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Evaluating the Filtration and Mud Cake Properties of Clay Deposits from a Part of Niger Delta, Up-Agbarho, Ughelli Town, Delta State, Nigeria

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Abstract: *The drilling mud clay, till date, is still being imported, and there is no insight on when it will stop except our local clay is found suitable as the imported clay. This is the basis of this research work. This study, to a large extent, will reduce the huge millions of dollars spent on importing the clay, and stop the additional cost created on the overall cost of drilling expenses, and increase revenue generation for the government. In addition, generate employment opportunity and trigger industrial growth. This experimental work evaluates the suitability of local clay filtration properties (water loss and filter cake thickness) and was compared with the imported mud clay to ensure it agreed with the acceptable API specification standard. From the experimental values, it's found the local clay has high fluid losses as seen the values 95.1 cc, 63.0 cc, 47.4 cc, 34.2 cc, 25.7 cc, 19.2 cc than 9.9 cc, 3.8 cc, 3.2 cc, 2.8 cc, 2.6 cc, 1.8 cc of imported clay. The mud cake thickness value of the local clay-mud is 2.50 mm while the conventional, is 1.03 mm. This indicates that the local mud cake had high water loss than the conventional mud, and which causes hole problems like: tight hole which resulted in excessive drag, increase in pressure surges due to reduced hole diameter, differential sticking due to an increased pipe contact with filter cake, and excessive formation damage and evaluation problems with wire-line logs. However, after beneficiating the local drilling mud with starch and dextrid, the result review dextrid was more superior to starch on both drilling mud samples. In addition, the local clay mud exhibited the characteristic of an API specification for drilling mud if further beneficiated, which then the local content development agenda would have achieved, would then be use as a substitute for the conventional imported clay and employment and industrial development and growth.*

Keywords: *Clays, additives, mud cake, water loss, filter press.*

1. INTRODUCTION

The world over has abundant solid and liquid minerals, and region one and more types which are unevenly distributed across the geographical earth surface area.

The sciences are consistently trying to unravel this mystery behind the non-uniform distribution of mineral resources in all regions of the world.

Of the mystery of these minerals, are the elements of clay minerals. Clay is genuinely found in every square inch of the land phase of the world but varies in a constituent that determines their use and the efficacies in their area of applications.

This, for example, the Montmorillonite clay was found in a settlement of Montmor in France, which gave the baptism name Montmorillonite, and also, the Bentonite/Wyoming clay founded in the cretaceous Benton shale near the Rock River, in Wyoming, United State of America earns its name after the Benton shale as reported by Wilbur C. Knight in 1898 and cited by Thomas A.D in 2014 [1].

The b

Bentonite clay is also called the Montmorillonite clay as cited by Ameloko(2020) and reported in FPS: Use of Bentonite support fluids, 2014[2-3]. The Montmorillonite clay has a very high percentage of sodium ions which when added to water, adsorb water, swell, develop gel, and becomes viscous and plasticity [4]. This characteristic of the clay, qualify it to be used as drilling mud in drilling operations of oil and gas wells [5].

In 2002, Rabia [6] reported that any reduction in the properties of the drilling mud, will not have only resulted in wasting materials and time, but will lead to a kick or a blowout. Preston in 1974 reported that clay is a reactive solid because when in contact with water, assumes plasticity and enhances the drilling mud performance.

Apart from reactive solids, there is also a non-reactive solid as reported by Omole in 2013. These solids are also called fire clay (active solids), and non-fire clay (inactive or inert solids) respectively [7]. The fire clay (non-swelling clay) lacks swelling and gelation properties when immersed in water and are useful in pharmaceutical, food, paper, ceramic, building

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industries, and it continued for the making of beads, clay pots clay beds, local huts, and mould artwork [8-10]. The non-fire clays (swelling clays) belong to the family of the Smectite clays, which are hydrophilic and readily aggregate into viscous structure and then plasticity, when in contact with water molecules. This characteristic endears its use as a drilling fluid for oil gas wells drilling operations.

The Nigeria economy is surviving on revenue generated from oil and gas produced by the operation of drilling. And to sustain her economy and the ever-rising demand for hydrocarbon energy sources, more and more exploration for oil and gas reserves are indulged in. This, consequently, involves drilling operations, which in turn involves drilling fluid.

The drilling fluid is essential in the drilling operation of oil and gas wells as it could be said to be directly proportional to safety, healthy borehole, and time economic. These factors ensured the successful drilling of oil and gas wells.

The drilling fluid is also called the drilling mud when the clay is in the solid phase [11]. The drilling

mud is a mixture of water, clay, and chemical [11]. Drilling muds have four ingredients which are; a liquid phase that supports other components, a viscosifier that produces viscosity and gel, a weighting agent which produces density, and chemicals that control changes to mud arising from interactions with the drilled formations [12].

The Nigeria soil is found to be a host to so many minerals (solids and liquid) and clay inclusive. The clay especially has been and still is under-use to date [13].

From the inception of the advert of oil discovery and drilling in Nigeria, this clay has been on importation and till now, there seems to be no end to the importation of this clay (Montmorillonite) [14]. This clay is imported raw or in a formulated form (already mixed drilling mud) into the country and this adds to the overall cost of the operations and reduces government revenue generation [15].

With huge losses in revenue generation through the importation of drilling clay, and its considered benefits of having to produce, which will promote the development of local industries, job creation and saving revenue for more infrastructural development, clamour for local content development was asserted to by the federal government of the federal republic Nigeria [16-18].

Several works on clays properties from some parts of Nigeria, for use as drilling mud in drilling wells for oil and gas, reviewed that Nigeria's Montmorillonite clay is a calcium base that has low swelling properties and has high fluid loss [12]. However, other studies in respect of the evaluation on the properties of Nigeria clay are available.

As earlier mentioned above about uneven distribution of minerals resources on the landmass, This, with the non-compliance directive on the use of imported clay by the drilling operating company, gives a prelude to this work to re-open study on the much said about properties of Nigeria clay, but from different part of Nigeria soil to ascertain if its properties under investigation meet the API recommended specification for drilling mud used in oil and gas well drilling operations.

As reported by Igwilo *et al.* [9] and Afolabi *et al.* [11], Nigeria clay cannot control water loss because of its little gel properties, which is below the acceptable API specification [19-20]. According to Afolabi *et al.* [11], Olatunde *et al.* [14], and Obaje [16], the Nigeria local clay is highly deficient in the rheological properties of the drilling mud and a well-planned solution such as beneficiation becomes an unavoidable option to be taken [20].

The filtration properties in drilling mud are very crucial during drilling oil and gas well operations. The lack of good filtration properties results in severe hole problems. Therefore, is important to thoroughly study the Nigeria local for its modification, to replace the imported sodium Montmorillonite clay.

Filtration can be defined as a process whereby the liquid phase in drilling mud is lost to surrounding formation. When this happens, large particles in drilling mud are restrained on the wall of the surrounding sand face while the liquid phase (water) is lost into the surrounding where it now invades the oil-bearing zone and causes a blockage to flow channels into the wellbore (wellbore damage).

The resultant phenomena from these two occurrences are called “water loss/filter loss” and “mud cake/filter cake” respectively and are referred to as properties.

The quality of these properties (water loss and mud cake) depends on how well the drilling mud is designed or formulated. For reference, a well-designed mud has less water loss and a thin mud cake thickness. Consequently, a shortfall in any of these properties results in devastating hole problems and which in turn leads to a huge loss of time and expenses.

In the case of the water loss, after drilling mud has lost its liquid phase, becomes viscous, and eventually turns into a cake. This then creates some hole problems like pipe stuck, difficult circulation of mud, and excess power. And if the excess water loss in mud is unattended to, the entire bottom hole equipment (Bottom hole Assembly) could be in danger.

While the mud cake thickness presents problems such as hole reduction, difficult mud circulation, and excess power loss from the electric generating plant. However, the mud cake thickness has the advantage of aiding borehole stability and reducing flushing length into the pay zone [21].

Many works on filtration loss and mud cake have been carried out and all reports point to the similar result of high-water loss, low mud weight, and thick mud cake and some that were investigated include the work of [5, 9,11, 21, 22].

Therefore, this paper will investigate the filtration properties of Ughelli clay deposits status in Delta State as a replacement for foreign Montmorillonite in the drilling operation of oil and gas wells.

1.1 Geographical Description of Clay Location

The clay sample was collected from Up-Agbarho village in Ughelli town, Ughelli North Local Government Area of Delta State.

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Ughelli is a Urhobos indigenous ethnic nationality with an area of 818 km^2 and a population of 312, 028. The city is in southern Nigeria, located about 30 miles east of the city of Warri.

The map location is N 5º 21' 32.3676", E 6º 18' 28.638" and on a latitude and longitude of 5.500187 N and 5.99383 respectively [23].

1.2 Equipment Used:

The filter press device was used for the experimental work, and the choice was strictly based on the properties being tested for.

1.2.1 Filter Press

The filter press consists of two major parts which are; the skeletal flame body and detachable mud cell unit.

1. ***1.2.1a Skeletal Flame Body:***

The flame has six fixed parts and they are T-Screw, top and centre bar, support rod, thumb screw, and the riding support base (or base cap) [7, 21].

2. ***1.2.1b Detachable mud cell unit***

The mud cell or mud cup represents the reservoir being drilled. The cell itself is detachable and when both the top cap and the base cap are removed, it looks like a piece of short cylindrical pipe [7, 21].

The mud cell in itself consists of six parts that are neatly and carefully arranged in order from the top cap to the bottom cap or base cap as follows: top cap with pressure in-let arm, rubber gasket, thick cylindrical short pipe-like cup cell, rubber gasket, filter paper, screen (wire sieve), rubber gasket, bottom/base cap, and filtrate/drainage tube. Each of these component parts has its principal function with all converging towards the safety and successful completion of the analysis.

1.3 *Descriptions of terms*

1.3.1 Filtration

Filtration, which is also referred to as water loss is the liquid phase in a mixture of water, clay, and chemical, usually refer to as drilling mud is passed into the surrounding formation under the condition of temperature and pressure.

The loss of the liquid phase is controlled by the restrained particles in the drilling mud which, is usually referred to as mud cake or filter cake and/or mud cake thickness.

1.3.2 Mud Cake

The mud cake is the retained particles of drilling mud by the sand face of the wellbore or filter paper as the liquid part permeates through the filter paper (sand face) under the pressure acting on the mud cell or wellbore. The thickness size of the mud cake determines the quality of the drilling mud. For example, a thin-compactable mud cake thickness represents "good design drilling mud while thick cake designates poorly designed drilling mud and its use will result in high fluid loss into the reservoir.

A thin mud cake has several functions which are geared toward remedying wellbore problems and the success of the entire drilling operations. These functions include: cementing of the wall of the wellbore, prevention of caving, water loss, drying up of mud, pipe stuck, difficulties in circulation, excess use of horsepower, and extra cost.

And while thick mud cake results in excess water loss (filtrate loss) which invasion and contaminates the pay zone as well as create blockage in the pore throat affecting flow from the reservoir into the wellbore. This phenomenon is called wellbore damage.

The mud cake was measured with either meter rule or venire calliper and is reported in 1/32 in. [23].

2. METHODOLOGY

2.1 Experiment

There are two sections to this experiment; Part A: formulation of local and foreign mud samples, and Part B: the determination of filtration loss and mud cake thickness.

Part A:

The formulation of drilling mud samples with local and foreign clay samples.

Aim:

To determine one equivalent laboratory barrel of a drilling mud.

2.1.1 Procedure

A weighing triple beam balance was used to weigh 22 g of the processed local and imported sodium Montmorillonite clay samples separately and was also kept differently for further analysis. Then a 350 ml of distilling water was measured twice with a 500 ml graduated glass measuring cylinder and then, poured into two different mud mixer cups that were already cleaned and dried with a rag. After which, the water was tested before clamping the mud cups to the mud mixer machine,

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and, afterward, clay samples were added gradually and allowed to stir for till a homogeneous mixture was achieved. The resulted mixtures were tested with phydriod pH paper for alkaline or acidity level.

The formulated mud samples were then allowed to hydrate for a quiescent time of 24 hours before is used for analysis.

Part B:
Determination of filtration (water loss) and mud cake properties in local and imported sodium Montmorillonite clay.

Aim:
To determine water loss property in local and imported clay
To determine mud cake compatibility in local and imported mud sample

2.1.2 Procedure
The low temperature-low pressure test is conducted using Filter Press and at a room temperature and pressure of 100 psi based on the API recommendation standard. The coupling of the mud cell follows the aforementioned listed items contained inside in figure 1 of Part B.
The drilling mud sample was carefully turned inside the mud cell, and replaced on filter press flame and screw tightly. Then a glass graduated measuring cylinder is placed under the drainage tube and pressure of 100 psi was let in into the mud cell while at the same time the drainage tube is freed and the timing begins for 30 minutes.
The volume of the filtrate is read and reported in cubic centimetres per 30 minutes (1/30 min) [7, 21].
At the end of the experiment, the pressure was bled off and the filter press un-coupled, and the mud cell was removed for the analysis/measurement of the thickness of the restrained sediments of mud colloid, called, mud cake thickness, and is reported in 1/32 in. [7, 21].

This experimental process was repeated during beneficiation of formulated drilling mud sample with two additives: starch and dextrid. Beneficiation is the process of enhancing clays found to be of low quality for use as drilling mud and is evolved by adding materials or chemical substances and/or both [4, 25].

3. RESULTS AND DISCUSSION

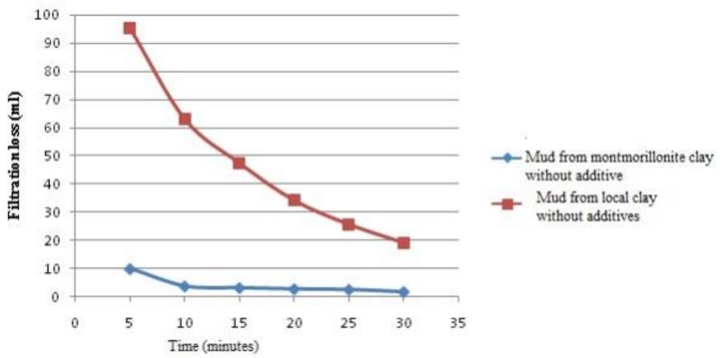

Figure1: Change in filtration loss with time in drilling mud prepared with local clay and Montmorillonite clay without additive

From Figure 1, the local mud has a very high fluid loss compared to imported sodium Montmorillonite mud. The experimental values of water loss for local and imported clay mud are 95.1 cc, 63.0 cc, 47.4 cc, 34.2 cc, 25.7 cc, 19.2 cc, and 9.9 cc, 3.8 cc, 3.2 cc, 2.8 cc, 2.6 cc, and 1.8 cc respectively.

The local clay mud has a cumulative volume of 284.6 ml of water loss and a percentage of 81.3 water loss. The highest fluid loss occurs at 5 minutes, with a value of 95.1 cc and this was followed by 63.0 cc at 10 minutes of time. This is due to the general poor absorption of water molecules leading to low swollen and gel in clay particles. The huge difference between 95.1 and 63.0 is largely caused by the reason stated above.

While the fragile close decrease in interval noticed from 10 minutes to 30 minutes was due to the gradual sealing of pore spaces by un-dissolved particles of clay as the liquid phase in mud decreases.

For the conventional sodium Montmorillonite clay drilling mud, the experimental values obtained as its water are 9.9 cc, 3.8 cc, 3.2 cc, 2.8 cc, 2.6 cc, 1.8 cc. These values are quite low compared to those obtained in local clay mud. The highest water loss occurs at 5 minutes with 9.9 cc and with a cumulative water loss of 23.8 ml and a percentage of 6.8 %. The low values of water loss in sodium Montmorillonite clay are completely associated with its clay particles having a high affinity for water molecules (cation ions exchangeable capacity), leading to absorption/hydration, swelling, viscous, and finally becomes plasticity in physical appearance [25-26]

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These qualities/characteristics develop high a viscosity which build-up mud weight and create a resistance that reduces the rate of flow that was recorded against the time in the experiment.

The mud cake thickness of local and imported clay drilling mud are reported as 2.5/32 mm and 1.03/32 mm. From indication, the small value of sodium Montmorillonite clay mud suggests it has a better cake which is a thin cake compared to local clay mud having thick cake.

Table I: Comparison of mud cake thickness of local /Montmorillonite drilling mud without additive.

Mud property	Local clay drilling mud without additive (mm)	Montmorillonite clay drilling mud with additive(mm)
Mud cake thickness Size	2.5	1.03

Table II: Comparison of mud cake thickness of local /Montmorillonite drilling mud with 4 g of Starchas additive

Mud Property	Local clay mud drilling mud & starch as an additive (mm)	Montmorillonite clay drilling mud & starch as an additive (mm)
Mud cake thickness Size	3.0	2.0

Table III: Comparison of mud cake thickness of Local /Montmorillonite drilling mud with 4 g of dextrid asan additive

Mud property	Local clay mud drilling mud & dextrid as an additive (mm)	Montmorillonite clay drilling mud &dextrid as additive (mm)
Mud cake thickness Size	4.2	2.0

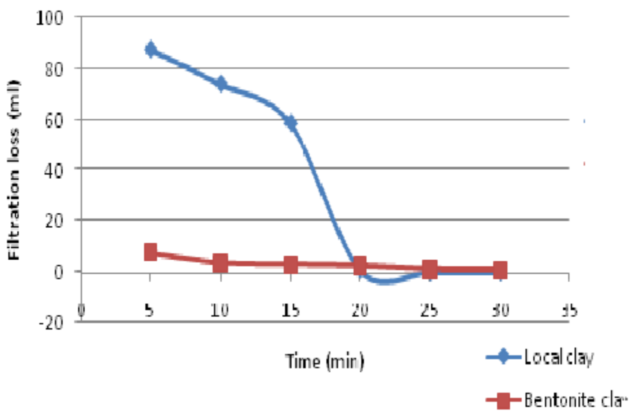

Figure 2: Change in filtration loss with time in drilling mud prepared with local clay and montmorillonite clay with starch

Figure 2, reported a high rate of water loss on local clay mud and a lower rate of water loss after beneficiated additive (Starch). The practical experimental values record without and with additive, starch is 87.7 cc, 74.3 cc, 58.8 cc, 1.0 cc, 0.0 cc, 0.0 cc and 7.8 cc, 3.7 cc, 3.1 cc, 2.6 cc, 1.1 cc, and 1.0 cc, and as against time beginning from 5 min, 10 min, 15 min, 20 min, 25 min to 30 min.

The local clay mud experiences a high-water loss from 5 min to 15 min times while it drops sharply from 20 min. to 30 min of time. The high fluid loss in the mud is due to poor gelling which as result not be able to build up a viscous structural appearance while the sharp drop noticed is caused by the starch effect as the mud completely loss its water.

For the Montmorillonite clay mud, a very low water loss was observed from the beginning of the experiment to when it ends. This is an indication of the high resistance to the rate of fluid flow caused by clay hydration, building up of viscous structure, and plasticity.

Coordinate points of interceptions are (20, 1.0 &2.6) and (25, 0.0 &1.1) which indicate common stability of both muds while the common uniform progressing line shows equilibrium in the mud properties of local and imported sodium Montmorillonite clay.

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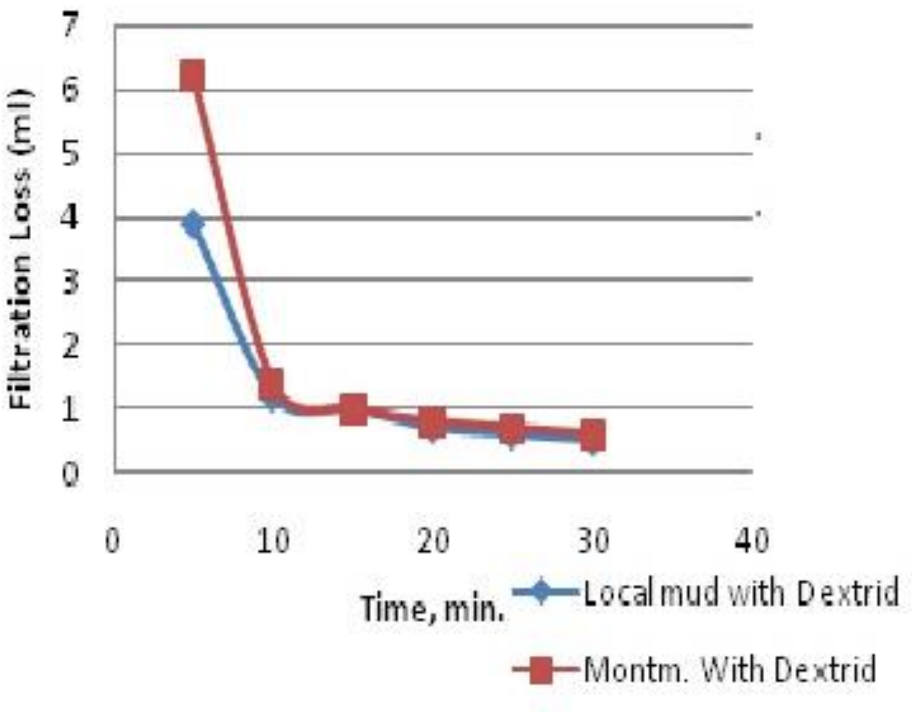

Figure 3: Change in filtration loss with time in drilling mud prepared with local clay and Montmorillonite clay with dextrid

From figure 3, after beneficiating with additive (dextrid) the value obtained for local and Montmorillonite mud against time are respectively listed as: 6.2 cc, 1.4 cc, 1.0 cc, 0.8 cc, 0.7 cc, 0.6 cc and 3.9 cc, 1.2 cc, 1.0 cc, 0.7 cc, 0.6 cc, and 0.5 cc and with a time of 5 min., 10 min., 15 min., 20 min., 25 min., and 30 min.

From observation, the amount of water loss in both mud is drastically low as against those obtained when beneficiated with starch.

The corresponding points of intersecting noticed at point coordinates (15, 1.0 & 1.0) is an indication that local drilling mud properties aligned with those of the imported clay mud, and from that point onward, both mud met the API standard recommended water loss for drilling mud. And also, each mud can function as a drilling fluid for drilling of oil and gas wells.

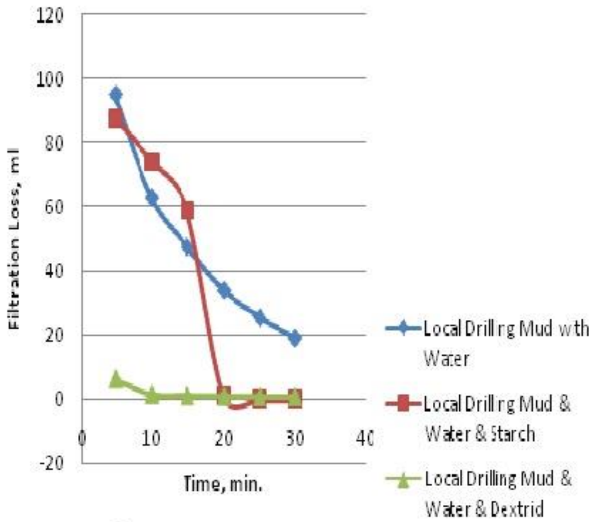

Figure 4: Change in filtration loss with time in drilling mud prepared with local clay and Montmorillonite clay with starch and dextrid

Figure 4 unveils the behaviour if the two additives (starch & dextrid) and non-additive in local clay mud as regard to its water loss. The experimental values of the water loss for the non-additive, starch and dextrid as against time are reported

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respectively as 95.1 cc, 63.0 cc, 47.7 cc, 34.2 cc, 25.7 cc, 19.2 cc, 87.7 cc, 74.3 cc, 58.8 cc, 1.0 cc, 0.0 cc, 0.0 cc and 6.2 cc, 1.4 cc, 1.0 cc, 0.8 cc, 0.7 cc, and 0.6 cc.

Of these values, the dextrid has the lowest water loss compared to starch and when not beneficiated with additive. At 25 min. to 30 min., the mud completely loses its water content as a result of the effect of starch.
The dextrid as an additive proved to be much better as a fluid loss control additive than starch due to its general decreasing values of fluid loss.

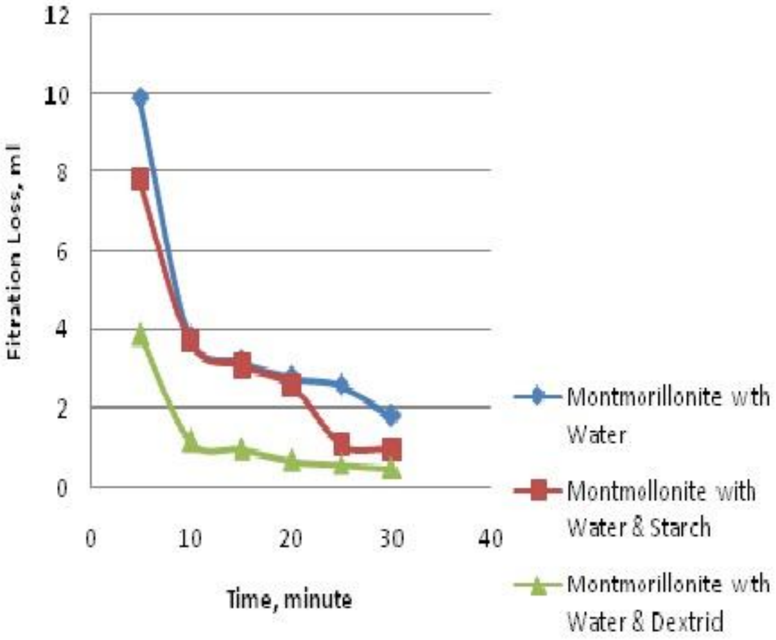

Figure 5: A sample line graph using colours which contrast well both on screen and on a black-and-white hdcopy

Figure 5 shows the relationship of water loss in mud formulated with sodium Montmorillonite clay in a case when the additive was not applied (i.e., mud + water) and it was applied. The additives are starch and dextrid.

The values of water loss for drilling mud from imported clay when not beneficiated and when does with starch and dextrid are listed accord to how is stated as follows: 9.9 cc, 3.8 cc, 3.2 cc, 2.8 cc, 2.6 cc, 1.8 cc (for without additive); 7.8 cc, 3.7 cc, 3.1 cc, 2.6 cc, 1.1 cc, 1.0 cc (for with additive starch) and 3.9 cc, 1.2 cc, 1.0 cc, 0.7 cc, 0.6 cc and 0.5 cc (for with additive dextrid).

From the figure, it is observed that dextrid is more effective as a fluid loss control agent than starch in sodium Montmorillonite mud. Furthermore, it was noticed that though, starch could meet the quality of the API specification for drilling mud, may not be as good as dextrid because of the progressing parallel line of starch and dextrid as seen in the graph.

However, there is general is a better improvement on local and Montmorillonite mud when beneficiated with additives (starch and dextrid) than when it was not beneficiated (i.e., just drilling mud and water).

4. CONCLUSION

From the general outlook of the experiment, the drilling mud formulated with clay obtained from Up-Agbarho in Ughelli Town has quite outrageous water loss than the drilling mud formulated with imported sodium Montmorillonite clay.

However, after beneficiating the drilling mud from both clays sample with starch and dextrid as additives, though, there was a reduction in water loss in both muds, the dextrid additive proved to be much better with both local and imported clay than starch. This is also applicable to the mud cake thickness obtained when beneficiated with dextrid additive.

Therefore, the drilling mud from local clay has high-water losses which indicate a low grade and, may only be used with the conventional sodium Montmorillonite as drilling mud. However, if further beneficiated, can be substituted for the conventional Montmorillonite mud-clay.

5. RECOMMENDATION

This research work will be a good resourceful material for the academician, individual, Federal government of Nigeria, and the Petroleum industrial for self-reliance in the production of drilling mud with locally sourced clay and the aftermath industrial development, and economic benefit for any class whose interest is based on sourcing local clay for use as drilling mud in drilling operations of oil and gas well.

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