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Performance of Selected Natural Bio-Polymers for Fluid Loss Control in Water Based Drilling Fluid: A Literature Review

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Abstract: Fluid loss to the formation is a well-known problem during exploration and production phases of the upstream sector of oil and gas industry. In fluid filtration formation reduction, it is customary to add chemical additives such as polyanionic, lignosulfonate and carboxyl methyl cellulose in different proportions to build a decent filter cake. This will serve as semi-permeable membrane around the well bore. However, to minimize the cost, the use of less expensive, widely available and environmental benign natural polymers is required. Therefore, the aim of this study is to evaluate the performance of some selected natural bio-polymers for fluid loss control in water-based drilling fluid as majority of the polymers used for controlling fluid losses are imported and are quite expensive. Importation, no doubt, adds to the overall cost of drilling operations. However, with the use of local polymers, the operational cost could be reduced, new markets created, which stimulate and promote their cultivation, preservation and job creation. In view of this, the study has evaluated and optimized four less investigated local biopolymers using a reduced central composite experimental protocol for the development of new generation of water-based drilling fluids. The study revealed that there is a significant improvement in the properties of the beneficiated clay. Therefore, the study upon review suggested that the rheological properties of the base fluid slurry significantly improved in the presence of *detarium microcarpum*, food gum, roseline fiber, coconut fiber and local barite. The study contribution to knowledge indicated that *C. populnea* (food gum fiber), coconut fiber and *C. sabdariffa* (roseline) has been widely used in polymer industry as reinforcements.

Keywords: Optimization, Polymer Admixture, Upstream Sector, Oil Industry, Gas Industry, Nigeria.

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1.0 Introduction

Drilling fluid is one of the most advanced fluids in existence (Abduo *et al*., 2015). The functions of the drilling fluid are very significant in the upstream petroleum industry. Shu *et al*. (2016) posited that most problems in the drilling operation are associated to erroneous drilling fluid formulation. Drilling fluid is essential for cooling and lubricating the drilling bit, transporting cuttings out of the hole, preventing formation damage, stabilizing the pressure in the well and aiding formation stability (Todd, 2001; Jerry *et al*., 2005; Shu *et al*., 2016). The cost of loss of drilling fluid to the formation can be significant. Drilling fluids are significant components possessing thixotropic shear-thinning characteristics with a yield stress (Wang *et al*., 2013). The drilling fluid is indispensable in production of oil and gas. They are designed to provide safety while drilling, carry cuttings to the surface, cool and clean the bit, reduce friction, and maintain wellbore stability. The filtration property of drilling fluids is important because the invasion of filtrate into the formation can substantially reduce the permeability of the near-wellbore leading to low productivity and well control problems (Jamal and Robello, 2007). Loosing fluid into the formation can decrease the production capability of the well by increasing the skin factor which reduces the permeability around the well bore (Amanulah *et al*., 2011).

Several synthetic polymers are being used in the oil and gas industry to prevent fluid loss over the years (Elkatatny *et al*., 2011). However, because of environmental issues associated with the use of some imported additives, there has been a stringent policy discouraging the use of certain materials for drilling activities. Research has shown that certain natural polymers have potential to give better control of both the fluid loss to the formation and the initial spurt loss in drilling fluid (Jamal & Robello, 2007; Apaleke *et al*., 2012; Hossain & Al-Majeed, 2012). In addition, different polymers can affect fluid loss properties of drilling fluid such as reduction of the fluid losses and impose fewer damages to the formation especially within the vicinity of the wellbore. Thus the right combination of polymer admixture can be beneficial environmentally and economically to the upstream sector of oil and gas industry. In view of the foregoing, the purpose of this study is to review critically the performance of some selected natural and less investigated fibers as fluid loss additives during the drilling fluid formulation. Fig. 1 below indicated the fluid loss in the process of drilling as reported by the geo drilling fluid (2015).

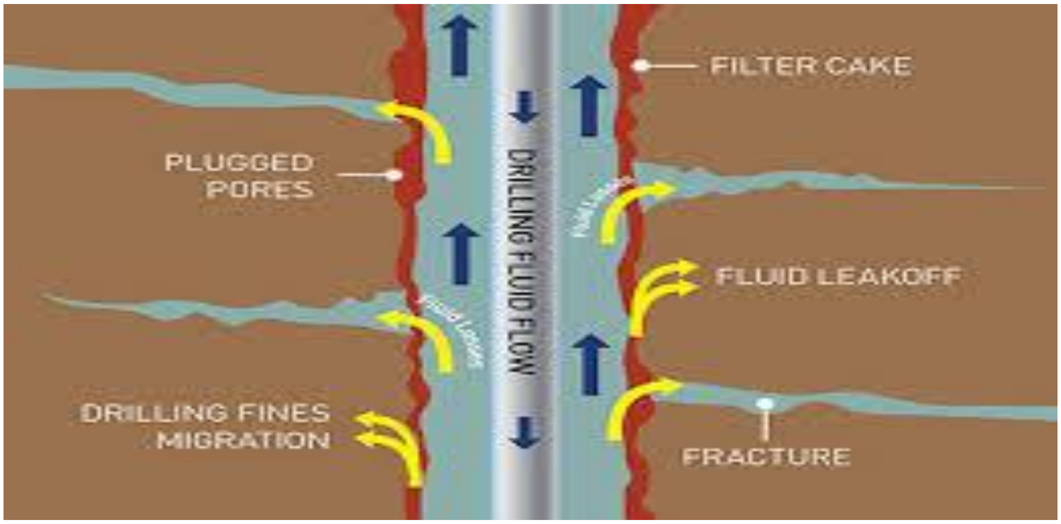

Figure 1. Fluid Loss in the Process of Drilling
Source: Geo Drilling Fluid (2015) cited in Oluwafemi (2019).

2.0 Literature Review

2.1 Drilling Fluid

Drilling fluid is formulated to specifically possess required properties to perform intended functions (Todd, 2001; Abduo *et al*. 2015; Shu *et al*. 2016). They can be described as thixotropic shear-thinning fluids with a yield stress (Adesina *et al*., 2012). The drilling fluid is originally designed to ensure possible and cost effective rotary drilling of sub-surface formation. Shu *et al*. (2016) mentioned that one of the most critical functions of drilling fluid is to minimize the amount of filtrate entering the hydrocarbon bearing formation. According to Li *et al*. (2005), drilling fluid filtrates can lead to formation damage by altering the rock wettability. The authors added that the clay fines migration can reduce the permeability and oil movement within the vicinity of the wellbore due to fluid flow. According to Elkatatny *et al*. (2011), drilling fluid filtrate may be incompatible with the formation water thereby causing a serious electrolytic imbalance and formation instability.

2.2 Types of Drilling Fluid

Drilling fluids are broadly classified into: oil based, synthetic based, aerated and water based drilling fluids.

2.2.1 Oil Based Drilling Fluid: Oil Based Fluid (OBF) use petroleum refinery direct products such as diesel oil as the continuous phase (Annudeep, 2009). However, this category of fluids has enjoyed increasing popularity because they offer stable rheology and filtration properties even at elevated temperatures (Horpibulsuk *et al*., 2007). The oil based fluid controls corrosion, borehole stability and ensures bit lubricity. According to Zhao *et al.* (2013), the problem of wellbore is largely suppressed by application of oil based drilling fluid due to its higher potential for strong plugging and corrosion inhibition. Wide use of oil-based fluids, however, is limited by environmental challenges. Abdou *et al. (*2013) stressed that oil based drilling fluid is not also cost effective and it is dangerous to the environment. Nonetheless, kick detection becomes more disastrous when using oil based fluid than water based fluid due to high gas solubility in the oil. Furthermore, Dardir & Hafiz (2013) opined that lost circulation becomes costly and almost uncontrollable in drilling operations while using oil based fluid. Consequently, in order to avoid skin contact with oil based fluid that easily leads to acceleration of allergic reactions from inhalation of fumes, Adesina *et al.* (2012) advised that special safety requirements and precautions are needed. Hence, oil based fluid can be dangerous to rubber parts of the circulating system and can result in another design with high cost.

2.2.2 Synthetic *Based Drilling Fluid:* In synthetic based drilling fluid, the continuous fluid may be ester or paraffin (Adesina *et al*., 2012; Dardir & Hafiz, 2013). Synthetic Based Drilling Fluid (SBF) is developed to combine the technical advantages of OBF with the low persistence and toxicity of water based drilling fluid (Neff *et al*., 2000; Elkatatny *et al*., 2011).

2.2.3 Aerated *Drilling Fluid:* Aerated Drilling Fluid is compressed air (or gas) that is circulated by pump either through the bore hole annular space or the drill string itself (Amir, 2010; Zhao *et al*., 2013). The authors mentioned that the aerated drilling fluid is preferred where there are serious challenges of severe circulation loss in drilling operation and less permeability of formation. Andi *et al.* (2010) reported that aerated fluid suppresses corrosion tendencies in the down hole tubulars and the surface equipment. In addition, Ihenacho *et al*. (2010) affirmed that aerated fluid in oil drilling is considered particularly to control differential sticking.

2.2.4 Water Based Drilling Fluid: Water Based Fluid (WBF) becomes homogenous suspension with the incorporation of specific additives with clay, as water acts as a continuous phase (Omole *et al*., 2013). According to Okorie (2009), water based fluid is thixotropic by becoming very thin and free flowing while pumped. However, when pumping is stopped, static fluid thickens until adequate pumping force is applied to regain free flowing. Water based fluid is well appreciated for being cost effective, less harmful, affordable and environmentally friendly to maintain than the oil based fluid (Elkatatny *et al*., 2011; Abdou *et al*., 2013). Disintegration and dispersion of clays are easily promoted in the WBM, as it easily encounters difficulties in drilling water sensitive shale or heaving shale and corrodes iron such as drill pipes, drill collars and drill bits with ease (Omotiowa *et al*., 2014).

2.3 Oil Based and Water-Based Drilling Fluids

Elkatatny *et al.* (2011) compared the suitability of both WBF and OBF at high temperature and pressure on the basis of their impacts on the environment. It was observed that the adverse effect of OBF on environment could not be overlooked despite its suitable rheological fitness. Wang *et al.* (2013) showed that the usual challenges of loss of viscosity and fluid loss control are better subdued using the oil based fluid than water based fluid in drilling operation. They added further that the oil based fluid is harmful to the environment. However, the oil based drilling fluid has hazardous contents with health implications. Consequently, this observation has led to strict environmental regulations discouraging the use of oil based fluid in drilling operation. The aromatic nature of oil based drilling fluid can escalate the level of toxicity of the formation water.

Behnamanhar *et al.* **(**2014) opined that oil-based drilling fluid had previous selection consideration to drill certain types of formations such as shale and clay-rich geological formations. However, the rate at which the contaminants suppress the quality performance of drilling fluid in deep formation is less with oil based fluid when compared with the water based fluid (Dardir & Hafiz, 2013). Oil based fluid maintains shale stability and enhances faster penetration rates but not always feasible due to its environmental and economic considerations which have led to increasing preference for application of water-based drilling fluid in drilling operations. Annudeep (2012) established that severe challenges of corrosion control in drilling operation is conveniently minimized with the use of oil based fluid and the ability of oil based fluid to yield better lubricity during drilling operation is a great advantage. Shale stability is maintained at ease with the use of oil based fluid during drilling operation but there is a wide range of legislations on environmental concerns when using oil based fluid as related to discharge of cuttings, loss of whole fluid and disposal of the oil based fluid that often become challenging with severe penalty (Abdou *et al*., 2013; Dardir & Hafiz, 2013).

2.4 Polymer and Fiber Additives in Drilling Fluids

Chesser *et al.* (2008) reported the significant effectiveness of polymer in water based drilling fluid. The authors discovered polymer latex as an additive in water-based drilling fluid reduces fluid invasion to the formation. The polymer latex was capable of providing semi-permeable medium for great improvement in osmotic efficiency. The pressure magnitude, pore size and blockage, reliability that can be disallowed are all enhanced by the latex addition. Dardir & Hafiz (2013) argued that controlling drilling fluid pressure is one of the most important factors in maintaining wellbore stability. Chesser *et al.* (2008) reviewed the performance of polymers as fluid loss control agents in water based fluid. These are starches, derivative starches, gums, derivative gums, and cellulosic materials. The authors reported that these polymers have certain advantages, but are usually unfit at high temperature. Unfortunately, the non - ionic water soluble polymers currently are not stable at temperatures exceeding about 225^o F with prolonged aging times. The study concluded that filtration control additives should quickly form a thin, dispersible filter cake to prevent fluid loss at high temperature for reasonable period of time.

Muhammed (2015) formulated fluid with date seeds, grass ash and grass as additives at different particle sizing to improve filtration control. It was conducted at high temperatures of 160 and 200^oF. However, they exhibited good thermal stability. The authors introduced cornstarch (bio-polymer) as a fluid loss control additive and thermally stable additives to increase stability of water based fluid dispersions, emulsions and rheological properties at high temperatures. Dagde *et al.* (2014) studied the properties of water based drilling fluid formulated with variable concentrations of cellulose locally processed from groundnut husk. The results obtained were compared with the regulations standard, and the results of fluid formulated from imported polyanionic cellulose (PAC). The results showed that cellulose from groundnut husk can significantly reduce fluid loss. The groundnut husk cellulose of 4.0 g has a lower fluid loss of 6.5 mls with a maximum percentage deviation of -0.02 % at 30 minutes when compared with that of polyanionic cellulose. This suggested that cellulose processed from groundnut husk is a better fluid loss control agent than polyanionic cellulose (PAC) for the preparation of drilling fluid.

3.0 Drilling Fluid Additives

3.1 Weighting Materials: Weighing materials are reported to have the ability to stabilize hydrostatic and formation pressure during drilling operation. Several researches suggest alternatives for the barite as weighting agent (Falode *et al*., 2008; Obaje, 2013). According to Adebayo and Imohke (2001), who examined the use of antimony sulphide, locally called *Tiro* (a word in Yoruba language), which has high specific gravity greater than 4.2 g/cm^3. *Tiro* has apparent health safety and cost effectiveness when compared with imported Barite. The authors observed that effect of Barite on fluid pH is considerably lower than the corresponding *Tiro*. Imported barite was also observed to pose retarding effect on the viscosity of the drilling fluid. The viscosity of the drilling fluid was maintained with just 5% weight of *Tiro* as the reverse was the case for barite (Falode *et al*., 2008; Obaje, 2013). The authors also suggested that *Tiro* as a weighting agent deserves high consideration purposely for its health safety, greater potential to sustain viscosity at HPHT conditions and high tendency for shale stabilization. This occurs through prevention of water contacting the open shale section which occurs when the additive encapsulates the shale, enters the exposed shale section and neutralizes the charges on it.

3.2 Bentonite Clay and Related Viscofiers: Bentonite clay (*sodium montmorillonite*) essentially improves swelling capacity of drilling fluid (Falode *et al*., 2008). According to Obaje (2013), Bentonite clay is added to drilling fluid to maintain the gel strength required to suspend and carry drill cuttings to the surface. Bentonite can form a thixotropic gel in the wellbore and helps to coat the wall of the borehole against loss of filtrate from drilling fluid to permeable formation. Numerous WBM additives are however available for use to optimize the rheological properties of the clay as some researches had been conducted to replace *Carboxymethyl* cellulose (CMC) and *hydroxyethyl* cellulose (HEC) with local natural polymers (Omotioma *et al*., 2014).

3.3 Thinners and Dispersants: In drilling operation, it is verifiable to counter balance down-hole pressure to avoid blow out as the well depth increases. This could be carried out by adding more weighting agent to the drilling fluid (Adebayo & Imohke, 2001). It was observed that the addition of weighting agent and bentonite to the fluid increases its viscosity. It also increases the pump pressure, raises the risk of loss of water and drilling solids to the formation. Thinners or dispersants are added to decrease viscosity and improve pumpability (Boehm *et al.*, 2001). Quebracho bark was applied in the 1940s and 50s, but discontinued for being sensitive to high formation temperatures. The use of Lignosulfonates, lignites, and tannins were introduced in the 1950s and for many years have been the most frequently used thinners for offshore WBM (Jerry *et al*., 2005).

3.4 Filtration Control Additives: Ikechi & Bright (2015) analysed that Perinwinkle shell ash (PSA) has suitable filtration (fluid loss) control properties due to its effectiveness on various fluid samples. This happens by improving filtration properties of formulated water-based drilling fluid with respect to minimum filtrate volume, thin and consistent fluid filter cakes. The result showed that fluid sample formulated with 2.0 g of PSA exhibited the best filtration control with minimal filtrate volume of 6.7 ml. The scenario occurred after 30 minutes of filtration and formation of the fluid filter cake with minimum thickness of 0.75 mm after 30 minutes of filtration showed that the fluid sample produced the best filter cake. The study found that the filtration properties are very important features of all drilling fluids. The invasion of filtrate into the formation can substantially lead to reduction in the permeability of the near-wellbore region by a group of mechanisms such as clay swelling, particles pore plugging, particles migration and water blocking. Moreover, the nature and thickness of filter cake deposited on the borehole wall will influence the potential for differential pressure sticking to occur (Kelessidis *et al*., 2007).

3.5 pH Control Additives: The pH control materials influence several fluid properties like detection and treatment of contaminants. In addition, to cement and soluble carbonates, dissolving many thinners and divalent metal ions such as calcium and magnesium (Okorie, 2009). Alkalinity and pH control additives are used to attain a specific pH and to maintain optimum pH and alkalinity in water based drilling fluids (Aremu *et al*., 2017).

3.6 Rheological Agents: So many researches have been conducted to stabilize rheological strength of drilling fluid for successful outcome in drilling operation. Abdo & Haneef (2013) showed the analysis of montmorillonite (Mt) and Pal nano particles which was purified, synthesized, characterized, functionalized, and tested for the first time in nano-form (10–20nm diameter). At high pressure and temperature (HPHT) conditions, the nano particles are able to maintain stable properties thus retaining versatile conditions. The best-recorded results were reported on the plastic viscosity, yield point, gel strength, density, shear thinning, spurt lost, fluid lost, and lubricity index after successive laboratory investigations. Xianghai *et al*. (2014) investigated the influence of carbon ash on the rheological properties of bentonite dispersions using particle size distribution. The rheological properties were determined as a function of the carbon ash concentrations according to the Herschel–Bulkley model. The experimental results indicated that the carbon ash adsorbed on the external surface of bentonite particles improved the dispersion of bentonite in the water-based drilling fluids.

4.0 Detarium Microcarpum

Detarium microcarpum is a popular biopolymer in West and Central Africa. It is typically a species of dry savanna (Arinkoola *et al*., 2018). It is common among the Ibo tribe of South-Eastern Nigeria. Detarium microcarpum bears different local names among socio-cultural groups of different countries. It is the most investigated species of the genus because of its importance in Africa traditional medicine. The legume is very rich in polysaccharide gum (Li *et al*., 2015). The fruit of Detarium microcarpum contains phenolic, flavonoid and antioxidants. However, acts as a stabilizer and gelling agent in some processed fruit products (Ikechi *et al*., 2012). According to Dias *et al*. (2015), the rheological properties of the fluid made with *Detarium microcarpum* are slightly better than the existing polypac fluid. The limitation with biomaterial was non-availability in commercial scale. The authors therefore, dissuaded the investors from using these products in their raw form.

4.1 Roseline Fiber (Hibiscus Sabdariffa): Hibiscus Sabdariffa is an annual shrub belonging to the family of Malvaceae, which is largely grown in tropics like Africa, Asia, South, and North American Continents (Gautam & Sorrel, 2014). According to Duke (2008), the plant possesses deep penetrating tap root with smooth, cylindrical and typically dark reddish green stem. The plant is about 3.45m tall, the leaves are alternate with long or short petioles. *Hibiscus Sabdariffa* comprises species of cultivated types, which are mostly classified on end use. There are species of *H. sabdariffa var. sabdariffa* and *H. sabdariffa var. altissima Wester*. The former possesses edible calyces and it is pigmented. The latter is an unbranched type bearing inedible calyces but mainly cultivated for stem fibers (Duke, 2008; Mahadevan *et al*., 2009).

4.2 Food Gum (Cissuspopulnea): *Cissuspopulnea* is an epiphytic plant found in Western part of Nigeria (Azeez & Onukwuli, 2016). It is probably one of the most ubiquitous biopolymers on the planet facilitating its wide range of application as renewable raw materials (Alakali *et al*., 2009). *Cissuspopulnea* is also known as fiber plant. The plant is very versatile due to the presence of mucilage at its bark and the stem of cissuspopulnea contains much viscous secretion with slippery nature and soothing properties (Brigida *et al*., 2010).

***4.3 Coconut Fiber** (Cocosnucifera):* Coconut fiber is one of the abundantly available natural fibers in tropical regions and contains cellulose, hemicellulose and lignin as major composition as well as pectin, waxes and water (Azwin *et al*., 2009; Raj *et al*., 2011). The tree plant grow well in saline soil, sandy and tropic climate. Coconut is highly nutritious and rich in vitamins, minerals and fibers (Alli, 2010). There are two types of coconut fibers; brown fiber extracted from matured coconuts and white fibers extracted from immature coconuts. Yarim *et al*. (2007) highlighted that brown fibers are thick, strong and have high abrasion resistance while white fibers are smoother, finer and weaker.

5.0 Synthetic Additives

Synthetic additives perform significant functions in drilling fluid additives. Table 1 showed various functional synthetic additives for drilling fluid.

5.1 Drilling Fluid Rheology

Rheology is the science of studying how matter flows and deforms (Thanarit, 2013). The application of rheological model by developing a mathematical relationship between shear stress and shear rate describes the flow behavior of a fluid (Annudeep, 2012).

Another study of Thanarit (2013), showed how drilling fluid rheology is illustrated by two widely used models such as Bingham Plastic Model and the Power Law Model and another significant model known as Herschel-Buckley Model. Table 1 indicated the various functional additives for drilling fluid.

Table 1. Various Functional Additives for Drilling Fluid

Functional Category	Function	Typical Chemicals
Weighting Materials	Increase density (weight) of fluid, balancing formation pressure, preventing a blowout	Barite, hematite, calcite, ilmenite
Viscosifiers	Increase viscosity of fluid to suspend cuttings and weighting agent in fluid	Bentonite or attapulgite clay, carboxymethyl cellulose, & other polymers
Thinners, dispersants, & temperature stability agents	Deflocculate clays to optimize viscosity and gel strength of fluid	Tannins, polyphosphates, lignite, ligrosulfonates
Flocculants	Increase viscosity and gel strength of clays or clarify or de-water low-solids fluids	Inorganic salts, hydrated lime, gypsum, sodium carbonate and bicarbonate, sodium tetraphosphate, acrylamide-based polymers
Filtrate reducers	Decrease fluid loss to the formation through the filter cake on the wellbore wall	Bentonite clay, lignite, Na-carboxymethyl cellulose, polyacrylate, pregelatinized starch
Alkalinity, pH control additives	Optimize pH and alkalinity of fluid, controlling fluid properties	Lime (CaO), caustic soda (NaOH), soda ash (Na_2CO_3), sodium bicarbonate ($NaHCO_3$), & other acids and bases
Lost circulation materials	Plug leaks in the wellbore wall, preventing loss of whole drilling fluid to the formation	Nut shells, natural fibrous materials, inorganic solids, and other inert insoluble solids
Lubricants	Reduce torque and drag on the drill string	Oils, synthetic liquids, graphite, surfactants, glycols, glycerin

Source: Murray (2007)

5.1.1 Bingham Plastic Model: This model is defined by the relationship: $\tau = \tau_o + \mu_\rho \gamma$ (Thanarit, 2013)

Bingham plastic fluid ceases to flow until the applied shear stress exceeds the minimum yield stress. The change in shear stress is proportional to change in shear rate and the slope is plastic viscosity. The plastic viscosity decreases with increase in shear rate due to the effect of shear thinning.

5.1.2 Power Law Model: The power law model is defined by the equation: $\tau = K\gamma^n$ (Thanarit, 2013)

The constant features, K and n are fluid parameters. K measures the consistency of the fluid and examines the viscosity of the fluid, while, the lower the value of k, the less viscous the fluid, vice versa. While, n is a measure of the degree of non-Newtonian behavior of the fluid. On the log-log plot of shear stress versus shear rate, both parameters, n and K, are obtained. The fluid behaves as a Newtonian fluid when, $n = 1$, and the Power-Law equation is identical to the Newtonian fluid equation, as shown by Figure 2 and 3. When, $n \geq 1$, the fluid becomes dilatant. Dilatant fluids are shear rate dependent. Their apparent viscosities increase with increase in shear rate. When, $n \leq 1$, the fluid becomes Pseudoplastic. Pseudoplastic fluids are also shear rate dependent with their apparent viscosities decreasing as shear rate decreases.

5.1.3 Herschel-Bulkley Model: Herschel-Bulkley model is defined by the equation: $\tau = \tau_\gamma + K\gamma^n$ (Thanarit, 2013)

This model also called the modified power law model and yield-pseudo plastic model. The model is used to depict the flow of pseudo plastic drilling fluid which requires a yield stress to initiate flow. A rheology of shear stress minus yield stress versus shear rate is straight line on log-log coordinates. This model is widely used because it explains the flow behavior of most drilling fluid including a yield stress value that is important for several hydraulic issues and includes the Bingham plastic and Power law model as special cases as shown by Figure 2 and 3.

5.2 Analytical Tools/Machines

X-ray Fluorescence (XRF) and X-ray Diffraction (XRD) are significant analytical tools to verify elemental composition and phase recognition of the materials.

5.2.1 X-Ray Fluorescence (XRF): X-ray florescence, a destructive technique which performs rapid multi-element analysis through assessment of elemental composition of materials (Angelo *et al*., 2001). The high sensitivity of the x-ray florescence allows simultaneous evaluation of many elements in solid or liquid state (Ankudinov *et al*., 2001). The technique of analysis for both major and trace elements in materials is efficiently and effectively determined. The major strategy of XRF is based on the fact that when electrons are ejected from inner shell of an atom, there is instant replacement of the electron by a higher shell electron filling the hole in the lower shell (Alexeev & Gates, 2000; Sinfelt, 2002). X-Ray Fluorescence comprised of three main components namely x-ray source, crystal spectrometer and detection mechanism (Ankudinov *et al*., 2001; Stokes, 2003).

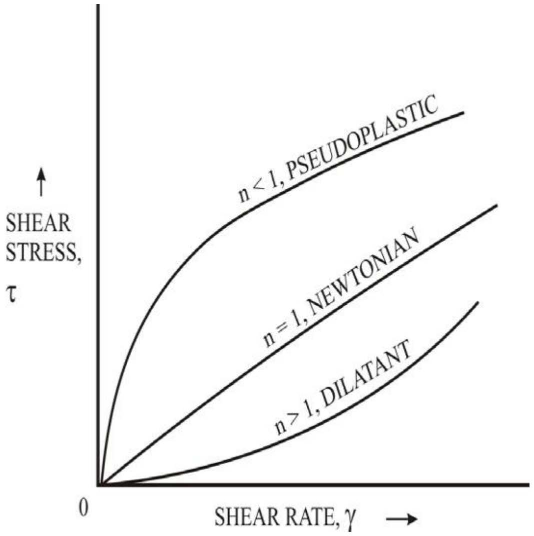

Figure 2: Flow Curve for Power Law Model**,** Thanarit (2013)

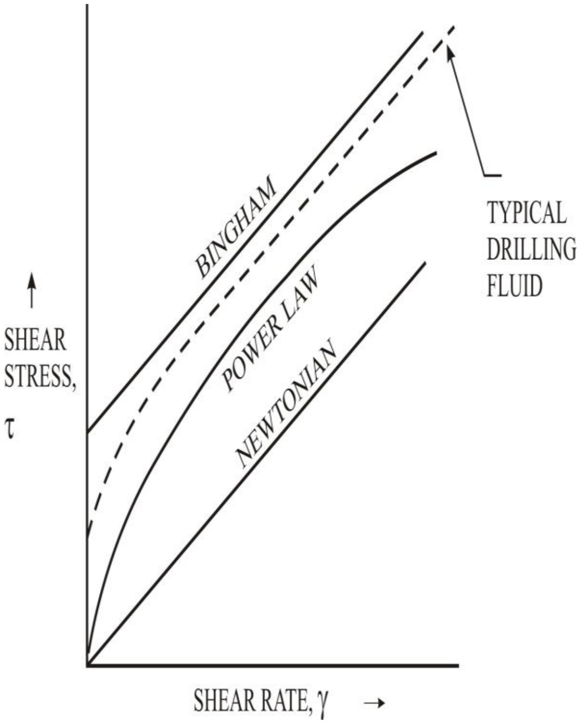

Figure 3: Flow curve for typical drilling fluid in comparison with Newtonian, Bingham plastic, and Power law model, Thanarit (2013).

5.2.2 X-Ray Diffraction (XRD)*:* The diffraction effects in x-ray diffraction technique are observed when electromagnetic radiation impinges periodic structures with geometrical variations. This occurs on the length scale of the wavelength of the radiation to verify phase recognition of crystalline materials and provide information on unit cell dimension (Isaenkol *et al*., 2006; Basalaev *et al*., 2007). The inter-atomic distance in crystals and molecules corresponds in the electromagnetic spectrum with the wavelength of x-ray having photon energies (Bhagavannarayana *et al*., 2010).

5.2.3 American Petroleum Institute (API): In drilling operation, it is required to compare laboratory experimental results with API Standard Value for Drilling Fluid. This is required to be able to access validity of results (Okorie, 2009). Table 2 indicated API standard values for drilling fluid.

Table 2: API Standard Values for Drilling Fluid

Drilling Fluid Property	Numerical Value Requirement
Fluid density (lb/gal)	8.65-9.60
Viscometer dial reading $(Ø_{600})$	30 cp
Plastic viscosity (cp)	8 – 10
Yield point (Ib/100ft^2)	3 x plastic viscosity
Fluid loss (Water)	15.0ml maximum
pH level	9.5min–12.5max
Sand content	(1-2)% maximum
Screen analysis	4 (maximum)
Moisture content	10% (maximum)
Ca^{2+} (ppm)	2.50 (maximum)
Marsh funnel viscosity	52 – 56 sec/q+
Fluid yield (bbi/ton)	91 (maximum)
API filtrate (ml)	30 (minimum)

Source: Geo Drilling Fluid (2015)

6.0 Conclusions of the Study

The objective of this study was to review critically the performance of some selected natural and less investigated fibers as fluid loss additives during the drilling fluid formulation. The review of this study showed that most of the polymers used for controlling fluid losses are imported and are quite expensive. Also, that importation, no doubt, adds to the overall cost of drilling operations in several part of the world where these operations are conducted. However, with the use of local polymers, the operational cost could be reduced, and new markets are created which stimulate and promote their cultivation, preservation and job creation. In view of this, the study has successfully evaluated and optimized four less investigated local biopolymers using a reduced central composite experimental protocol for the development of new generation of water-based drilling fluids. Furthermore, the study finds that there is a significant improvement in the properties of the beneficiated clay. The study also finds that the rheological properties of the base fluid slurry significantly improved in the presence of detarium microcarpum, food gum, roseline fiber, coconut fiber and loca l barite. As a result of the evaluated experimental outcome and API standards, the performance of various biopolymers in the water-based fluid is in line with the API specifications. The two factors detarium microcarpum and food gum are good source of viscosity while roseline and coconut fibers are good fluid loss reducers. The study suggested an **e**xtensive survey be carried out for identification of local barites from different mineral deposits in Nigeria for documentation and evaluation for industrial applications. Also processing and modification of Nigerian barite to meet the specific gravity as required by the American Petroleum Institute standard should be carried out. The study contribution to knowledge indicated that *C. populnea* (food gum fiber), coconut fiber and *C. sabdariffa* (roseline) has been widely used in polymer industry as reinforcements.

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