on the use of three oil-based mud samples from a particular field in the Niger Delta basin. The samples included; a reconditioned mud, a freshly prepared mud (both with standard industry additives), and a back-loaded mud respectively. Seven [7] different mud property tests were carried out on the samples to determine their current state. After that, the back-loaded mud was upgraded with the locally derived additives and it's rheological and filtration properties were observed and compared to the results of the first two samples. The effects of high temperature and high pressure on the stability of the locally-derived additives were also observed. This was paramount because the chemical additives underwent thermal degradation at these conditions. The most significant finding is that the locally derived additives worked at the same level or probably better than the industrial additives.

The novelty of this research was to evaluate the potential of locally derived additives for improvement of mud rheology and filtration in comparison with industrial additives. Also, a reduction in the cost of purchasing foreign viscosifiers and filtration control additives by patronizing locally derived additives hence reducing the overall cost of a mud program. Lastly to make sure that wastes like rice husks and plantain peelings are recycled by usage in drilling mud formulations so as to prevent environmental problems such as heaping of refuse on the streets.

Introduction

Drilling fluid is a composite and multi-functional liquid used to drill boreholes into the earth. The drilling fluid is an important part of the entire drilling process, therefore it should be employed to complement other parts of the operation in order to ensure a safe and efficient drilling process (Awele, 2014). A complete drilling fluid system must be properly designed in order to efficiently construct a well. The basic functions of drilling fluids are; controlling of subsurface pressure, transporting cuttings, supporting and stablizing the wellbore, supending cuttings, sealing permeable formations, minimizing formation damage, etc (Darley, Gray, & Caenn, 2011). The basic use of oil-based muds is to drill through troublesome shales and improve the stability of the hole drilled. They are also utilized when drilling in deviated wells due to their great degree of lubricity, capability to prevent clay hydration and ability to withstand very high temperature when selected for distinctive applications such as HP/HT wells and minimizing formation damage. They are also used when drilling low pore pressure formations (Dyke, Baker, & R, 1998). Oil base muds offer better advantage over regular mud such as shale and temperature stability, lubricity, higher rates of penetration, corrosion control, reduced production damage, etc (Amoco Production Company, 2001).

Literature Review

Drilling in high temperature wells have adverse effects on drilling fluid. High temperature wells are wells where the bottomhole temperature and pressure have values greater than 120°C (350°F) and 20000psi and the pore pressure of the formation has a hydrostatic pressure gradient of 0.8psi/ft and equipment with a working pressure that is greater than 10,000psi is required. In the Niger Delta basin in Nigeria, HT/HP wells encountered have temperatures and pressures of (177°C - 204°C) and 20000psi (UK Department of Energy and Climate Change, 2014). Key issues that arise in HT – HP operations are low operating margin, borehole instability, difficult well control, misinterpretation of well signals, limited hydrostatic overbalance due to little margin that exists between the fracture and pore gradients and inability of logging tools to function properly making it difficult to obtain pressure measurements at downhole that are to be used for pressure management (Karstad & Aadnoy, 1998), (Bland, Mulleng, Gonzalez, Harvey, & Pless, 2006).

At high temperatures, mud rheology decrease exponentially as the temperature increases (Adekomaya, Anifowose, & Wale, 2011), the bentonite becomes hydrated, coalesce and then undergoes passivation (reduction of chemical reactivity of a surface by applying a coating) making the clay properties to be affected. It reduces the performances of mud additives, causes dispersion of clay and the biodegradation of organic materials. It increases the rate of reaction between base compounds and compounds containing silica (Amani & Al-jubouri, 2012), (Wenjun, Shixian, Fan, Weimin, & Zhitao, 2014). Different drilling fluids disintegrate at different temperatures depending on their composition (Ibeh, 2007). At high pressures, viscosity increases due to the fact that the molecules are pulled together. Oil based muds are more sensitive to pressure compared to water based muds as a result of the compressibility of oil (Amani, 2012).

Figure 1—Rice Husk

In Nigeria, agro-wastes like rice husk and plantain peelings are produced in very high concentrations, due to the fact that most of the general populace dont know what to do next with it. Plantian peelings are the soft coverings of plantains that are removed when it is to be used. These peelings are rich in cellulose, hemicelluloses, lignin and phytic acid (Adebowale & Raji, 2015). Plantain peelings also contains 6–10% of protein, 6–12% of ash, 2–6% of lipids, 11–39% of starch, and 33–43% of total dietary fiber (TDF) (Happi-Emaga, et al., 2011). It is the presence of these properties that makes it a good candidate to be evaluated as a rheological control additive.

Rice husk (Figure 1) are the hard protective covering of grains of rice. It is an agro waste because some farmers don't have the knowledge of how to make use of it due to its large volume and because it is indigestible to humans. It contains contains roughly 20% opaline silica in conjunction with a huge amount of the phenyl propanoid structural polymer known as lignin. Such a high concentration of silica is very rare within nature and this mixture of silica and lignin makes the rice husk not only impervious to water penetration but also fungal and thermal decomposition (Olivier, 2004). It also posseses good compressive strength when it is increased in concentration and its particles are compressible at high pressures (Samsuri, 1999), (Okon, Udoh, & Bassey, 2014). These properties of rice husk makes it a good candidate to be utilized as a filtration control additive.

Some of the most important functions of drilling mud is its rheological state and its ability to reduce the amount of fluid lost to the formation (Filtration). Rheology is important because, it permits the mud to be examined in terms of hole cleaning ability, pressure loss, equivalent circulating density, fluid flow profile and in general the hydraulics of the wellbore (Amoco Production Company, 2001). Rheological characteristics of drilling mud include yield point, gel strength, plastic and apparent viscosity. Filtration is achieved by the formation of a low permeable membrane on the walls of the formation or borehole. Invasion of fluids into the wellbore can cause formation damage and block hydrocarbon flow paths hence reducing productivity (Kosynkin, et al., 2011). Mud filtration behavior influences aspects such as differential sticking, wellbore stability, lost circulation and formation damage.

Drilling in HT/HP wells has adverse effects on drilling fluids. At high temperatures the chemical additives used in drilling fluid formulations experience thermal degradation leading to strong variations in rheological and filtration characteristics. The industrial additives used in controlling the mud behavior at these conditions such as, Carbooxymethylcellulosics (CMC), Polyanionic Cellulosics (PAC), Sodium Polyacrylates (SPA), Lignins, Tannins and Polymers are imported from other countries. Due to the current economic crisis in the Country today, the lack of foreign exchange has seen the value of the Naira drop to a very low level in just less than a year. This has made it much more expensive than before to source for foreign materials. A lot of the drilling materials are imported and this constitutes an undue financial burden for the petroleum industry and the overall cost of a drilling program. For the Nigerian Petroleum Industry to advance, research must be done on local additives which are readily available in order for them to be used as substiutes for foreign additives so as to encourage local expertise, enterprise and reduce the cost imposed on companies when sourcing for foreign additives. If the industry is to make use of local materials there will be availability of jobs in the manufacturing sector, there ill be more research done on local material.

This paper in line with the stated drive above evaluates the potential of local materials as rheological and filtration additives in oil based drilling muds.

Materials and Methods

Mud Sample and Additives

Aged Rice Husk was collected from a rice mill in Sango, Ogun state. The rice husk was sun-dried for 72 hours in order to eliminate moisture from the substance. It wasnt dried in an oven so as to prevent destruction of some of it natural properties. It was then grounded into powdered form then sieved to 125 microns to obtain fine particles.

Ripe plantain peelings were obtained from local plantain traders in Lagos state. Just as the rice husk it was sun-dried for 96 hours eliminate most of the moisture and grounded into powdered form. After being grounded it was sun-dried even further for another 48 hours. It was then sieved to 125 microns to obtain fine particles.

Three [3] different mud samples obtained from a particular field in the Niger Delta basin were experimented on during the course of this research. The state of the samples were unknown prior to the beginning of the research. Therefore seven [7] different tests were carried out on the samples to determine the current state of the samples in order to ascertain the condition of each of the samples. The tests that were carried out on the samples are density, rheology, filtration, resistivity, pH, oil-water content and sand content tests. The results of the tests are presented in Table 1.

Table 1—Properties of the Original Mud Samples

	PARAMETERS	UNIT	MUD A	MUD B	MUD C
	Volume Mud Type	bbl			
		SBM/WBM/OBM	**OBM**	**OBM**	**OBM**
DENSITY	Mud Weight	ppg	11.0	11.1	11.6
	Specific Gravity		1.3	1.3	1.4
RHEOLOGY	600	rpm	330	271	239
	300	rpm	239	162	146
	200	rpm	200	120	112
	100	rpm	153	75	71
	60	rpm	132	54	52
	30	rpm	118	38	37
	6	rpm	108	22	20
	Plastic Viscosity	Centipoise	91	109	93
	Yield Point	$lbs/100ft^2$	148	53	53
	10 Second Gel	$lbs/100ft^2$	108	25	24
	10 Minute Gel	$lbs/100ft^2$	111	75	63
	Apparent Viscosity	Centipoise	165	135.5	119.5
FILTRATION (HT-HP)	Temperature	°C	200	200	200
	Pressure	psi	2000	2000	2000
	Test Time	minutes	30	30	30
	Sample volume	mililitres	500	500	500
	Filtrate Volume	mililitres	23	13	17
	Filter Cake Thickness	cm	2.04	1.68	1.21
FILTRATION (LT-LP)	Temperature	°C	29.4	30	28
	Pressure	psi	105	105	105
	Test Time	minutes	30	30	30
	Sample volume	mililitres	400	400	400
	Filtrate Volume	mililitres	13	10	19
	Filter Cake Thickness	cm	0.23	0.25	0.18
ALKALINITY	pH	ppb	10.00	8.00	6.20
OIL WATER CONTENT	Solid	%	17	12	15
	Oil	%	45	50	49
	Water	%	38	38	36
	Oil Ratio	%	1.18	1.32	1.28

	PARAMETERS	UNIT	MUD A	MUD B	MUD C
RESISTIVITY	Mud Resistivity	ohm-m	1.75		1.85
	Conductivity	mV	-170.00	-30.00	31.00
	Temperature	°C	29.40	31.70	31.00
SAND CONTENT	Volume of Sand	%	2.00	0.70	0.40

After analyzing the results, it was observed that the three samples were composed of;

- Mud A – Freshly prepared oil based mud mud with standard industry rheology and filtration additives
- Mud B - Reconditioned oil based mud with standard industry rheology and filtration additives
- Mud C - Already screened back-loaded oil based mud.

Afterwards the back loaded mud was then divided into 3 samples; BL-1, BL-2, BL-3. Then the additives were then added in different concentrations to the sample. Using the ratio Plantain Peelings: Rice Husk in grams, it became; 75:25, 50:50, and 25:75. The results of the reconditioned mud were then set aside to be used as reference values for comparism with results from the backloaded mud after the local additives had been added to it.

Laboratory Measurement Procedure

Density. The mud balance was calibrated with distilled water. Afterwards it was then clean and wiped dry. It was then placed on a flat level surface and filled to the top with the mud sample. The lid was then placed on the cup and set with a gentle twisting motion and mud flowed out of the hole in the cup to ensure that any trapped air was freed. The hole in the lid was covered and every mud from the outside of the cup and arm was washed and the whole balance was dried. The balance was placed on the knife edge and the rider was moved along the outside of the arm until the cup and arm were balanced as indicated by the bubble (Figure 3). The mud weight was read at the edge of the rider towards the mud cup.

Figure 2—Rotary Viscometer

Figure 3—Mud Balance

Rheological Properties. The rotational viscometer (Figure 2) was ued in preference to the marsh funnel viscometer because it gives measurements of the actual flow parameters of the shear rate and shear stress and also renders a means of measuring gel strength making it easier to diagnose flow behavior and suggest better mud treatment (Annis & Smith, 1996). The mud sample was poured into the sample cup and the rotor sleeve was immersed exactly to the fill line on the sleeve by elevating the platform. The equipment was turned on. The speed selector knob was rotated to the stir setting and the sample was mixed for a few seconds. The knob was rotated to the 600 RPM setting and dial reading was taken when the dial reached a steady reading. This was also done for RPMs of 300, 200, 100, 60, 30, and 6. The dial reading at rotor speeds of 600 and 300 were used to evaluate the mud's plastic viscosity, apparent viscosity and yield point based on the Bingham plastic model.

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

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

$$AV = \frac{\theta_{600}}{2} \quad (3)$$

The 10-second and 10-minute gel strength ere alsp determined. The speed selector knob was rotated back to the stir setting and the sample was re-stirred for a few seconds. The speed selector knob was rotated to the gel setting and immediately the power was shut off. The sample was then left undisturbed for 10 second after which the power was then turned on while looking at the dial. The maximum dial deflection was recorded before the gel was broken at the 10-second gel strength. The same procedure was applied for the 10-minute gel strength.

pH Value. pH is a measure of the concentration of hydrogen ions in aqueous solution. A digital pH meter (Figure 4) was used to measure the acidity/alkalinity of the mud. The pH meter was calibrated using a sample of de-ionied water (Annis & Smith, 1996). Afterwards the sample was transferred to a beaker and the pH meter probe was inserted into mud sample. After waiting 60 – 90 seconds for the reading to stabilize, the pH value was then recorded.

Figure 4—Digital pH Meter

Filtration. The API LT-LP (Figure 5) filter press was used to check for the static filtration property of the mud at ambient temperature and at 120psi for 30 minutes. It consist of; a mud reservoir (top cap, cell, rubber gaskets, and base cap) mounted in a frame, a filtering medium (filter paper), a means of collecting and measuring the amount of filtrate (graduated glass cylinder) and a source of pressure (cylinder filled with compressed nitrogen). The mud reservoir was filled with the sample and the necessary sonnections were made. Afterwrds a pressure of 120 psi was supplied to the top of the cell and the filtrate (mL) through the filtrate paper was collected over 30 minutes. After the experiment, the flter paper was then removed and the residual cake thicknes (cm) was measured using a digital caliper.

Figure 5—(a) LT-LP (b) HT-HP Filter Press

A HT-HP filter press was also used to check for the filtration properties of the sample at pressures and temperatures above 1000psi and 150°C respectively (Figure 5). It consisted of a 500ml steel cell in which the sample was pourd into. Then the cell was sealed shut by tightly fitting the respective screws. After that the cell was placed in the HT-HP apparatus and the gas lines were the connected to the cell. After turning the knod to the required tempearature value. A thermometer was then used to observe if the desired temperature had been reached. When that was done the gas was the released into the cell at the desired pressure. The experiment was carried out for 30 minutes and the filtrate collected (mL) was measured. The apparatus was then allowed to cool down (for several hours) before the cell was removed, **properly depressurized (can lead to fatal accident if the cell is opened when it hasent been properly depressurized),** and the filter paper was removed and the filter cake thickness (cm) was measured with a digital caliper.

Results and Discussions

The important aspect of this paper is the control of mud rheology and mud filtration uing plantain peelings and rice husk. So othe properties are not really put into consideration. From Table 1 the mud properties depict that mud A had a lower plastic viscosity than mud B. This was due to the fact that after the mud was spent (mud C), more additives and solids were added to it in order to withsatnd the current drilling situatiion at that moment. Table 1 also shows that the gel strength of mud B increased from its previous state in mud C (from 63 – 75 lb/100ft^2; for the case of 10-mintute gel). This due to the fact that addition of solids which promotes the linking of particales thereby increasing gelation.

For the case of the LT-LP filtration test. It was observed that addtion of standard industry additives lead to a reduction in the fluid losss volume from mud C to mud B (19 – 10mL). This observed result is due to the fcat that after the mud was spent (mud C), standard industrial additives were added to it control the filtration property and bring it to that of mud B. Also the addition of standard additives lead to an increase in filter cake thickness from mud C to mud B (0.18 – 0.25cm). This increase in filter cake thicknes is what resulted in a lower fluid loss volume for mud B.

From Table 2, Addition of plantain peelings, was able to increase the plastic viscosity of the samples. It was observed that as the concentration of the plantain peelings decreased, so did the plastic viscosity of the mud (from 108 – 104cp). At a concentration of 75g, BL-1 had a plastic viscosity (108cp) very close to that of Mud B (109cp). It also showed an increase in apparent viscosity (from 119.5 – 133cp), which is also close to that of mud B (135.5cp). The table also depicted a decrease in yield point (53 - 50 lbs/100ft^2). This because the compared to the standard additives, plantian peelings don't flocculate as much as them but close. It can also be observed that as the concentration of rice husk increased, it was able to maintain the yield point of mud C. For the case of the 10-minute gel strength, the plantain peeling indicated an increase in the gel strength (from 63 – 74 lbs/100ft^2) which was very close to that of mud B (75 lbs/100ft^2).

Table 2—Properties of the Sample after Addition of Local Additives

	PARAMETERS	UNIT	MUD B	MUD C	BL - 1	BL - 2	BL - 3
	Volume Mud Type	bbl					
		SBM/ WBM/OBM	OBM	OBM	OBM	OBM	OBM
DENSITY	Mud Weight	ppg	11.1	11.6	11. 2	11.0	11. 2
	Specific Gravity		1.3	1.4	1.35	1.3	1.35
RHEOLOGY	600	rpm	271	239	266	264	262
	300	rpm	162	146	158	159	158
	200	rpm	120	112	117	116	116
	100	rpm	75	71	73	72	70
	60	rpm	54	52	53	53	53
	30	rpm	38	37	38	35	36
	6	rpm	22	20	21	20	21
	Plastic Viscosity	Centipoise	109	93	108	105	104
	Yield Point	$lbs/100ft^2$	53	53	50	54	54
	10 Second Gel	$lbs/100ft^2$	25	24	25	25	25
	10 Minute Gel	$lbs/100ft^2$	75	63	74	73	73
	Apparent Viscosity	Centipoise	135.5	119.5	133	132	131
FILTRATION (HT-HP)	Temperature	°C	200	200	200	200	200
	Pressure	psi	2000	2000	2000	2000	2000
	Test Time	minutes	30	30	30	30	30
	Sample volume	mililitres	500	500	500	500	500
	Filtrate Volume	mililitres	13	17	16	15.4	14
	Filter Cake Thickness	cm	1.68	1. 21	1.58	1.63	1.66
FILTRATION (LT-LP)	Temperature	°C	30	30	30	30	30
	Pressure	psi	120	120	120	120	120
	Test Time	minutes	30	30	30	30	30
	Sample volume	mililitres	400	400	400	400	400
	Filtrate Volume	mililitres	10	19	13.6	11.9	9.6
	Filter Cake Thickness	cm	0.25	0.18	0. 19	0. 22	0. 24

This was because the plantain peelings was able to link the particles of the mud.

Also from Table 2, for the case of LT-LP filtration, as the concentration of rice husk increased, the filtrate volume decreased (from 19 – 9.6mL) at 75g of rice husk content, which is better than that of mud B (10mL). This is because the cross-link beteen the particles in the mud reduced the permeable state of the mud by increasing the edge-to-edge and edge-to-face bond between the particles in the mud. As the concentration of rice husk increased, the filter cake thickness increased (from 0.18 – 0.24cm) which is also close to that of mud B (0.25cm). This is also attributed to the cross-linking abilities of the rice husk causing most of the mud particles to be entrapped on the filter paper hence building an effective and low permeability mud cake.

For the case of HT-HP filtration, as the concentration of rice husk increased, the filtrate volume decreased (from 17 – 14mL) at 75g of rice husk content. Compared to that of mud B (13mL), it shows that the rice husk is effective and stable at very high temperatures. This development is due to the fact that, the presence of lignin in the rice husk increased the binding strength and flocculating property of the mud, making the particles to create a low permeability seal when subjected to high pressure (compression). Also at 75g concentration of rice husk, the thickness of the filter cake increased (from 1.21 – 1.66cm) which is almost ckose to that of mud B (1.68cm). This shows that the presence of rice husk make the mud particles to be very compressible at very high pressures thus preventing decrease in hole diameter that migh lead to mechanical sticking problems (pipe sticking).

Conclusion

Mud Rheology is an important aspect in drilling fluid development and management. This is because it describes the flow properties of the mud under various settings or situations. In order to be able to forecast the consequences of flow, it is required to have good knowledge of the flow behavior a different areas of interest. The ability of the mud to create a low permability seal (filter cake) on the walls of the formation is important because it prevents the invasion of prous formations by liquid leading to formation evealuation and completion problems hence also reducing the amount of fluid lost to the formation (lost circulation). Due to this issues, plantain peelings and rice husk were evaluated as rheology and filtration control additives respectively in oil based mud. The results show that at a 75g plantain peeling concentration, the plastic and apparent viscosities increased by 16.1% and 11.3% respectively. The yield point decreased by 5.66%. Standard addtives resulted increased by 17.2% and 13.4% the values of plastic and apparent viscosity respectively, but the yield point remained the same.

For LT-LP filtration, the standard additive decreased fluid loss by 47.4%, while filter cake thickness increased by 38.9%. The results show that at a 75g rice husk concentration, the fluid loss decreased by 49.5% which was better than the standard additives, while the filter cake thickness increased by 33.3%. For the case of the HT-HP filtration, the standard additive decreased fluid loss by 23.5%, while filter cake thickness increased by 38.8%. The results show that at a 75g rice husk concentration, the fluid loss decreased by 17.64%, while the filter cake thickness increased by 37%.

From the stated results above it shows that use of plantain peelings and rice husk as rheology and filtration control additves at a substantial and sizeable concentration compares favouably to standard addtives due to the fact that they exhibit good rheology and filtrate control pontentials

Nomenclature

API American Petroleum Institute
AV Apparent Viscosity
Bbl Barrel
BL-1 Mud C + (75g of Plantain Peelings, 25g of Rice Husk)
BL-2 Mud C + (50g of Plantain Peelings, 50g of Rice Husk)
BL-3 Mud C + (25g of Plantain Peelings, 75g of Rice Husk)
Cm Centimetres
CMC Carbooxymethylcellulosics
g grams
HT – HP High Temperature – High Pressure
$lb/100ft^2$ Pounds per 100 feet squared
LT – LP Low Temprature – Low Pressure
mL Millilitre
Mud A Freshly prepared oil based mud mud with standard industry rheology and filtration additives
Mud B Mud C reconditioned with standard industry rheology and filtration additives

Mud C Already screened back-loaded oil based mud
°C Degree Celsius
OBM Oil Based Mud
ppg Pounds per gallon
PAC Polyanionic Cellulosics
Psi Pounds per square inch
PV Plastic Viscosity
SPA Sodium Polyacrylates
YP Yield Point

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