The Use of Periwinkle Shell Ash as Filtration Loss Control Agent in Water-Based Drilling Mud

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Abstract— Experimental assessment of the suitability of Periwinkle Shell Ash (PSA) for use as filtration loss control additive in water-based drilling mud has been presented. Locally sourced periwinkle shells were soaked overnight in warm water treated with Sodium Chloride (NaCl) to remove dirt and any contaminant. Thereafter, the periwinkle shells were washed and air dried, and then heated in an electric muffle furnace at 995 ^{o}C. The calcined shells were then crushed with the aid of a jaw crusher and grinded to fine particles. The ensuing ash was then sieved through BS sieve (75microns) to obtain a fine ash (nanoparticles). This fine ash particles is the PSA used for the formulation of the mud sample of interest. The filtration characteristics of the formulated mud samples were tested using American Petroleum Institute (API) filter press and in accordance to API recommended practice for field testing water based drilling fluids (API RP 13B-1). Filtration control characteristics of the mud samples were demonstrated by the filtrate volume and the thickness and consistency of the mud filter cake deposited on the filter paper after 30 minutes of filtration. Physical examination of the filter cakes indicates that filter cake formed by sample C, prepare with 2.0 g of PSA, was thinner (0.75 mm thick) and more consistent than the rest. After 30 minutes of filtration, mud samples A, B, C, and D produced 7.7 ml, 7.2 ml, 6.7 ml, and 7.0 ml filtrate volumes, respectively. This imply that sample C formulated with 2.0 g of PSA, which produced the least filtrate volume (6.7 ml) after 30 minutes of filtration, demonstrated better filtration control characteristics than samples A, B, and D. Addition of PSA to the various mud samples improved the filtration characteristics of the formulated water-based drilling mud with respect to reduced filtrate volume and thinner and consistent mud filter cakes. PSA has proved to possess good filtration (fluid loss) control properties.

Keywords— API Filter Press, Drilling Fluid, Filter Cake, Filtration Control, Filter Cake Thickness, Filtrate Volume, Periwinkle Shell Ash, Water-based Mud, Waste to Wealth.

INTRODUCTION

Rotary drilling process, the most widely used drilling method in the oil and gas industry, involve the circulation of drilling fluids. These fluids in its liquid form are called water-based drilling mud (if water is the continuous phase) or oil-based drilling mud (if oil is the continuous phase). Rapid filtration of drilling fluid into surrounding permeable formation occurs during drilling operations, resulting to loss circulation problems. Fluid loss is minimized by the creation of low permeable filter cake at the surface of the wellbore, which prevents solid particles from flowing into the pores of the formation together with the continuous phase [1]. These solid particles tend to plug the pore spaces of the formation either by physical or chemical processes, thereby reducing the permeability and porosity of the formation and by so doing, hamper the flow of fluids through such formations to the wellbore [1]. This is generally referred to as formation damage. Formation damage associated with drilling mud occurs when particles (such as drill solids, weighting agents and/or soft particles like polymers) invade the reservoir rock, thus plugging pores and forming internal filter cake [1].

Most Particulate materials contained in water-base mud (clays, cuttings, and weighting agents) are potentially damaging, and if forced into the pay zone, they can progressively fill the pores of the reservoir rock. Any subsequent production of hydrocarbon or injection of fluids at moderate or high flow rates will cause these materials to bridge over pore throat entries and severely decrease permeability near the wellbore region [2]. Such damaging process is limited to the first few inches around the wellbore (an average value of 3 in. (7.5 cm) is commonly used), but the resultant permeability reduction can be as high as 90% [2]. Invasion of formation rock by drilling fluid solids is favored by large pore size of the formation rock, presence of fissures and natural fractures in the reservoir, small particle size of the solid components of the drilling fluid (weighting agents and lost-circulation preventers whose initial particles are usually coarse and can be fragmented by the drilling bit), low drilling rate resulting in mud cake destruction (mud loss increase) and long mud-to-formation contact time, high drilling fluid circulation rate (mud cake erosion), high drilling fluid density causing large overbalance pressure, and scrapping mud cake which provokes pressure surges and increase formation-to-mud contact time during bit trips [2].

Water-based mud filtrates may have a low salinity and a high pH and may contain dispersants and polymers. Polymers are stable at circulating temperatures, but can decompose and form residues when subjected to static reservoir temperatures for long periods of time. High salinity water-base mud generates filtrates that can react with formation brines and precipitate various types of scale. Formations drilled at high circulation rates are invaded by filtrates with temperatures well below the reservoir temperature. The cooling they cause may provoke the deposition of paraffin and/or asphaltenes [3]. These numerous drawbacks of water-base drilling fluid led to the development of oil-based mud for drilling through clayey sandstone [4]. The initial conclusion was that this new mud was a safe, all-purpose drilling fluid. It is now recognized, however, that although the problems of oil-base mud are less numerous than those of water base mud, they are often much more severe [5]. Oil based mud contain more solids than water-based mud. Consequently, particle invasion is more pronounced. Several types of materials are used to reduce particle invasion (filtration rate) and improve mud cake characteristics. Since filtration problems usually are related to flocculation of the active clay particles, deflocculants also aid filtration control. When clays cannot be used effectively as deflocculating agents, water-soluble polymers are substituted. The common water soluble polymers used for filtration control are Starch, Sodium carboxy methyl cellulose (CMC), and sodium polyacrylate. Polymers reduce water loss by increasing the effective water viscosity [6].

Particulate invasion of the region around the wellbore, and subsequent solid entrainment, as well as loss circulation are the major formation damage mechanisms associated with water-base drilling mud. These mechanisms usually lead to the formation of zone of altered permeability around the wellbore (skin effect), which adversely affects the productivity of such well [1]. During hydrocarbon production, backflow with hydrocarbons may partially clean up the internal filter cakes, but in general, the permeability of the invaded region is seriously impaired such that hydrocarbon production is reduced. For this reason, several experimental works have been done to control solid entrainment in porous media due to drilling operation [1].

Various research works have been done on the formulation of drilling mud using locally available materials as additives. These research ranges from the use of locally available clay as a substitute for bentonite to the use of local starch as a fluid loss control additive. Olatude *et al.* [7] formulated water based drilling fluid using bentonite, guar gum, polyanionic cellulose (PAC) and gum Arabic. The rheological behavior and the filtration loss property of each drilling fluid developed were measured using API recommended standard procedures. They noticed that Guar gum shows the highest gel strength and the most stable rheological properties with poor filtration loss property while gum Arabic had unstable rheological properties with stable gel strength and good filtration loss property [7]. However, gum Arabic is only found in the northern part of Nigeria and not in the southern part (Niger Delta region) where major drilling operations take place. This makes Periwinkle shells, waste product found in abundance in the Niger Delta region of Nigeria, more economical than the gum Arabic.

Omotioma *et al.* [8] used locally sourced cassava starch to improve the rheological properties of water based mud. Their results show that the rheological properties of water based mud were improved with the addition of 4% locally sourced cassava starch addictive to it. Samavati *et al.* [9] investigated the rheological and fluid loss properties of water based drilling mud containing acid modified *fufu* starch (cassava derivative)**.** Their result show that the rheological properties, which (viscosity, plastic viscosity, yield point and gel strength) for the modified *fufu* showed significant improvement when 16% acid was employed. A significant amount of fluid loss reduction was also obtained within light and average mud weights formulation (75 pcf and 100 pcf). However, none of the samples (modified and unmodified) meet the fluid loss standard requirement for the applied temperature [9]. Also, Ademiluyi *et al.*, [10] compared local polymer (cassava starch) with an imported type in controlling viscosity and fluid loss in water-based mud. Five different cassava starches were tested as viscosifiers and fluid loss control additives in water based mud and compared with Barazan D, an imported sample. Their experimental results indicated that at same concentration, the imported sample had higher rheological properties compared with the local samples. They also discovered that some of the newly developed local starch products (with high amylose content and high water absorption capacity) have similar or better filtration control properties than the imported sample. However, the viscosity of the drilling fluid produced from the local starches was lower than that of the imported type [10]. Amanullah and Yu [11] investigated the use of corn-based starches for oil field application in terms of suitability as drilling fluid additives. Their experimental results showed that some of the newly developed starch products had similar filtration control properties than that of a widely modified starch. Cassava and corn are major food items, and in high demand, in most part of Nigeria. It should be more economical and environmentally profitable to used non-food resources such as periwinkle shells (waste product) for drilling mud formulation (filtration control agent). Hence, the needs for this research work.

Periwinkle or winkle (*Littorina littorea*) is a species of small edible sea snail, a marine gastropod mollusc that has gills and an operculum, and is classified within the family Littorinidae, the periwinkles [12]. This is a robust intertidal species with a dark and sometimes banded shell. It is native to the rocky shores of the northeastern, and introduced to the northwestern, Atlantic Ocean. The shell is broadly ovate, thick, and sharply pointed except when eroded [12]. The shell contains six to seven whorls with some fine threads and wrinkles. The color is variable from grayish to gray-brown, often with dark spiral bands [12]. The width of the shell ranges from 10 to 12 mm at maturity, with an average length of 16–38 mm. Shell height can reach up to 30 mm, 43 mm or 52 mm [12]. They are found in the lagoons and mudflats of the Niger Delta region, between Calabar in the South and Badagry in the West of Nigeria [13]. The people in these areas consume the edible part as sea food and dispose the shells as waste [13]. Few people utilize the shells as coarse aggregate in concrete works in areas where there are neither stones nor granite. However, a large amount of these shells are still disposed as waste and with disposal already constituting a problem in areas where they cannot find any use for it, and large deposits have accumulated in many places over the years [13].

Most technical application of Periwinkle Shell Ash (PSA) in Nigeria have been in the area of Civil Engineering, using PSA as partial replacement for ordinary Portland cement in concrete [13, 14, 15, 16, 17]. There is no known application of PSA in the formulation of drilling mud. The successful application of PSA in concrete should encourage research on its applicability in other area of engineering. This work intends to use PSA as filtration control addictive in the formulation of water-based drilling mud. Thereby, converting waste to wealth, creating wealth and job opportunities. This will impact positively on the Nigeria economy and the environment, considering the local content policy of the Nigerian National Petroleum Corporation (NNPC), which encourages the development and use of local contents in the oil and gas sector.

MATERIALS AND METHODS

A. Apparatus and Materials

The following apparatus were used for the experiments: conical flask, beakers, pH meter, baroid mud balance, jaw crushers, BS sieve, wire mesh, furnace, thermometer, stopwatch, graduated cylinder, and API filter press. The raw materials (addictives) used for the experiments and their functions are presented in table 1.

Table 1: Raw Material/Addictives and their Functions

Raw Material/Addictive	**Function**
Water	Continuous phase
Caustic Soda	pH modifier (to add alkalinity to the mud)
Soda Ash	pH modifier (to add alkalinity to the mud)
Xanthium Gum	Viscosifier and fluid loss control agent
Polyanionic Cellulose (PAC)	Viscosifier and fluid loss control agent
Potassium Chloride (PCl)	Shale Hydration Inhibitor
Barite	Weighting agent
Periwinkle Shell Ash (PSA)	Filtration control agent

B. Preparation of Periwinkle Shell Ash (PSA)

The periwinkle shells used for this work were sourced from Soku community, in Akuku-Toru Local Government Area of Rivers State, Nigeria. The periwinkle shells were soaked overnight in warm water treated with Sodium Chloride (NaCl) to remove dirt and any contaminant as shown in fig.1. Thereafter, the periwinkle shells were washed and air dried, and then heated in an electric muffle furnace at 995 ^{o}C. The calcined shells were then crushed with the aid of a jaw crusher and grinded to fine particles. The ensuing ash was then sieved through BS sieve (75microns) to obtain a fine ash (nanoparticles). This fine ash particles shown in fig.2 is the PSA used for the formulation of the mud sample of interest.

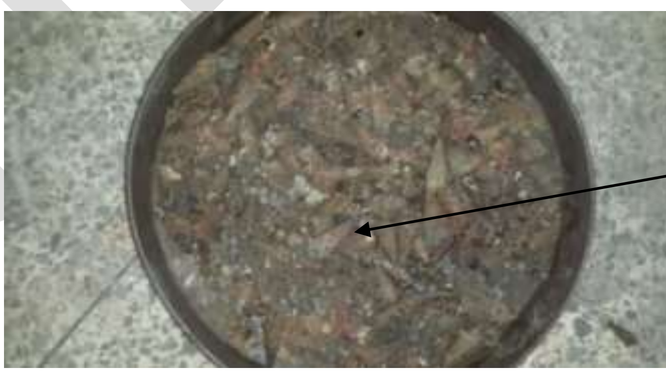

Fig.1: Soaked Periwinkle Shells

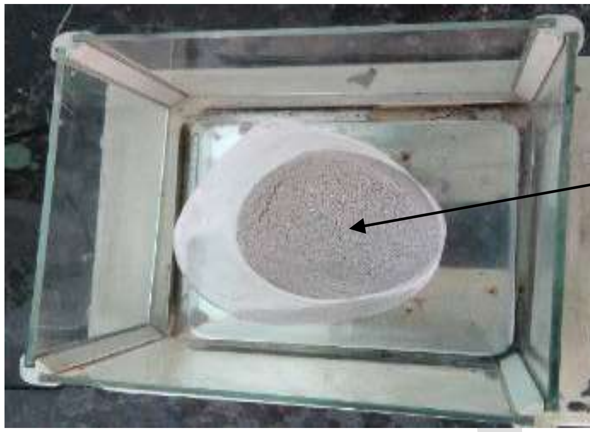

Fig.2: Grinded Periwinkle Shells

C. Formulation of Mud Samples

Four (4) different mud samples (A, B, C, and D) were formulated with varying amount of the various addictives. The composition of the various mud samples are presented in table 2.

Table 2: Composition of Mud Samples

Addictive	Sample A	Sample B	Sample C	Sample D
Water (ml)	350	350	350	350
Caustic Soda (g)	0.2	0.2	0.2	0.2
Soda Ash (g)	0.2	0.2	0.2	0.2
Xanthan Gum (g)	1.5	1.5	1.5	1.5
Bentonite (g)	20	20	20	20
Polyanionic Cellulose (PAC) (g)	0.8	0.8	0.8	0.8
Potassium Chloride (KCl) (g)	25	25	25	25
Barite (g)	30	30	30	30
PSA (g)	-	3.0	2.0	2.5

D. Filtration Test Experiment

Static filtration test was carried out on samples A, B, C, and D using API filter press. API recommended practice for field testing water based drilling fluids, API RP 13B-1 [18], was strictly followed during the experiment. The filtration test was conducted for thirty (30) minutes of filtration. Filtration control characteristics of the mud samples were demonstrated by the filtrate volume and the thickness and consistency of the filter cake (the residue) deposited on the filter paper after 30 minutes of filtration. The filtrate volume and filter cake characteristics for each of the samples tested were measured and recorded accordingly. The mud filter cake thickness is measured to the nearest millimeter.

RESULTS AND DISCUSSIONS

The results of the filtration experiment are presented in tables 3 and 4. The filtrate volumes after 30 minutes of filtration are presented in table 3 while the filter cake thickness of each mud sample after 30 minutes of filtration are presented in table 4 and shown graphically in fig.3. Physical examination of the filter cakes indicates that filter cake from sample C, prepare with PSA was thinner (0.75 mm thick) and more consistent than the rest. Table 3 shows that after 30 minutes of filtration, sample A, B, C, and D produced 7.7 ml, 7.2 ml, 6.7 ml, and 7.0 ml filtrate volumes, respectively. This imply that sample C formulated with 2.0 g of PSA, which produced the least filtrate volume (6.7 ml) after 30 minutes of filtration, demonstrated better filtration control characteristics than samples A, B, and D. Hence, PSA have proved to possess good filtration control properties which were majorly responsible for the thinner filter cake and minimal filtrate volume produced from sample C. However, increasing the quantity of PSA to 2.5 and 3.0 g in samples D and B, respectively, did not result to better filtration characteristics. The results show that increased filtrate volume indicates poor filtration control characteristics of mud (filter cake). The relationship between mud filter cake thickness and filtration volume is somewhat linear as shown in fig.4. Therefore, periwinkle shells, waste products found in abundance in the Niger Delta region of Nigeria, can be converted to wealth, to create wealth and business venture for the people of the region.

Table 3: Filtrate Volume from the Various Mud Samples

Time (min)	Filtrate Volume (ml)			
	Sample A	Sample B	Sample C	Sample D
5	3.2	3.0	2.6	2.8
10	4.7	4.5	4.4	4.5
15	6.1	5.4	5.1	5.2
20	6.6	5.9	5.4	5.7
25	7.0	6.5	6.0	6.2
30	7.7	7.2	6.7	7.0

Table 4: Filter Cake Thickness after 30 minutes of Filtration

Mud Sample	Sample A	Sample B	Sample C	Sample D
Filter Cake Thickness (mm)	1.0	0.9	0.75	0.8

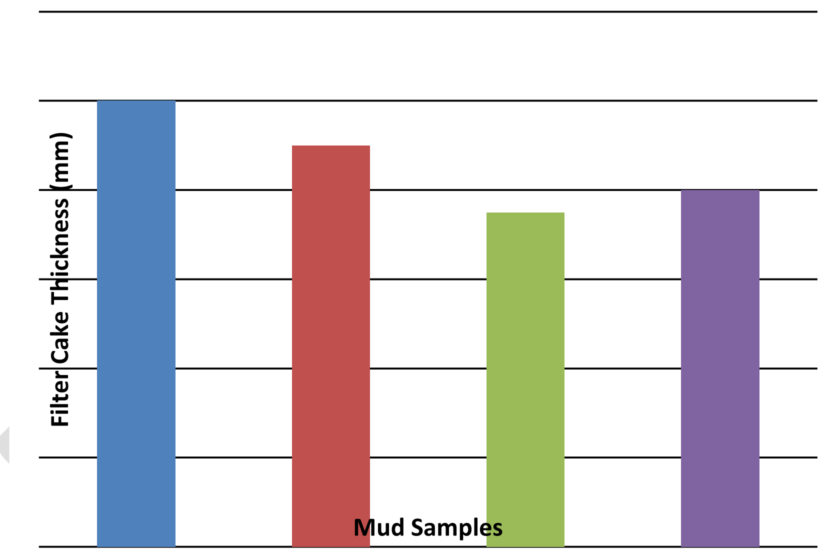

Fig.3: Mud Filter Cake Thickness

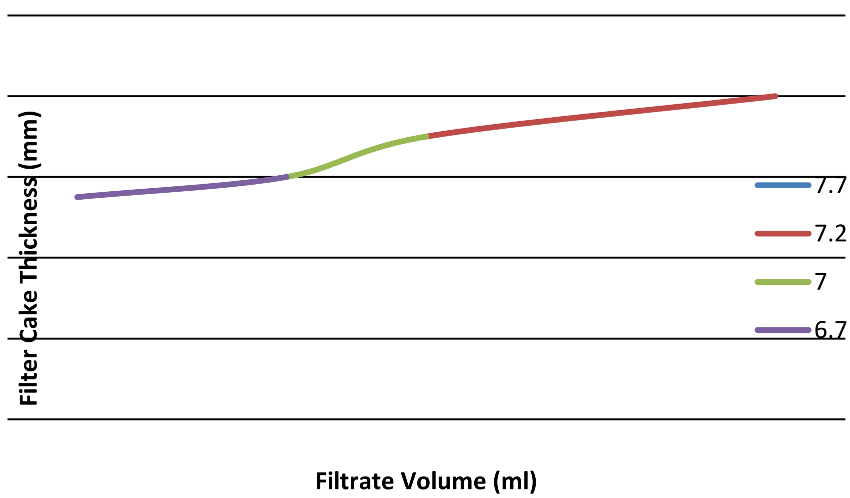

Fig.4: Relationship between Mud Filter Cake Thickness and Filtration Volume

CONCLUSIONS

This research has shown that PSA has good filtration (fluid loss) control properties. Addition of PSA to the various mud samples improved the filtration characteristics of the formulated water-based drilling mud with respect to reduced filtrate volume and thinner and consistent mud filter cakes. Mud sample C formulated with 2.0 g of PSA exhibited the best filtration control characteristics with minimal filtrate volume of 6.7 ml after 30 minutes of filtration. Physical examination of the mud filter cakes formed after 30 minutes of filtration show that sample C produced the best filter cake with minimum thickness of 0.75 mm. However, increasing the quantity of PSA to 2.5 and 3.0 g in samples D and B, respectively, did not result to better filtration characteristics. The relationship between mud filter cake thickness and filtration volume is somewhat linear. Therefore, periwinkle shells, waste products found in abundance in the Niger Delta region of Nigeria, can be converted to wealth, to create wealth and business venture for the people of the region.

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