Research Article / Review Article

FUPRE JOURNAL 6(3):148- 162(2022)

FUPRE Journal of Scientific and Industrial Research

ISSN: 2579-1184(Print)

ISSN: 2578-1129 (Online)

https://fupre.edu.ng/journal

Investigating the Effects of Contaminants on the Rheological Properties of Water-Based Mud

Okotie Sylvester[1,*], **Kassim Mahmud**[2] **Ovuema Augustina**[3]

[1,2,3] *Department of Petroleum Engineering, Federal University of Petroleum Resources, Effurun*

ARTICLE INFO

Received: 24/03/2022

Accepted: 25/05/2022

Keywords

water base muds (WBM), oil base muds (OBM), synthetic-base muds (SBM), apparent viscosity, plastic viscosity yield point, gel strength, mud contaminants.

ABSTRACT

For any drilling operation to be termed successful, care must be taken during the selection and application of the drilling fluid which are key factors that should be considered. Any actions contrary to carefully selection and application of drilling fluids could have very dire consequences. Based on the experiment work done on water base mud system to ascertain the effect of contaminants (salt, silica sand, cement and carbonate) on the rheological properties and performance of the mud, it shows that the presence of a contaminant on the drilling mud either reduces or increases the rheological properties of the mud system and in turn affects the rate of penetration, it performance and also poses serious drilling problems. It was observed that the presence of Sodium salt in the mud system increased the fluid loss into the formation. It was further observed that while Apparent Viscosity, Gel Strength increases as the mass increase from 1g to 5g, the pH and Plastic Viscosity almost did not change. The Yield point increases little. With Cement as contaminant, it shows all rheological properties of the mud increased markedly, as the quantity of the cement used is increased from 1g to 5g and the pH does not change. Silica contamination has not showed any marked effect on the nature of the drilling mud. In fact, the more the amount of the contaminant (Silica) is added, the closer it properties are to the blank sample that do not have contaminants. The carbonate effect is largely on the Gel strength which decreases as the amount of added carbonate increases. The pH has no charges, which also means carbonate keeps the mud in it alkaline state, as it was with cement.

1. Introduction

Whenever hydrocarbons are discovered in some subsurface formations, it sounds interesting to all parties involved but in reality, we cannot confirm the presence of the hydrocarbon without making a hole to the target zone. Thus, the drilling of oil and gas well is a high risk and challenging venture with some associated problems. Despite these challenges, wells are still being drilled globally and only experience a slow or no drilling operations in recent times due to the global drop in oil price. It is the aim of every field operator to get the oil or gas from the reservoir rock to the surface production facilities in a safe and cost-effective way thereby maximize profit by reducing the cost of drilling the required number of wells to drain the reservoir fluid.

In the cause of drilling a well to the target

*Corresponding author, e-mail: okotie.sylvester@fupre.edu.ng
DIO

zone, there are some associated problems that might occur such as lost circulation, formation damage, kick and if not control can result to a blowout, pipe sticking, hole instability etc. which can be prevented by the use of adequate drilling mud. Also, a poor hole cleaning can lead to a reduced penetration rate, a loss circulation of fluid, and increase in rotary torque, break down in the formation and stuck pipe (Hussain et al, 2010). Therefore, to successfully drill a well to the pay zone of the reservoir requires the formulation of appropriate drilling fluid which is a primary well control technique to overcome the formation pressure as the well Deepings? Drilling mud is seen as the life blood of every drilling operation which implies that drilling mud needs to possess some required properties (both physical and chemical) withstand various well conditions encountered with even greater variety. When the drilling fluid is not monitored properly leads to intrusion of contaminants that alter the rheological properties of the drilling fluid thereby making it not to perform it require functions properly.

In general, a contaminant is any material that causes undesirable changes in drilling fluid properties. Solids are by far the most prevalent contaminant. Excessive solids, whether Commercial or from the formation, lead to high rheological properties and slow the drilling rate. Most other contaminants are chemical in nature and require chemical treatment to restore fluid properties. While there are specific treatments for each contaminant, it is not always possible to remove the contaminant from the system.

Some contaminants can be predicted, and a treatment started in advance. The Predictable contaminants are: cement, make-up water, and sometimes salt, gypsum, and acid gases such as, hydrogen sulfide and carbon dioxide. Pretreatment can be advantageous as long as it is not excessive and does not adversely affect mud properties. Other contaminants may be unexpected and unpredictable such as those whose concentration increases gradually. Eventually, the contaminant shows its effect by altering the fluid properties. This change in fluid properties often occurs at times when deflocculants are expended at high down hole temperatures. It is essential to keep accurate records of drilling fluid properties to ensure that any gradual buildup of a contaminant is monitored and detected.

The effect of contaminants on the drilling mud performance is aimed at a comprehensive investigation into the rheological behavior of drilling mud properties when contaminated with the following: drilling solid, cement, sodium chloride (NaCl) etc. The success of any drilling operation depends on the ability of drilling fluid to perform it various functions. Also, the higher the concentration of these contaminants, the higher the rheological properties and other related mud properties. Thus, higher concentration of contaminants in a drilling mud system causes detrimental effect on its performance.

Besides, to optimize the drilling mud performance, we need to understand the functions of the drilling mud so as to enhance the drilling operations. Some of these functions are: i. Cooling and lubricating of bits, ii. Transmission of hydraulic horsepower to the bits, iii. Cleaning the bottom of the hole, iv. Removing the cuttings from the bottom of the hole to the surface v. Releasing the cuttings at the surface vi. Control of formation pressure vii. Ability to suspend cuttings during circulation stoppage viii. Stabilizes the wellbore ix. Aid formation evaluation.

The science and expertise of drilling wells depends on the application of drilling muds for certain reasons which includes removal of cuttings to the surface and maintenance of wellbore stability. This means that the selection of drilling mud is dependent on the behavior of the formation to be drilled. The contamination of the drilling fluid is a continuous process while drilling a well and the problems that emanate from the drilling operations such as kick/blowout, pipe sticking, lost circulation, hole instability, and formation damage etc., is often as a result of the contamination. Contaminants on the drilling mud alter its properties which result to inadequate performance of the drilling mud. Some problems with these contaminants are: addition of solids in drilling fluid, which can increase the viscosity, fluid loss, filter cake and gel strength which as a result cause loss circulation and mud cake. Also, High Concentration of sodium chloride in bentonite-based mud generates an energy barrier and result to several flocculation's. Thus, in small amounts, sodium chloride thickens freshwater mud and also increases the filtration rate.

The objective of this study is to determine the effect of contaminants on the drilling fluid properties and performance and determine which of the contaminants will have significant effect on the drilling fluid properties. The aspect of research on the effect of contaminant on the drilling mud performance cannot be overemphasized. Thus, this study is important to reduce drilling cost, increase personnel safety, minimize downtime, and increase productivity

As stipulated by Bourgogne (1986); Stated that drilling fluid is directly or indirectly related to most drilling problems, the presence of hydrated clays in the water has undesirable as well as desirable effects on the rotary drilling process. A reduction in penetration rate and an increase in the frictional pressure losses are observed when the clay content of the drilling fluid increases. Besides, a high mud pH is desirable to suppress the corrosion rate, hydrogen embrittlement and the solubility of Ca^{2+} and mg^{2+}. Also, the high pH is a favorable environment for many of the organic viscosity control additives, the pH of the most mud is maintained between 9.5 and 10.5 and even higher pH may be used if H_2S is anticipated.

Medermonth (1973), states in his book titled "Drilling mud and fluid additives" that contaminants are encountered on every phase of the drilling operation. They also exist in drilled formations, water supply and in materials used in formulating and maintaining the drilling fluid properties. They can rapidly alter the physical and chemical characteristic of the drilling mud. We must note that the severity of the problems experienced depends on the type of contaminant, degree of contamination and the type of drilling mud used. Bariod (1985) divided the drilling fluid contaminants into six groups to be able to look at their adverse effects. These include contaminants due to solids, contaminants due to sodium chloride, contaminants due to calcium, contaminants due to soluble carbonate, contaminants due to bacterial and contaminants due to hydrogen sulphide.

Olufemi *et al* (2011) did a work to experimentally investigate the alteration of flow properties of oil-based mud after the intrusion of contaminants and based on their results, they deduced that maintaining a low mud density minimizes its viscosity, and when the pressure within the wellbore annulus is reduced which is caused by the fluid circulation, it minimizes the filter cake thickness. In a scenario where there is a thick filter cake sealing or restricting flow, the pressure beneath the bit increases and can result to loss circulation of mud. They also concluded that as the drill cuttings are removed, the plastic viscosity decreases and a decrease in the plastic viscosity will increase the low shear rate viscosity which will bring larger, more easily removable cuttings to the surface.

Ali et al. (2013) investigated the effect of NaCl salt contamination on rheological properties of bentonite drilling mud and from the result they obtained, they inferred that both plastic viscosity and the electrical resistivity were reduced with an increase in salt content. Basirat et al (2013) also conducted similar research and stated that for a mud system that is contaminated, there is about 30% increase in the filter loss and 86% decrease in resistivity as compared to the same sample without contamination. Furthermore, the result obtained by Hassiba, and Amani (2013) showed that NaCl contamination increases the shear stress/shear rate while KCl contamination decreases the shear stress/shear rate curves of water-based mud.

Hussain *et al* (2010) state that in the process of drilling, one of the major problems affecting its operation is poor or inadequate hole cleaning which can result to loss circulation, it reduces the rate of penetration, breakdown of the formation, pipe sticking and high rotary torque amongst others. Chinwuba (2000) stated that the geographical location affects the composition of the drilling mud as well as the well depth and rock type. Kumapayi et al., (2014) investigated the effect of clay and sea water containing magnesium and calcium ions contaminations on the rheology of the oil-based invert emulsion fluid.

1. Material and Experimental Method

The experimental methodological design approach for this study is presented and it is represented in Figure 1

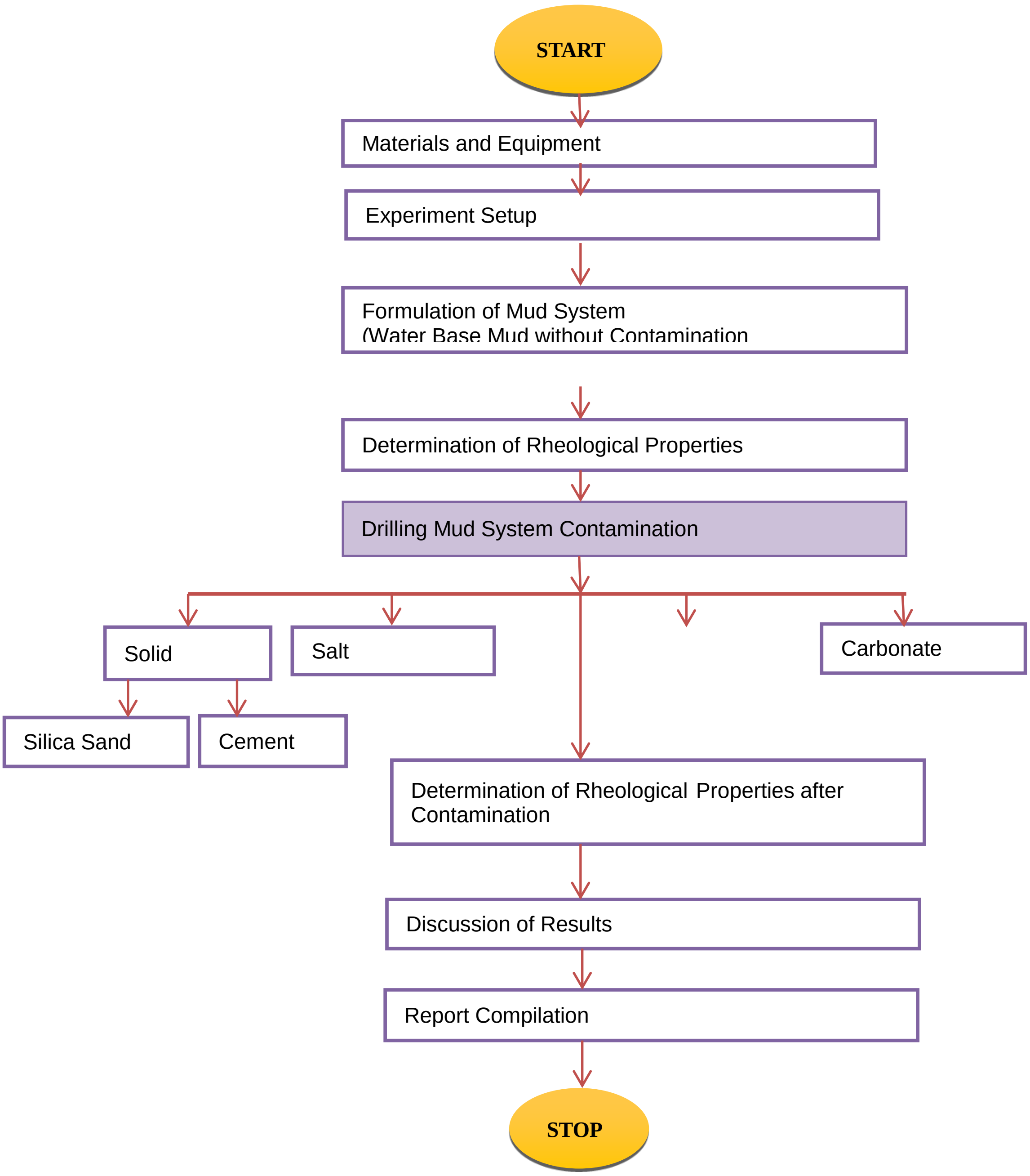


Figure 1: Experimental workflow

3.1. Materials Used

In the course of this study, the materials used to achieve the said objectives above are: a. distill water, Par-R, Par-L, Soda ash, Betonite, Barite, salt (KCL) and Caustic soda.

Figure 1: Mud additives

Table 1: Additives, composition for mud formulation and their functions

Additive	**Weight (g)**	**Function (S)**
Bentonite (Gel)	5	Control of viscosity and filtration
Barite	24.5	Weighting agent
Soda Ash (sodium carbonate)	0.2	Calcium precipitant and pH reducer in cement contaminated mud
Water	350ml	Base fluid
XCD	0.5	Control of viscosity and filtration
Par R	0.5	Viscosifier and fluid loss control
Par L	1.3	Viscosifier and fluid loss control
Caustic soda (sodium hydroxide)	0.5	pH control
KCl	20	Control borehole stability

2.1. Equipment Used

Weighing balance, Retort, Mud mixer, Mud balance, Round bottom flask, API filter press,



Figure 2: Weighing balance Figure 3: Mud mixer Figure 4: Formulated Water-Based Mud

Figure 5: Brookfield rheometer

Figure 6: Marsh Funnel and One-liter Cup

3.2. Formulation of a Water (Bentonite) Mud

The materials and composition by weight used in the formulation of the water base mud (Figure 4) to determine the rheological properties are given in the Table 1. Four different contaminants with varying weight were used to formulate twelve samples plus a blank standard sample as shown below:

1. Blank (Control Specimen- with no contaminants)
2. Cement (of: 1g, 3g & 5g)
3. Silica Sand (solid) (of: 1g, 3g & 5g)
4. Salt (NaCl) (of: 1g, 3g & 5g)
5. Carbonate (Na_2CO_3) (of: 1g, 3g & 5g)

Procedure

i. 350ml of water was measured and poured into the Hamilton mixing cup
ii. The mixing cup was placed in the Hamilton beach mixer.
iii. 5grams of Bentonite was added and prehydrated for 25 minutes under stirring condition.
iv. Add 0.2grams of soda ash into the water
v. Add 0.5grams caustic soda
vi. 0.5grams of XCD, 0.5grams of Pac-R, 1.3grams Pac-L respectively were added to the mixing cup
vii. Add 24.5gramsbarite with mixed water 350ml and addictive listed above to form one-Standard Lab bbl.
viii. Allow the sample to age for 24-hrs
ix. Stir it continuously with the Hamilton beach mixer
x. The mixture was stirred further for another 20 minutes for homogeneity before taking the rheological readings and (10 seconds/minutes) gel strength.

Mud density Measurement Test Procedure

i. Remove the lid from the cup
ii. Completely fill the cup with the mud to be tested.
iii. Replace the lid and rotate until firmly seated, making sure some mud is expelled through the hole in the cup.
iv. Wash or wipe the mud from the outside of the cup.
v. Place the balance arm on the base, with the knife-edge resting on the fulcrum and move the rider until the graduated arm is level, as indicated by the level vial on the beam.
vi. At the left-hand edge of the rider, read the density on either side of

the lever in all desired units without disturbing the rider and record the mud temperature corresponding to density. (King Fahd University laboratory manual, 2003)

Funnel viscosity Test Procedure

i. Cover the orifice with a finger (Figure 6) ensuring the funnel is in an upright position and pour the freshly collected mud sample into a clean, dry funnel through the screen until the fluid level reaches the bottom of the screen (1500ml).

ii. Immediately remove the finger from the outlet and measure the time required for the mud to fill the receiving vessel to the 1-quart (946 ml) level.

iii. Report the result to the nearest second as Marsh Funnel Viscosity at the temperature of the measurement in degrees Fahrenheit or Centigrade. (King Fahd University laboratory manual, 2003)

Viscosity Measurement Procedure

i. Place a recently agitated sample in the cup, tilt back the upper housing of the rheometer, locate the cup under the sleeve (the pins on the bottom of the cup fit into the holes in the base plate), and lower the upper housing to its normal position.

ii. Turn the knurled knob between the rear support posts to raise or lower the rotor sleeve until it is immersed in the sample to the scribed line.

iii. Stir the sample for about 5 seconds at 600 RPM, and then select the RPM desired for the best.

iv. Wait for the dial reading to stabilize and record the dial reading and RPM.(King Fahd University laboratory manual, 2003)

Gel Strength Measurement Procedures

i. Stir a sample at 600 RPM for about 15 seconds.
ii. Turn the RPM knob to the STOP position.
iii. Wait the desired rest time (normally 10 seconds or 10 minutes).
iv. Switch the RPM knob to the GEL position.
v. Record the maximum deflection of the dial before the Gel breaks, as the
vi. Gel strength in lb/100 ft^2. (lb/100 ft^2x 5.077 = Gel strength in $dynes/cm^2$).

Therefore, to experimentally calculate the required rheological properties, we repeat the experiment using the Brookfield rheometer to obtain dial readings at 3, 300 and 600 RPM. By means of the rheological calculations procedure, (King Fahd University laboratory manual, 2003).

$$Plastic\ Viscosity\ (cp) = \mu_p = 600\ RPM\ reading - 300\ RPM\ reading$$

$$\mu_p = \theta_{600} - \theta_{300}$$

$$Apparent\ Viscosity\ (cp) = \mu_a = \frac{600\ RPM\ reading}{2}$$

$$\mu_a = \frac{\theta_{600}}{2}$$

$$Yield\ Point\ \left(\frac{lb}{100}ft^2\right) = Y.P = 300\ RPM\ reading - Plastic\ Viscosity$$

Determine the Apparent and Plastic Viscosities, Yield Point and initial 10 sec. and final 10-minute Gel Strength parameters and tabulate your results as shown in Table 2:

Table 2: Mud rheology test result sheet

Table 2: Mud rheology test result sheet

Sample No.	**Viscosity (cp)**					**Gel strength ($lb/100ft^2$)**	
	Θ_{600}	**Θ_{300}**	**μ_p**	**μ_a**	**Y_p($lb/100ft^2$)**	**Initial 10 sec. Gel**	**Final 10 min. Gel**

Test Procedure for Mud Contamination

This procedure was adopted for all (Salt, Cement. Silica Sand, Carbonate, & High Temperature) contaminants used for this study.
13 blank samples are prepared, which are to be contaminated by 1g, 3g and 5g of each of Cement, Silica Sand, Sodium Chloride (salt) and Carbonate as contaminants.

i. Measure a certain amount of the newly prepared water base mud from the mixing cup into different flask

ii. Test the base mud for weight (ppg), plastic viscosity (cp), apparent viscosity (cp), yield point ($lb/100\ ft^2$) and other properties.

iii. Add each of the contaminants of different grams into each of the flask and measure the desired properties after each addition (stir every time).

iv. Report the results in a convenient table for the number contaminants. (King Fahd University laboratory manual, 2003)

2. Results and Discussion

Since drilling fluid/mud is the life blood and primary well control of every drilling operation, implies that a drilling fluid with stable rheological properties is required in the drilling operation. This fluid leaves the mud pit/tank to the formation and back to the mud pit via the annular space. As the well is drilled deeper, the mud encounters different formations and may be contaminated in the process. Hence, requires a careful monitoring of the parameters that enable the mud to perform its required functions adequately.

Based on the results obtained from the laboratory experiments of this study, it was found that the rheological and filtration properties of the water base drilling mud formulated were affected by the intrusion of contaminants. It was indicated that these contaminants either increase or decrease the plastic viscosity, yield point, gel strength pH, API filtrate, sand content, water, mud and filtrate alkalinity, chloride and calcium contents for the used drilling mud samples which also affect their efficiencies.

Table 3: Sample + Salt (NaCl) Contaminant

RPM(CP)	600	300	200	100	pH	Gel Strength (10sec)	Gel Strength (10min)	Apparent Viscosity	Plastic Viscosity	Yield Point
1g	64	53	47	40	10.5	34	39	32	11	42
3g	77	66	60	51	10.5	37	40	38.5	11	55
5g	56	46	42	37	10	26	32	28	10	36

Table 4: Sample + Carbonate (Na_2CO_3) Contaminants

RPM(CP)	600	300	200	100	pH	Gel Strength (10sec)	Gel Strength (10min)	Apparent Viscosity	Plastic Viscosity	Yield Point
1g	52	28.4	37.5	58.4	8.7	18.6	24.3	26	10.5	17.8
3g	48	37	34	31	10	24	26	24	11	26
5g	42	37	34	37	10	21	22	21	5	32

Table 5: Sample + Cement Contaminants

RPM(CP)	600	300	200	100	pH	Gel Strength (10sec)	Gel Strength (10min)	Apparent Viscosity	Plastic Viscosity	Yield Point
1g	85	75	69	64	12	52	108	42.5	10	65
3g	138	132	116.5	108	12	82	89	69	16	106
5g	300	300	277	248	12	90	98	150	0	300

Table 6: Sample + Solid (Silica) Contaminant

RPM(CP)	600	300	200	100	pH	Gel Strength (10sec)	Gel Strength (10min)	Apparent Viscosity	Plastic Viscosity	Yield Point
1g	39	24	18.5	11	9.5	3	18	19.5	15	9
3g	36	24	18.5	12	9.5	4	20	18	12	6
5g	44	28	21	14	10	3	19	22	16	12

*Corresponding author, e-mail: okotie.sylvester@fupre.edu.ng
DIO

3.1. Result of Salt contamination

It is usually easy to detect salt when it enters the mud system while drilling. Once it contaminates the mud, there will be an increase in the chlorides content of the filtrate, an increase in rheology; specifically, the yield point, an increase in fluid loss, and a possible decrease in pH and alkalinities and the observed results show an increase in rheological properties. It was also observed that the presence of Sodium salt in the mud system increased the fluid loss into the formation. Thus, if the salt source is a saltwater flow, there may also be a decrease in mud density and the result obtained shows that the source of salt contamination is not a saltwater flow. There was a drastic increase in the chloride content which will require a high treatment cost and if the cost of treatment is excessively high; the mud can be converted to another mud system that tolerates the salt problem.

It was further observed that while Apparent Viscosity, Gel Strength increases as the mass increase from 1g to 5g (Figures 8-10), the pH and Plastic Viscosity almost did not change. The Yield point increases too but not too much appreciable. The plastic viscosity is essentially a function of the viscosity of the liquid phase and the volume of solids contained in a mud. The Yield Point is the internal resistance to flow of the mud due to different charge surfaces. As the salt quantity increases the charge surfaces increase, and this increase the rheological properties of the mud.

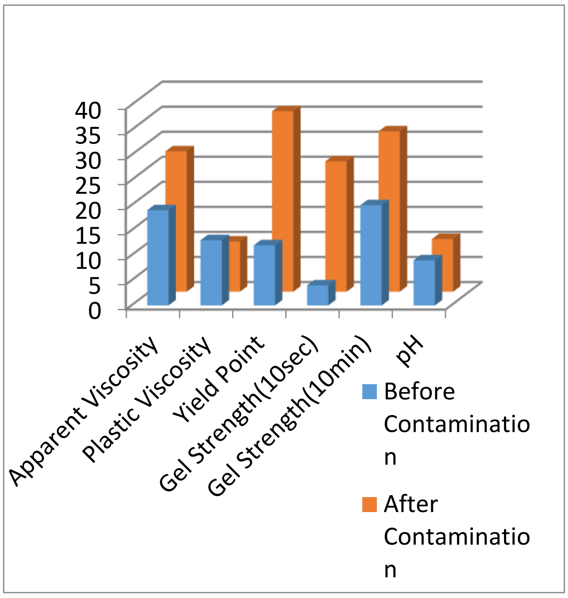


Figure 8: Salt (NaCl) of 1g as contaminant

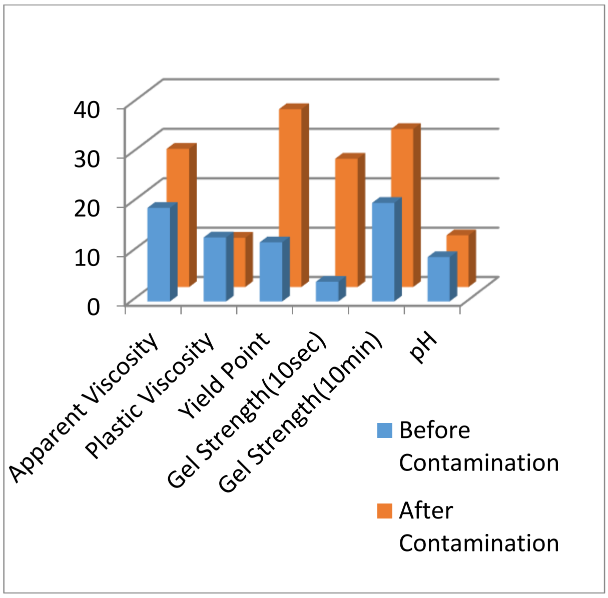


Figure 9: Salt (NaCl) of 3g as contaminants

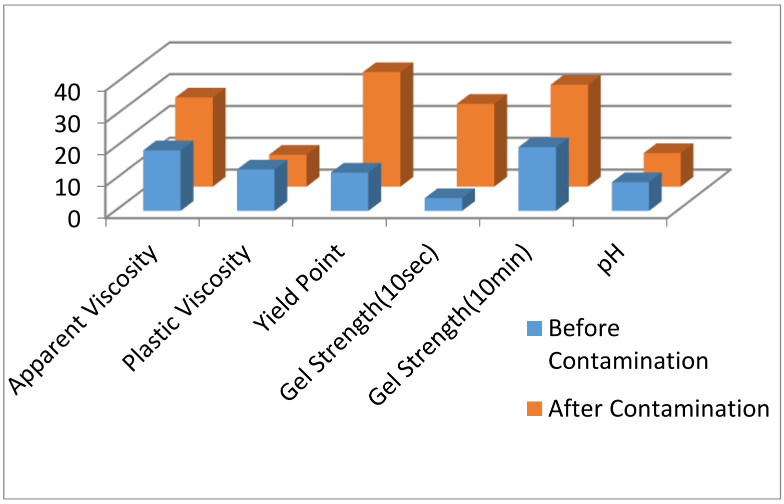
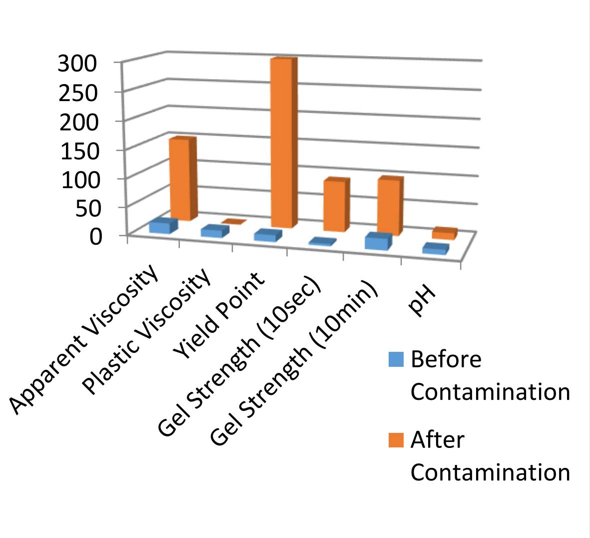


Figure 10: Salt (NaCl) of 5g as contaminants

3.1. Result of Solids Contamination with Silica Sand and Cement

The properties to identify when a mud system is contaminated with clay/silica sand are: increase in solids, increase in cation exchange capacity (CEC) or MBT, decreases in alkalinity, density increases. While the case of cement is identified by API/HTHP filtrate increase, increase in pH, Pm/Pf increase and high calcium. The result observed when the mud system was contaminated with Silica and cement show different trend in some properties. In shale contamination, the filtrate alkalinity decreases but increases rapidly in cement contamination. There was no change in calcium content for shale/clay contamination but a rapid increase for cement contamination.

With Cement as contaminant, it shows all rheological properties of the mud increased, and as the quantity of the cement used is increased from 1g to 5g (Figures 11-13), there was astronomical increase in the rheological properties mud. This effect shows that cement contamination cannot be tolerated in a mud system. It also shows that cement contamination has no effect on the pH of a mud, hence the mud Alkalinity nature remains intact, but both its filtration and rheology is altered significantly. Silica contamination has not showed any marked effect on the nature of the drilling mud. In fact, the more the amount of the contaminant (Silica) is added, the closer it properties are to the blank sample that do not have contaminant. Hence, for Silica, it has an inverse effect of what cement has on a drilling mud (Figure 14-16)



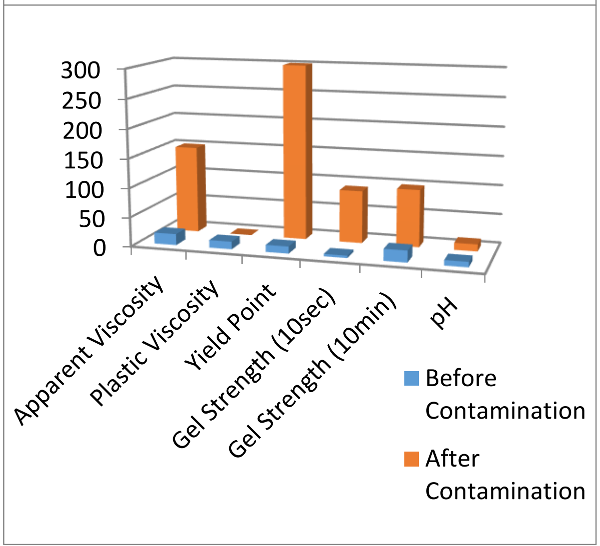
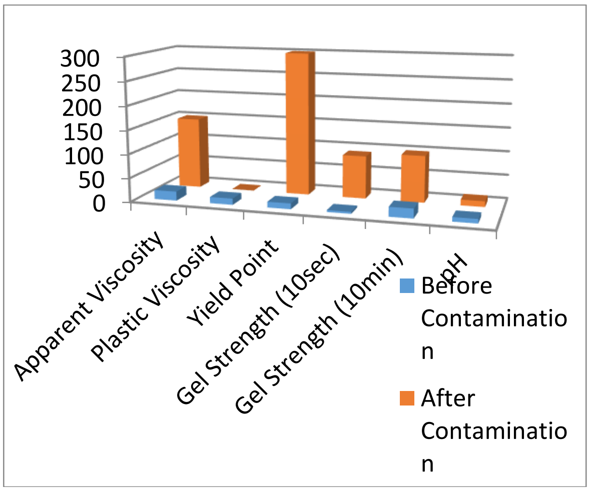


Figure 11: Cement of 1g as contaminants
Figure 12: Cement of 3g as contaminants



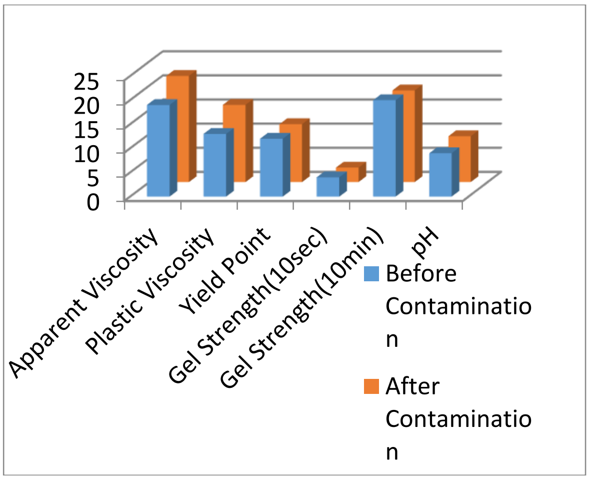
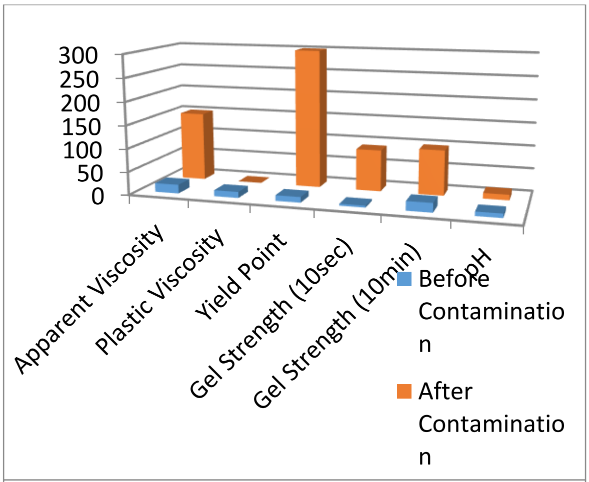


Figure 13: Cement of 5g as contaminants
Figure 14: Sand (silica) of 1g as contaminants



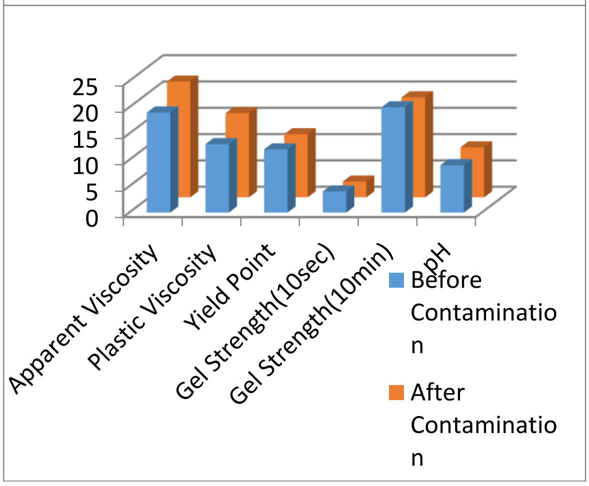


Figure 15: Sand (silica) of 3g as contaminants Figure 16: Sand (silica): 5g as contaminants

3.1. Result of Carbonate Contamination

To identify a carbonate contaminant in the mud system, there will be an indication of high gel strengths, high filtrate, high Mf, no calcium present but in the case of carbonate contamination, the Pf high and low for bicarbonate contamination.

The observed result in Figures below shows certain properties variations when carbonate is added. The carbonate effect is largely on the Gel strength which decreases as the amount of added carbonate increases. The pH has no charges, which also means carbonate keeps the mud in it Alkalinity state, as it was the case with cement.

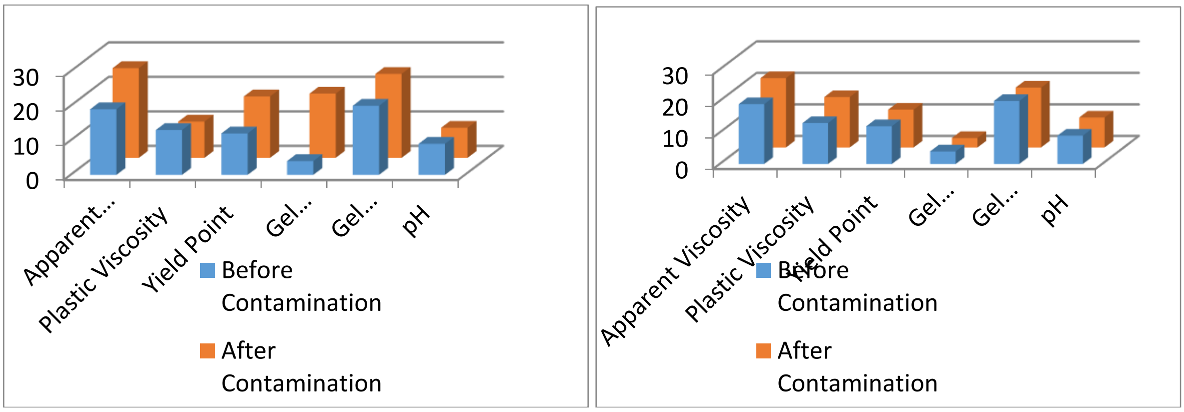


Figure 17: Carbonate (Na_2CO_3) of 1g & 3g as contaminants

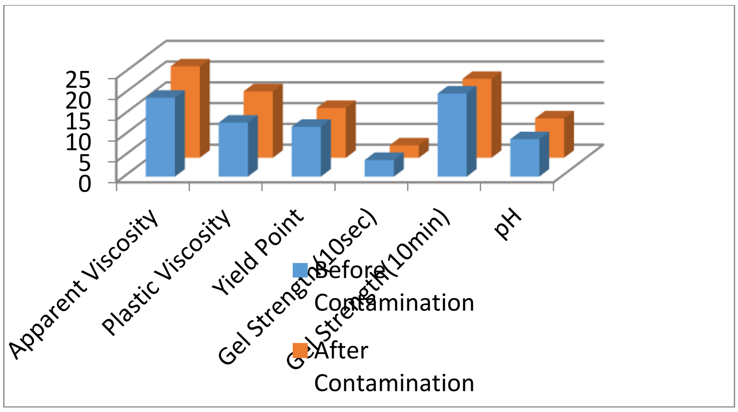


Figure 18: Carbonate (Na_2CO_3) of 5g as contaminants

Figure 10: Salt (NaCl) of 5g as contaminants

Salt Contamination; ions, $Na^{+}Cl^{-}$, that enter the mud system as a result of drilling salt sections or from formation saltwater flow cause a mud to have high Yield Strength, high fluid loss, and pH decrease.

Cement contamination: in which calcium ion tends to replace the sodium ions on the clay surface through a base exchange, thus causing undesirable changes in mud properties such as rheology and filtration.

Carbonate contamination; ions (CO_3^{-}, HCO_3^{-}), these contaminants cause the mud to have high yield and gel strength and a decrease in pH. The changes are shown (figure 17 & 18).

4. Conclusion

Based on the experiment work done on water-based mud system to ascertain the effect of contaminants; salt, silica sand, cement and carbonate on the rheological properties and performance of the mud, the following conclusion can be drawn:

i. It means that the presence of a contaminant on the drilling mud either reduces or increases the properties and rheological properties of the mud system and in turn affects the rate of penetration, it performance and also poses serious drilling problems.
ii. Salt Contamination; ions, $Na^{+}Cl^{-}$, that enter the mud system as a result of drilling salt sections or from formation saltwater flow cause a mud to have high Yield Strength, high fluid loss, and pH decrease
iii. Cement contamination; in which calcium ion tends to replace the sodium ions on the clay surface through a base exchange, thus causing undesirable changes in mud properties such as rheology and filtration
iv. Carbonate contamination; ions (CO_3^{-}, HCO_3^{-}), these contaminants cause the mud to have high yield and gel strength and a decrease in pH.

References

[1] Ali, K., Vipulanandan, C. and Richardson D. (2013), Salt (NaCl) contamination of the resistivity and plastic viscosity of bentonite drilling mud, Proceedings of the center for innovative grouting materials and technology (CIGMAT) Conference & Exhibition.

[2] Bariod N. L. Inc (1985):" Source of mud problem, Volume1" (page 207-218).

[3] Basirat B, Vipulanandan C, Richardson D (2013): Proceedings of THC-IT Conference & Exhibition, Pp 1-2.

[4] Bourgoyne, A.T., Millheim K. K., Chenevert M. E., Young Jr F. S (1986), Applied Drilling Engineering, SPE Textbook Series, Volume 2, Pp 42 – 78, Richardson, TX.

[5] Hassiba, K. J., and Amani, M. (2013), The Effect of Salinity on the Rheological Properties of Water Based Mud under High Pressures and High Temperatures for Drilling Offshore and Deep Wells, Earth Science Research, 2(1): 175-186.

[6] Al-Kayiem, H. H., Zaki, N. M., Asyraf, M. Z. & Elfeel, M. E. (2010). Simulation of the Cuttings Cleaning During the Drilling Operation. American Journal of Applied Science 7(6):800-806.

[7] Kumapayi, Y., Bello K., Adekomaya, O., Akintola, A., Dala, J., Mohammed, I., and Olafuyi, O., (2014), Investigating the Effects of Contaminants on the performance of Oil Based Invert Emulsion Drilling Fluid, Petroleum Technology Development Journal, 2: 60-74.

[8] Laboratory Manual (2003). Drilling Engineering (PETE 203), Department of Petroleum Engineering, King Fahd University of Petroleum & Minerals, Pp 1-14 & 25-27

[9] Medermont, J. (1973). Drilling Mud and fluids Addictive. *Park Ridge, N.J., Noyes Data Corp.*, Page 4, 32-34, 44

[10] Olufemi. A. A., Olalekan O., (2011), an experimental study of the effect of contaminants on the flow properties of oil-based drilling mud. Journal of Petroleum & Coal 53(4): 315-319.