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EFFECT OF SEAWATER AND CEMENT CONTAMINANTS ON DRILLING WATER AND NON-WATER BASED DRILLING MUDS

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Abstract

Over the years, drilling for oil and gas is a high-risk and challenging venture. Despite the uncertainty and the problem associated with the drilling operations, wells are being drilled every day. To overcome these problems, the drilling mud engineers must prepare for these challenges to meet the expected revenue and the time allocated for a particular drilling job. A practical test was conducted at a temperature of 120^{o}F and an atmospheric pressure of 14.7 psi to determine the effects of seawater and cement slurry contaminant on drilling water and non-water-based drilling mud. The results of the sea water contaminant on water-based mud shows that there is slight increase in the plastic viscosities from 27cP to 30cP, yield point from 14 Ib/100ft^2 to 18 Ib/100ft^2, while the results of the cement contaminant of oil-based mud of 10 grams to 50 grams show plastic viscosities increase from 24cP to 25c and yield point decrease from 12 Ib/100ft^2 to 8 Ib/100ft^2 respectively. The presence of other contaminants in the drilling mud reduces the properties as well and in turn affects the rate of penetration and its performance, and poses serious drilling problems. Based on the practical conducted and analysis of results obtained, It is recommended that a mud program should be designed to gives provision for correction of suspected or expected contaminant(s) beforehand and basic knowledge of the drilling mud chemistry must be known to effectively supervise the contaminants control and mud must be properly treated to prevent the destruction of subsurface equipment.

Keywords: Drilling fluids, contaminants, water base mud, oil base mud

Introduction

Drilling fluids are usually formulated to meet certain properties to enable the mud to carry out its basic functions. A properly designed drilling fluid should be able to perform some major functions perfectly. Contaminants are materials that cause undesirable changes in drilling fluid properties. Solids are by far the most prevalent contaminants, which leads to high rheological properties and slow the drilling rate. Some contaminant can be predicted before treatment start. The predictable contaminants are cement, make-up water, salt, and acid gases such as hydrogen sulphide and carbon dioxide. Pretreatment can be advantageous as long as it is not excessive and does not adversely affect mud properties (Bairs, 1967). Other contaminants may be unexpected and unpredicted such as those whose concentration increases gradually, and eventually shows their effect by altering the fluid properties. These changes in fluid properties occur when deflocculants are expended at high downhole temperatures

The composition and treatment of drilling mud depend largely on the formation encountered or material added during drilling operations. To optimize the drilling mud performance, we need to understand the functions of the drilling mud to enhance the drilling operations. The drilling fluid can be Pneumatic/ Air**;** Water Based Mud**;** Oil-based Mud and Synthetic:

In general, a contaminant is any material that causes undesirable changes in drilling fluid properties. Solids are by far the most prevalent contaminants. Excessive solids, whether introduced into the formation or from the formation, lead to high rheological properties and slow the drilling rate. Most other contaminants are chemical treatments 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 sulphide and carbon dioxide. Pretreatment can be advantageous as long as it is not excessive and does not adversely affect mud properties. (Medermonth, 1973)

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 downhole temperatures. It is essential to keep accurate records of drilling fluid properties to ensure that any gradual build-up of a contaminant is monitored and detected. The composition and treatment of drilling mud depend on the formation encountered or material added during drilling operations. Some of these materials under certain circumstances, along with cuttings, can be considered contaminants. If large quantities of these contaminants are encountered during drilling, certain factors must be taken into account depending on the contaminant. These factors are considered individually in the following discussions of each type of contaminant.

Bentonite added in excess, drill cuttings, or barite may lead to unacceptable rheological and filtration and affect the drilling operation. Water or excessive chemical treatment can lead to unacceptable mud changes and cause unscheduled viscosifier additions. Chemicals to remove contaminants are possible for some and impossible for others. The important rule is that treatment must match the contaminant and result in the desired effect on the mud. Some of these contaminants can be predicted and pretreated or controlled. The predicted contaminants are cement; makeup water, massive salt, anhydrite formations, or gases such as hydrogen sulphide and carbon dioxide in areas where documentation shows a probable presence. These contaminants can be chemically removed in some cases before they can have an overall negative effect on the clay or organic deflocculants. Pretreatment has advantages as long it is not excessive and does not adversely affect the mud properties.

Pretreating mud with sodium bicarbonate before drilling cement is an example. Other contaminants are unpredictable and unexpected, such as those which result from small feed-ins with a gradual build-up of a contaminant. Predicting contamination-potential problems while drilling, an exploration test is difficult. The contaminant shows its effect by altering the properties of the system and part is determined by the resultant properties. When deflocculants are slightly depleted or after a long trip when the fluid is allowed to remain stagnant and subjected to elevated downhole temperatures or after additional contaminant enters the system, changes become evident. It is always necessary to keep a complete and accurate record of drilling fluid properties to see the gradual onset of contamination and avoid deterioration of an otherwise good system. Rig site oven testing a mud provides the necessary data for monitoring and treating purposes (Baroid, 1985).

Often occurs at times when deflocculants are expended at high downhole temperatures. It is essential to keep accurate records of drilling fluid properties to ensure that any gradual build-up of a contaminant is monitored and detected. Thus, the higher concentration of contaminants in a drilling mud system causes a detrimental effect on its performance (Broughton, 1938)

DRILLING FLUID SELECTION CRITERIA

Drilling fluids are selected based on cost, application and performance, production concerns, logistics, exploration concerns, and environmental impact and safety. Drilling mud gets contaminated and poses a serious problem to a drilling operation. To be successful in any drilling operation, early detection of these contaminants and application of the necessary preventive measures needs to be carried out thereby reducing their effects to a minimum. However, the instability in the drilling mud properties is as a result of various contaminants incorporated into the mud system.

DRILLING FLUID CLASSIFICATIONS

Drilling fluids are classified into the following: pneumatic/air, water-based, oil-based and synthetic
Pneumatic (air/gas-based) fluids are used for drilling depleted zones or areas where abnormally low formation pressures may be a concern or encountered. An advantage of pneumatic fluids over liquid mud systems can be seen in increased penetration rates. Cuttings are blown off the cutting surface ahead of the bit as a result of the considerable pressure differential. The high-pressure differential also allows the formation of fluids from permeable zones to flow into the wellbore (Bourgoyne, 1986). Air/gas-based fluids are ineffective in areas where large volumes of formation fluids are encountered. A large influx of formation fluids requires converting the pneumatic fluid to a liquid-based system. As a result, the chances of losing circulation or damaging a productive zone are greatly increased.

Water-based fluid are the most extensively used drilling fluids. They are generally easy to build, inexpensive to maintain, and can be formulated to overcome most drilling problems. Freshwater drilling fluids are cheaper and easier to maintain on land locations. Saline water drilling fluids are cheaper offshore of the salinity is sea salt. Saline water drilling fluids include potassium chloride and calcium chloride salts. These salts are used to provide less damage to formations and to delay wellbore instability (Baroid, 1985).

Oil-based fluid A primary use of oil-based fluid is to **d**rill troublesome shales and to improve hole stability. They are also applicable in drilling highly deviated holes because of their high degree of lubricity and ability to prevent the hydration of clays. Oil-based fluid may also be selected for special applications such as in high-temperature/high-pressure wells and used to minimizing formation damage on native-state coring. Another reason for choosing oil-based fluid is that they are resistant to contaminants such as anhydrite salt, and CO_2 and H_2S acid gases.

Synthetic fluid In a quest to find a drilling fluid that behaves like oil at the bottom of the hole and water at the top of the hole, different liquids are now used instead of mineral oil... Disposal of oil-based drilling fluids adds significance to the cost of drilling. New types of fluids have been introduced and are being used. These are synthetics since they are neither water- nor oil-based. Each major drilling fluid company has developed a synthetic fluid to replace oil mud. When drilling conditions require oil mud offshore, diesel in drilling fluids has generally been replaced with mineral oil.

METHOD AND PROCEDURE

The method and procedure used to investigate the effects of salt and cement on the drilling fluid properties of both water-based mud and oil-based mud are summarized below. The fluid properties test was conducted at a temperature of 120^0F, atmospheric pressure (14.7psia), and dial reading values at 600 rpm, 300 rpm, 6 rpm, and 3 rpm respectively. All the equipment used during the experiment were calibrated and tested according to API specifications for equipment and testing procedures. The drilling fluids were formulated to meet certain properties and to enable the mud carry out its basic functions.

RESULTS ANALYSIS

The experimental results obtained and the various method of treating the drilling mud contaminants are analysed and discuss below.

Table 1 Analysis of drilling mud properties of OBM and WBM without contaminants

RPM (Θ)	OBM	WBM
600	58	65
300	36	40
6	8	6
3	7	5

Table 2 Rrheological analysis of uncontaminated OBM and WBM

Drilling Mud Properties	OBM	WBM
Plastic viscosity (PV), cP	22	25
Yield Point (YP), Ib/100ft^2	14	15

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Gel strength, 10sec/10mins (lb/100ft^2)	8/9	6/7
Mud weight, ppg	9.0	8.5
pH	9	9
Chlorine ion,(mg/l)	12,000	15,000
Fluid loss, (ml)	3	5

Table 1 and **Table 2** showed the fluid properties of uncontaminated Water and Oil Based Mud respectively. It was observed that the viscosity readings at 600 rpm and 300 rpm for water-based mud were 65 cP and 40 cP whereas oil-based mud had 58 cP and 36 cP respectively. Conversely, at the viscosity readings, 6 rpm, and 3 rpm the oil-based mud was 8 cP and 7 cP whereas water-based mud had 6 cP and 5 cP. The viscosity reading at 600 rpm and 300 rpm indicate the drilling mud flow characteristic within the drill pipe while 6 rpm and 3 rpm indicate the drilling mud flow characteristic within the annulus. It implies that the water-based mud had a higher shear rate than the oil-based mud whereas the reverse was the case at low viscosity readings. Therefore, the flow regime must be considered independently at each stage of the rotary system to achieve effective hole cleaning.

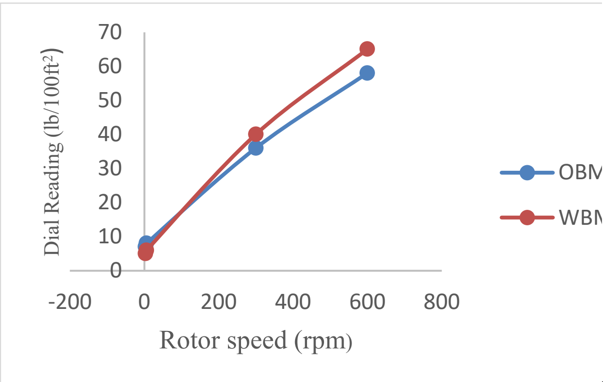

Fig. 1. Rheological analysis of OBM and WBM without contaminants

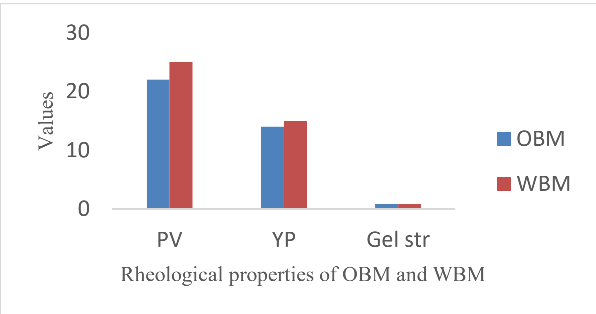

Fig. 2. Comparing the uncontaminated rheological properties of OBM and WBM

Again, it was observed that there was a slight difference in plastic viscosity, yield point, and 10-second/10 minutes gel strength. Plastic viscosities of oil-based mud and water-based mud were 22 cP and 23 cP respectively; yield points were 14 lb/100ft^2 and 15 lb/100ft^2, 10 seconds/10 minutes gel strength were 8/9 lb/100ft^2 and 6/7 lb/100ft^2 . However, there was no significant change in viscosity in liquid and solid phases in both drilling muds. This indicate that there was no significant difference in bit meaning the penetration rates were the same in oil-based mud and water-based mud which is the function of the plastic viscosity. Similarly, there was no significant difference in the yield points of both oil-based mud and water-based mud. This also indicate that the electrochemical or attractive forces of both drilling muds are the same, hence they will slightly exhibit the same hole-cleaning capacity.

There was a slight difference in the 10 seconds/10 minutes gel strength. Although both drilling muds had progressive gel strength that is 10-second/10 minutes gel strengths differ significantly which means the 10 minutes gel strength was higher than the 10 seconds gel strength. Both drilling muds had 10 seconds and 10 minutes gel strength higher than 4 lb/100ft^2 which is better for a weighted mud to be able to suspend barite.

Again, the decrease in the 10 seconds and 10 minutes gel strength in the water-based mud may have contributed to the presence of the deflocculation. The mud weight for oil-based mud was 9.0 ppg and for water-based mud was 8.5 ppg. The chlorine ion of oil-based mud and water-based mud were 12,000 mg/l and 15,000 mg/l respectively. It indicates that the high content of sodium in the water than in the oil-based mud. Besides, the volume of water used in the formulation was higher than in the oil-based mud. Therefore, chlorine content must be evaluated before drilling mud formulation. The fluid loss of oil-based and water-based muds were 3 MLS and 5 MLS respectively meaning there was a slight difference in the fluid loss.

Table 3 Chemical and rheological properties of sea water contaminant of WBM

Properties	Volume, V(ml)				
	10	**20**	**30**	**40**	**50**
PV	27	29	29	30	30
YP	14	15	17	18	18
Gel. str (sec/min)	9/10	9/10	10/11	10/11	10/11
Mud W.	9.0	9.0	9.0	9.0	9.0
pH	8.5	8.5	8.3	8.2	8.2
Ch. ion mg/l	15,000	15,300	15,500	16,000	16,000
Fl. loss (ml)	5	6	7	8	8

Table 3 and Table 4 shows the results of the diagnostic test of properties of sea water contaminant of water-based mud .and the properties of cement contaminant of oil-based mud respectively.

In Table 3, upon the concentrations of seawater contaminant from 10grams to 50 grams, there was a slight increase in the plastic viscosities from 27 cP, to 30 cP; yield points from 14 lb/100f^{t2}, to 18 lb/100f^{t2}; and 10 seconds and 10 minutes gel strengths from 9/10 lb/100f^{t2} to 10/11 lb/100f^{t2} respectively. When comparing the results obtained with contaminated water-based mud to uncontaminated water-based mud it can be seen that there was a clear indication of an increase in the rheological properties meaning seawater has an impact on drilling fluid properties. There was also an increase in plastic viscosities because of the additional increase in the liquid and solid phases obtained from the seawater. Although there was a threshold point at 40 grams concentration, an increase in pressure drops down the drill string caused by an increase in plastic viscosity reduces the available flow rate and tends to offset any increase in lifting ability. However, high plastic viscosity is never desirable and should be maintained as low as practical, hence attention must be paid to the plastic viscosity of water-based drilling mud.

In the case of yield point, there was a slight increase upon the incremental increase of seawater meaning sea water had an impact on the yield point which is in line with the result of Kassim M, 2009. Although, the threshold point was observed at a concentration of 50 grams. A higher yield point is appreciated to achieve the effective carrying capacity of the cuttings to the surface and to increase the circulating pressure drop in the annulus. The yield point is a good indicator of flow behavior in the annulus and compositional changes that affect the flow behavior in the annulus. An increased yield point aids in hole cleaning detrimental to the problems of lost circulation and swabbing so a compromise must be reached. Therefore, for this reason, no absolute guideline for yield point values can be given.

Furthermore, it was an appreciable increase in the 10 seconds and 10 minutes gel strengths upon the corresponding increase of the seawater contaminant when compare with the uncontaminated water-based mud. It was obvious that the increase was caused by electrically charged particles that linked together to form a rigid structure in the drilling fluid. Attention must be paid to the gel strength because higher gel strengths are undesirable because they retard the separation of cuttings and entrained gas at the surface, and also because they raise the pressure required to re-establish circulation after changing bits.

Again, an increase in gel strength is normally the first indication of the beginning of flocculation, therefore, higher gel strength should be minimized. Upon seawater concentrations of 10 grams to 50grams, the mud weight reached a constant of 9.0ppg meaning there was no significant change upon the incremental increase of the seawater. When compared to uncontaminated water-based mud, there was a significant increase from 8.5 ppg to 9.0 ppg meaning the seawater had an impact on mud weight of the water-based mud. Similarly, upon the concentrations of 10 grams to 50 grams sea water contaminant, the chlorine ion increased correspondingly from 15,000 mg/l to 16,000 mg/l respectively. It was observed that there was no change in chlorine ions upon 10grams sea water concentration when compared with the uncontaminated water-based mud. However, as the concentration of seawater increased there was an appreciable increase in the chlorine ion content. Attention should be paid to the chlorine ion of the drilling fluid because if in excess, it may lead to downhole assembly corrosion. With the concentrations of seawater from 10 grams to 50 grams, it was further observed that there was a corresponding decrease in pH from 8.5 to 8.2 respectively. This means the presence of seawater contaminant still retains the mud system in an alkaline state, it has no negative effect on the mud system. Although, it is important to note that the pH levels still affect the solubility of the organic thinners and the dispersion of clay presents in the mud. Further investigation was done on the fluid and upon the concentration of seawater contaminant of 10 grams to 50 grams, fluid loss increases from 5 ml.8 ml respectively. It was shown that the presence of seawater contaminant in the mud system increased the fluid loss which had a similar investigation with (Kassim 2009). Proper care must be taken on the fluid loss property of a mud system when contaminated with seawater as the fluid loss increases with an increase in seawater contamination which will lead to formation damage, fines migration in the formation, wettability changes, and it will lead to a reduction of the drilling mud efficiency.

In Table 4, it was found that upon the cement concentration on oil-based mud of 10 grams to 50 grams, they were corresponding plastic viscosities of 24 cP to 25 cP; yield points from 12 lb/100f^{t2} to 8 lb/100f^{t2}; 10 seconds and 10 minutes gel strengths from 9/12 lb/100f^{t2} to 16/17 lb/100f^{t2} respectively. When comparing the results obtained with contaminated oil-based mud to uncontaminated oil-based mud, it was noted that there was a slight increase in the plastic viscosity which shows that cement had an impact on the oil-based mud system. With the increase of cement concentrations in the mud system, it was shown that there was an unevenness in the plastic viscosities. It was also observed there was an appreciable decrease in yield points with a corresponding increase in cement concentration on the oil-based mud system in comparison with uncontaminated oil-based mud.

Table 4 Chemical and Rheological Properties of Cement Contaminant of OBM

Properties	**Quantity, Q(g)**				
	10	**20**	**30**	**40**	**50**
PV(cP)	24	25	24	25	25
YP(Ib/100ft^2)	12	11	10	8	8

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Gel str(sec/min)	10/12	12/13	14/15	16/17	16/17
Mud W.	10	10.5	11	11.3	11.6
pH	9.2	9.4	9.5	9.5	9.5
Ch. ion mg/l	12,000	12,000	12,000	12,000	12,000
Fl. loss (ml)	3.1	3.1	3.1	3.1	3.1

Conversely, the presence of cement in the mud system caused a decrease in the yield points with a corresponding increase in the cement concentration which means the electrical chemical interaction of the solid in the mud system is been affected adversely, and ultimately effective hole cleaning may not be achieved which leads to operational failure. Furthermore, the 10 seconds and 10 minutes gel strengths of the mud system increased drastically with the presence of cement contaminant. In practice, higher gel strengths are undesirable because they retard the separation of cuttings and entrained gas at the surface, and also because they raise the pressure required to re-establish circulation after changing bits. It is advocated to maintain low gel strength to suspend barite.

For the cement concentrations of 10 grams to 50 grams, the oil-based mud had mud weights of 10 ppg to 11.6 ppg. There was a drastic increase in the mud density when comparing the uncontaminated oil-based mud to the contaminated oil-based mud. This implies that effort must be made to avoid cement contamination on the mud system to achieve successful drilling operations. An investigation was carried out on the effect of the pH of the oil-based mud when contaminated with cement.

For the concentration of cement of 10 grams to 50 grams, the pH increase from 9.2 to 9.5. The result shows that there was a slight increase in the pH of the oil-based mud system. However, there was a threshold at 30 grams concentration of cement, and the mud system retained its alkaline state meaning cement contaminant has no adverse effect on oil-based mud system.

Table 5 Effects of seawater contaminant on rheological properties of WBM

Seawater (ml)	Speed (rpm) 600	300	6	3	PV	YP
10	66	44	8	6	22	22
20	68	47	9	7	21	26
30	69	50	10	8	19	31
40	69	51	11	9	18	33
50	69	51	11	9	18	33

Table 5 to **Table 8** show the effect of seawater and cement contaminants on oil and water-based muds. In Table 5, it is observed that upon the 10 grams concentration of seawater on water-based mud, and at a shear stress of 600 rpm, the dial reading was 66 cP as against 65 cP uncontaminated mud system meaning that there was a slight significant increase at higher and lower shear stress. As the sea water concentrations uniformly increased by 10 grams interval each, there was also a corresponding slight increase in the shear rate and at 30 grams, the threshold was observed. This indicate that the presence of seawater does not have a drastic effect on the dialing readings. However, since plastic viscosity and yield point are obtained from the dial readings of 600 rpm and 300 rpm, attention should also be paid to be able to maintain the rheological drilling mud properties for successful drilling and completion operations.

Table 6 Effect of seawater contaminant on the rheology of OBM

Seawater	Speed (rpm) 600	300	6	3	PV	YP	Gel
10	68	41	9	8	27	14	9/10
20	73	44	9	8	29	15	9/10
30	75	46	11	10	29	17	10/11
40	78	48	11	10	30	18	10/11
50	78	48	11	10	30	18	10/11

Table 6 shows that upon the 10 grams concentration of seawater on oil-based mud at a shear stress of 600 rpm, the dial reading was 68 cP as against 58 cP for uncontaminated oil-based mud system which show there was a significant increase at the higher shear stress on the 10 grams sea water contaminant on oil-based mud. This change will affect the mud flow behavior in the drill pipe which in turn will adversely affect drilling operations when not controlled. There was also an incremental increase with increase in seawater concentrations. However, the reverse was the case at low shear stress. However, there was no significant increase when both mud systems were contaminated with cement contaminant as shown in Tables 7 and 8.

Table 7 Effect of cement contaminant on the rheology of WBM

Grams(g)	Speed (rpm) 600	300	6	3	PV	YP
10	67	45	7	5	22	23
20	68	46	8	6	22	24
30	70	47	9	7	23	24
40	70	47	9	7	23	24
50	70	47	9	7	23	24

Table 8 Effect of cement contaminant on the rheology of OBM

Grams(g)	Speed(rpm) 600	300	6	3	PV	YP	Gel
10	60	36	8	7	24	12	10/12
20	61	36	8	7	25	11	12/13
30	58	34	5	4	24	10	14/15
40	58	33	4	4	25	8	16/17
50	58	33	4	4	25	8	16/17

Upon 10 grams concentration of cement in water-based mud, the 600 rpm was 67 cP in the water-based mud system whereas uncontaminated was 65 cP and in the oil-based mud system the 600 rpm was 60 cP whereas uncontaminated was 58 cP. Consequently, this paper has shown that there is slight significant increase in higher shear stress in the presence of cement contaminants in both water and oil-based mud systems, Kassim M. (2009).

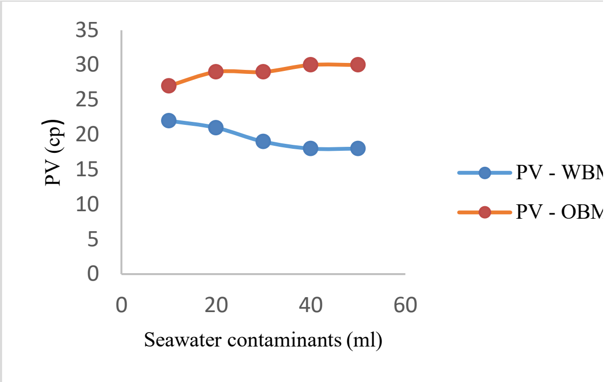

Fig. 3. Effect of Seawater Contaminants on PV of OBM and WBM

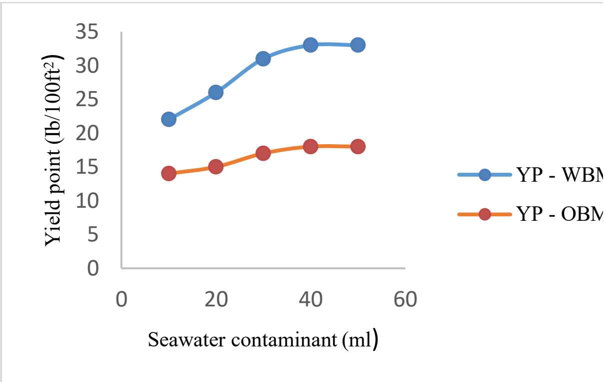

Fig. 4. Effect of Seawater contaminant on yield point of OBM and WBM

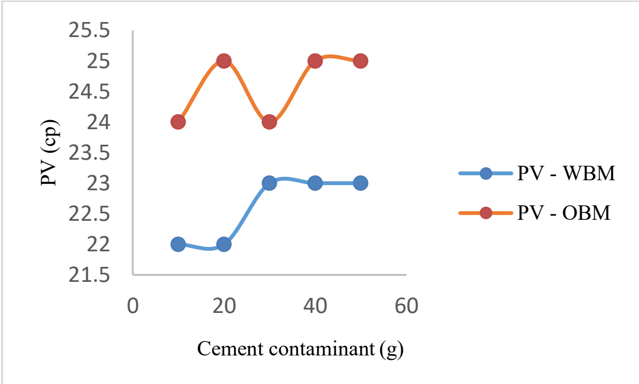

Fig. 5. Effect of cement Contaminant on PV of OBM and WBM

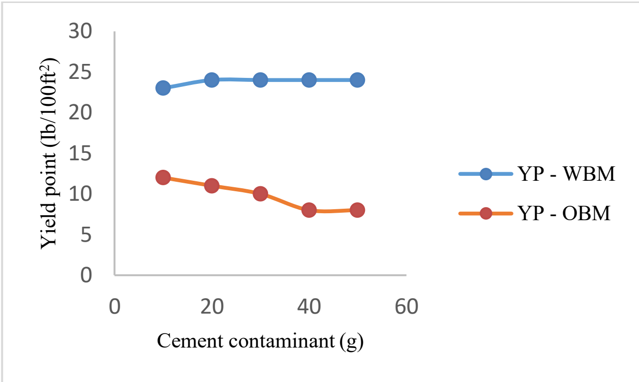

Fig. 6. Effect of cement contaminants on yield point of OBM and WBM

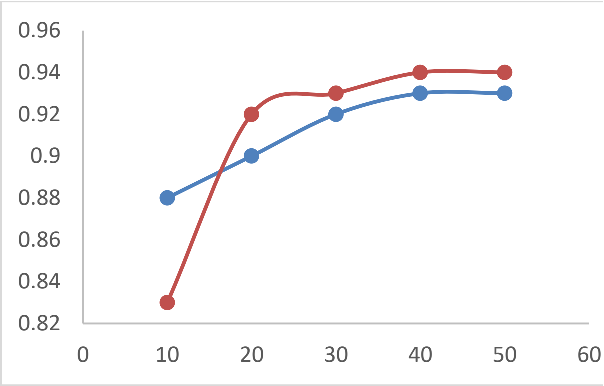

Fig. 7. Effect of Cement Contaminants on Gel Strength of OBM

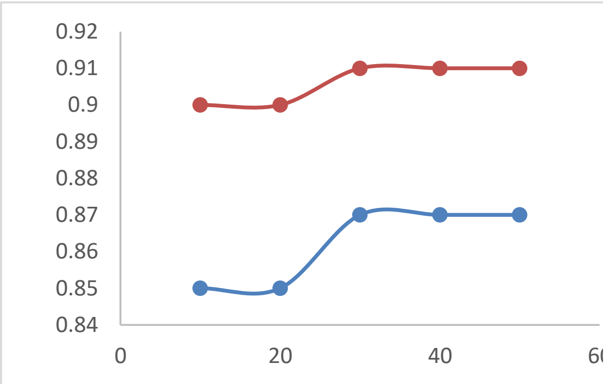

Fig. 8. Effects of seawater Contaminants on Gel Strength of OBM

CONCLUSIONS

The experimental results of seawater and cement contaminants have shown that introduction of foreign agents into mud affects the rheological properties and chemical properties of both water-based mud and oil-based systems respectively. Also, the presence of other contaminants in the drilling mud will lead to change in the rheological properties as well and in turn affects the rate of penetration, and its performance and develops serious drilling problems.

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