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Sudan University of Science And Technology

College of Petroleum Engineering & Technology

Petroleum Engineering Department

Experimental Studyto Recognize the Effects of Salts (potassium and sodium chloride)Contamination on Rheological Properties of Water Base Mud Under Different Temperatures

دراسة معملية لتاثير دخول الملح على الخواص التيارية لسائل حفر ذو اساس مائي تحت تاثير درجات حرارة مختلفة

Graduation Project Submitted to The College of Petroleum Engineering & Technology, Sudan University of Science & Technology.

Partial Requirement For BscDegree in Petroleum Engineering

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Dedication

Our exalted teachers,,,

Whom we met and a lot learned thought out our educational life ,,,

Thanking and very grateful for theirs great efforts ,,,

Guidance and assistance ,,,

Kind advice and encouragement ,,,

To them ,,,

We would like to dedicate and present this simple efforts on this study ,,,

Abstract

The drilling engineer must have a good estimate of how the stability of drilling fluid changes due to salt contamination encountered during drilling operation. a mud sample with different concentrations of sodium and potassium chloride salt (KCl,NaCl) was formulated in order to study they effect on the rheological properties of drilling fluid at ambient and elevated temperature conditions. This study shows that the drilling mud efficiency is affected with temperature as the result of thermal degradation. It was concluded that the rheological properties such as viscosity, yield point, and gel strength of drilling mud decrease as the concentration of KCl and NaCl salt increases. This indicates that with the KCl and NaCl salt contamination, there is an advanced decline in the performance of drilling mud and the salt affects the dispersion, hydration and flocculation behavior of the particles which make it incompetent for cutting suspender. Also, it was observed that when the concentration of salts increases in the drilling mud sample the fluid loss into the formation increases.

تجريد

يجب ان يكون لدى مهندس الحفر تقدير جيد لمدى أستقرارية سائل الحفر للتغيرات الناتجة من التلوث من جراء دخول الملح على سائل الحفر اثناء عمليات الحفر. تم تكوين عينة من سائل الحفر مع تراكيز مختلفة من املاح كلوريد البوتاسيوم وكلوريد الصوديوم وذلك لدراسة تاثيرهم على الخصائص التيارية لسائل الحفر تحت تاثير درجات الحرارة المختلفة .هذه الدراسة تظهر ان كفاءة سائل الحفر تتاثر بالتغير في درجات الحرارة . وتم التوصل الى ان الخصائص التيارية لسائل الحفر كاللزوجة ، مقاومة الجل ، نقطة الخضوع تقل بالزيادة في تراكيز كل من كلوريد الصوديوم وكلوريد البوتاسيوم. هذا يشير الى ان دخول هذه الاملاح يؤدي الى انخفاض في ادائية سائل الحفر وتم ايضا ملاحظة زيادة في فواقد سائل الحفرخلال التكوين مع زيادة تراكيز الاملاح المذكورة انفاً.

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CHAPTER (1)

INTRODAUCTION

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1.1. Introduction:

In drilling operation, the drilling fluid system assuming that the condition of the hole is stable, the drilling fluid properties such as density, viscosity, filtration, etc. should not change during the drilling operation but in normal operation the drilling fluid properties are changed by contamination in the borehole, because the condition of the hole is unstable. This contamination can affects on the rheological properties of drilling fluid. Rheology refers to the flow behavior of all forms of matter. Certain rheologic measurements made on fluids, such as viscosity, gel strength, etc. help determine how this fluid will flow under a variety of different conditions. This information is important in design of circulating systems required to accomplish certain desired objectives in drilling operation. Drilling fluid tests are performed to evaluate the properties and characteristics of the fluid, and to determine its performance limitation .The rheological properties affected by contamination during drilling mud circulation .Actually we have several type of this contamination such as (salt ,cutting, Gypsum ,Anhydrite ,Cement, etc …)

Any change in rheological properties will change the performance of drilling mud .It is very important to treat drilling mud from any foreign material causes undesirable changes in mud properties. A good mud engineer should measure and maintain drilling fluid composition with regular tests of fluid composition and implements solutions to drilling-related problems. Drilling engineers select specific drilling fluid with most favorable properties for the job. Most of the drilling fluid functions are controlled by its rheological properties. A drilling fluid specialist or a “Mud Engineer” is often on site to maintain and revaluate these properties as drilling proceeds. The main factors governing the selection of drilling fluids types of formation to be drilled, The range of temperatures and pore fluids pressure exhibited by the formation. While, in addition to the above, selection of the drilling fluid can be informed through consideration of other factors such as - production concerns, environmental impact, safety . The most important factor that governs selection of drilling fluid is the “overall well cost” This study shows that the drilling mud efficiency is affected with contamination at different concentrations and different temperatures, to Evaluation the drilling mud.

1.2. Problem Statement:

Enter Nacl and kcl to the mud system as a result of drilling salt section or from formation saltwater flow , it considered to be a contamination to drilling fluid , and have the ability to effect on the drilling fluid properties .

1.3. Objectives of the study:

- To study the effect of salt contamination (Nacl, Kcl) on Rheological Properties of drilling fluids with different concentrations.
- To study the effect of salt contamination (Nacl, Kcl) on Rheological Properties of drilling fluids under different temperatures.
- To evaluate drilling mud before and after contamination.
  sub objective:
  To study the effect of filtration.

1.4. Methodology:

1. Prepare a water base drilling fluid using commercial bentonite.
2. Identify the rheological properties of the prepared mud before and after adding salts (NaCl and KCl), with different concentrations and temperatures.

CHAPTER (2)

LITERATURE REVIEW AND THEORATICAL BACKGROUND

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LITERATURE REVIEW AND THEORATICAL BACKGROUND

2.1. Literature Review:

Olufemi et al. (2011)studied the effect of cutting on drilling fluid of oil base mud and found that drilling fluid viscosity, fluid loss and density are increased.

Khaled J. Hassiba1 and Mahmood Amani1in 2012 studied the effect of kcl and Nacl on the rheological properties of the water based mud under High Pressures and High Temperatures for DrillingOffshore and Deep Wells the shear stress-shear rate high when add Nacl and low of the shear stress-shear rate when add Kcl .

Joel, O.F α, Durueke, U.J σ & Nwokoye C.U ρ.(2012) Effect of KCL on Rheological Properties of Shale Contaminated Water-Based mud The rheological values using FANN viscometer with different concentration of KCl Test results indicated that the KCl inhibited the swelling tendencies of the shale and the rheological values reduced drastically.

Nagham Sami(2015) is found that the rheological and filtration properties of drilling mud are affected by magnesium salt contamination and concluded that magnesium salt contamination decreases the plastic viscosity ,yield point ,gel strength and makes the drilling mud has a poor filtration loss characteristic.

H. I. Kula and C. Vipulanandan, Ph.D., P.E.(no date) studied the effect of gypsum on resistivity of Water-Based mud the changes in electrical resistivity of drilling mud at room temperature was investigated. The results showed that the calcium sulfate decreased the resistivity of the drilling mud.

2.2. Drilling Fluids Background:

"In geotechnical engineering, drilling fluid is used to aid the drilling of boreholes into the earth. Often used while drilling oil and naturalgas wells and on exploration

drilling rigs, drilling fluids are also used for much simpler boreholes, such as water wells. Liquid drilling fluid is often called drilling mud. The three main categories of drilling fluids are water-based muds (which can be dispersed and non-dispersed), non-aqueous muds, usually called oil-based mud, and gaseous drilling fluid, in which a wide range of gases can be used.

The main functions of drilling fluids include providing hydrostatic pressure to prevent formation fluids from entering into the well bore, keeping the drill bit cool and clean during drilling, carrying out drill cuttings, and suspending the drill cuttings while drilling is paused and when the drilling assembly is brought in and out of the hole. The drilling fluid used for a particular job is selected to avoid formation damage and to limit corrosion.

2.2.1. Types of drilling fluid:

"Many types of drilling fluids are used on a day-to-day basis. Some wells require that different types be used at different parts in the hole, or that some types be used in combination with others. The various types of fluid generally fall into a few broad categories.(Wikipedia)

- Air
- Air/water
- Air/polymer
- Water
- Water-based mud (WBM)
- Oil-based mud (OBM)

2.2.2. Functions of drilling fluid:

The main functions of a drilling mud can be summarized as follows:

- Remove cuttings from the well.
- Suspend and release cuttings.
- Control formation pressures.
- Seal permeable formations.
- Maintain wellbore stability.
- Minimizing formation damage.
- Cool, lubricate, and support the bit and drilling assembly.
- Transmit hydraulic energy to tools and bit.
- Ensure adequate formation evaluation.
- Control corrosion (in acceptable level.
- Facilitate cementing and completion.
- Minimize impact on environment.

2.2.3. Composition of drilling fluid:

Water-based drilling mud most commonly consists of bentonite clay (gel) with additives such as barium sulfate (barite), calcium carbonate (chalk) or hematite.

2.2.4. Factors influencing drilling fluid performance:

Three factors affecting drilling fluid performance are:

1-The change of drilling fluid viscosity.

2-The change of drilling fluid density.

3-The change of mud PH.

2.1. 5. Properties of drilling fluid:

The properties of drilling fluids are:

- **Density (specific gravity):**

Density is defined as weight per unit volume. It is expressed either in ppg (lbs gallons) or pound per cubic feet or compared to the weight of an equal volume of water as specific gravity. Density is measured with a mud balance. One of the main functions of drilling fluid is to confine formation fluids to their native formations or beds".(Rabia_Hussain-Well Engineering&Construction)

- **Apparent Viscosity(AV) :**

Apparent viscosity is the ratio of stress to rate of strain of drilling fluid. And it can measure by using marsh funnel. Funnel viscosity is reported as seconds required for one quart of slurry to flow out a full funnel.

- **Plastic viscosity (PV):**

Plastic viscosity is that part of flow resistance, which is caused by mechanical friction. This friction occurs:

i. Between the solids in mud.
ii. Between the solids and liquids that surround them.
iii. With the shearing of the liquid itself.
iv. For practical field purpose, however the PV depends upon the concentration of mud solids.

- **Yield point (YP):**

Yield point is the second component of resistance to flow in a drilling fluid on account of the electro-chemical or attractive forces present in mud. These forces are as a result of negative and positive charges located on or near the particle surfaces. Yield point is a measure of those forces under flow conditions and depends upon:

i. Surface properties of the mud solids.
ii. Volume concentration of solids.
iii. The electrical environment of these solids.

- **Gel strength:**

The gel strength is shear stress of drilling mud that is measured at low shear rate after the drilling mud is static for a certain period of time. The gel strength is one of the important drilling fluid properties demonstrates the ability of the drilling mud to suspend drill solid and weighting material when circulation is ceased.

- **Filtration loss:**

The filtration property of a drilling fluid is indicative of the ability of the solid components of the mud to form a filter cake and the magnitude of cake permeability. The lower the permeability, the thinner is the filter cake and lowers the volume of filtrate from mud. Filtration property is dependent upon the amount and physical state of colloidal material in the mud. A thick filter cake is undesirable as it constricts the walls of the borehole and allows excessive amount of filtrate to move into the formation resulting in further problems such as caving, tight pulls, held ups, stuck ups etc.(Rabia Hussain-Well Engineering &Construction)

2.3. Drilling fluid contamination:

During drillingfluid circulation, the drilling fluid faces many problems and one of these problems is mud contaminants.A mud is said to be contaminated when a foreign material enters the mud system and causes undesirable changes in mud propertiessuch as density, viscosity, and filtration. Generally, water-based mud systems are the most susceptible to contamination. Mud contamination can result from overtreatment of the mud system with additives or from material entering the mud during drilling.

There are different types of contaminants of drilling mud such as:

Solids contamination:

Solids are materials that are added to make up a mud system (bentonite, barite) these solids are desirable to improve the performance of drilling mud. Another type of solids from the bore hole while drilling (cuttings). Excess solids, of any type, are the most undesirable contaminant to drilling fluids. They affect all mud properties, and must be removed by use of mechanical separating equipment (shakers, desanders, desilters, and centrifuges).

Calcium-ions contamination:

The sources of calcium ions are:Gypsum, Anhydrite, Cement, Lime, Seawater and Hard/brackish makeup water.

The calcium ion is a major contaminant to freshwater-based sodium-clay treated mud systems. The 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. It also causes added thinners to the mud system to become ineffective.

Biocarbonate and carbonate contamination: (HCO_3^{-}, CO_3^{-})

The contaminant ionsbiocarbonate and carbonate are from drilling a carbon dioxidebearing formation, thermal degradation of organics in mud, or over treatment with soda ash and bicarbonate. These contaminants cause the mud to have high yield and gel strength and a decrease in pH.

Hydrogen sulfide contamination:

The contaminant ions (HS^{-}, S^{-}) generally are from drilling an H_2S-bearing formation. Hydrogen sulfide is the most deadly ion to humans and is extremely corrosive to steel used during drilling operations.

Salt/saltwater flows:

The 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. Some actions for treatment are dilution with fresh water, the use of dispersants and fluid-loss chemicals, or conversion to a mud that tolerates the problem if the cost of treatment becomes excessive.(Rabia Hussain-Well Engineering&Construction)

CHAPTER (3)

LABORATORY EXPERIMENTS AND PROCEDURES

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LABORATORY EXPERIMENTS AND PROCEDURES

This chapter describes in details the methodologies used to determine the rheological properties of the mud before and after adding the contaminants under effect of temperature changing.

3.1. Drilling mud preparation materials, equipments and procedures:

In order to prepare a drilling mud commercially available bentonite was used with water and some materials.

3.1.1. Drilling mud materials preparation:

The tables below describe the materials types, concentrations, additives and the function of each additive that used to formulate the drilling mud.

Table(3-1): Types of materials used in WBM preparation

Materials type	FUNCTION(S)	Material concentration (%)
Bentonite	Base fluid	7.14
Barite	Viscosity and Filtration control	2.00
Starch	Weighting agent	0.40
caustic soda	Fluid loss control	0.02

*(Nagham amer 2015)

Fig. (3-1) below shows the materials that used to formulate the water base mud which is used as the original mud for the experiments.

The principal additives used in formulating mud are as follows(Nagham Amer 2015):

•bentonite 7% % **Fig.(3-1-a**)

•barite 2% **Fig(3-1-b)**

•starch 0.4% **Fig.(3-1-c)**

•caustic soda 0.02% **Fig.(3-1-d)** was used to maintain on PH between(9-10.5) .

Fig(3-1-a)bentonite

Fig(3-1-b)barite

Fig(3-1-c)starch

Fig(3-1-d)caustic soda

3.1.2 Drilling mud equipments preparation:

1.Electronic scale:

It is a device used to measure weight or calculate mass. Scales using a balance beam compares masses by balancing the weight due to the mass of an object against the weight of known masses.**Fig. (3-2)**

Fig. (3-2): Electronic scale (Drilling fluids lab., CPET, SUST)

2.Mud Mixer:

This instrument used for mixing the mud components. As shown in **Fig(3-3)**it consist from crank connected to an electronic motor and fan to stir the components.

Fig. (3-3): Mud Mixer (Drilling fluids lab., CPET, SUST)

3.1.3 Drilling mud procedures preparations:

1.The weights of the components of mud (bentonite, barite, starch) were measured by the Electronic scale.

2.A certain amount of water was prepared(500 ml).

3.The components of the mud were added to the water in the mud mixture.

4.The mixing time between adding each components was from 2min to 3min , and for all mixture was for 5min.

5.After the mud mixing and ensuring that the mud is homogenous , the PH was measured. The ph was controlled between 9 to 10.5 by adding a certain amount of caustic soda(.02%)

3.2.Test equipments:

1.The heater with a thermometer:

Used to heat up the drilling mud, and with the thermometer we can heat to the wanted temperature.**Fig.(3-4)**

Fig.(3-4): heater (Drilling Fluid Lap.,CPET,SUST)

2. The API Filtrations Press:

Filter Press consists of a mud reservoir mounted in a frame, a pressure source, a filtering medium and a graduated cylinder for receiving and measuring filtrate. The basic unit has a cell assembly constructed of stainless steel and includes the required screen and gaskets.**Fig.(3-5)**

Fig.(3-5): API Filtrations Press (Drilling Fluid Lap.,CPET,SUST)

3.The 6 speeds Viscometer:

The Viscometer has 6speeds (model 35 viscometer).Fann produces a range of true coquette coaxial cylinder rotational viscometer. The test fluid is contained in the annular space or shear gap between the cylinders. Rotation of the outer cylinder is accomplished through precision gear. The viscous drag exerted by the fluid creates a torque on the inner cylinder or bob. **Fig.(3-6)**

Fig.(3-6): 6 speeds Viscometer (Drilling Fluid Lap.,CPET,SUST)

3.3 Test procedures:

3.3.1The rheological properties of the Original drilling mud Test:

plastic viscosity measurement procedure:

1. 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.
2. 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.
3. Stir the sample for about 5 seconds at 600 RPM, then select the RPM desired for the best.
4. Wait for the dial reading to stabilize (the time depends on the sample's characteristics).
5. Record the dial reading and RPM.

(PV) in (cp)= 600 RPM reading – 300 RPM reading

Gel Strength Measurement Procedures:

1. Stir a sample at 600 RPM for about 15 seconds.
2. Turn the RPM knob to the STOP position.
3. Wait the desired rest time (normally 10 seconds or 10 minutes).
4. Switch the RPM knob to the GEL position.
5. Record the maximum deflection of the dial before the Gel breaks, as the Gel strength in lb/100 ft2.

(lb/100 ft2 x 5.077 = Gel strength in dynes/cm2).

Yield point Measurement Procedures:

1. Obtain a recently agitated mud sample.
2. Using the 6 speeds viscometer, obtain dial readings at 300 and 600 RPM.

3. By means of the rheological calculations procedure, determine Plastic Viscosities, Yield Point and initial 10 sec. and final10-minute Gel Strength parameters.
4. Tabulate your results.

(YP) in (Ib/100ft2)= 300 RPM reading – (PV)

Filtration loss Measurement Procedures:

1. Detach the mud cell from filter press frame.

2. Remove bottom of filter cell, place right size filter paper in the bottom of the cell.

3. introduce mud to be tested into cup assembly, putting filter paper and screen on top of mud tighten screw clamp.

4. With the air pressure valve closed, clamp the mud cup assembly to the frame while holding the filtrate outlet end finger tight.

5. Place a graduated cylinder underneath to collect filtrate.

6. Open air pressure valve and start timing at the same time.

7. Report cc of filtrate collected for specified intervals up to 30 minutes.

The results of the rheological properties showed in Table(4-1)and for the filtration in Table(4-2).

3.3.1 The rheological properties of the drilling mud whit KCl test :

The procedures of adding the KCl to the drilling fluid:

1. The mixer was used after adding 0.75 g of KCl to the mud (400 ml) to ensure homogeneous mixture .

2. We took a sample from the mud in order to measure the filtration loss in the filtration press device and recorded the result.

3. Next we used the heater to heat up the remaining mud for three temperatures (50, 60 and 70°C). Then we took the sample that been heated to the 6 speeds viscometer to read 600 RPM reading, 300 RPM reading, 3 RPM @10 second reading and 3 RPM @10 minutes and recorded the result.

4. For another sample with same additives, we added 2.5 g and 5 g of KCl to the mud with same procedures as previous. We measured the filtration loss by API Filtration Press and recorded the readings.

5. The results of contamination by KCl showed in Table(4-3) and of the filtration showed Table(4-4-a), Table(4-4-b) and Table(4-4-c).

3.3.2 The Rheological properties of the drilling mud whit NaCl Test :

The procedures of adding the NaCl to the drilling fluid:

1. The mixer was used after adding 0.75 g of NaCl to the mud (400 ml) to ensure homogeneous mixture .

2. We took a sample from the mud in order to measure the filtration loss in the filtration press device and recorded the result .

3. Next we used the heater to heat up the remaining mud for three temperatures (50, 60 and 70°C). Then we took the sample that been heated to the 6 speeds viscometer to read 600 RPM reading, 300 RPM reading, 3 RPM @10 second reading and 3 RPM @10 minutes and recorded the result.

4. For another sample with same additives, we added 2.5 g and 5 g of NaCl to the mud with same procedures as previous. We measured the filtration loss by API Filtration Press and recorded the readings.

5. The results of contamination by NaCl showed in Table(4-5) and the filtration showed Table(5-4-a), Table(5-4-b) and Table(5-4-c).

CHAPTER (4)

RESULTS AND DISCUSSION

CHAPTER (4)

RESULTS AND DISCUSSION

4.1Experimental Results:

As mentioned earlier, a WBM (original mud) was prepared in the laboratory, and the tables below shows the rheological and filtration properties of the original mud before and after adding the salts (KCl and NaCl) at different concentrations and different temperature.

Table (4-1): Rheological properties of original drilling mud

Temperatures (^{o}C)	ϴ600 (RPM)	ϴ300 (RPM)	PV (cp)	YP (lbs/100ft^2)	Gel strength (lbs/100ft^2) (10 sec./10 min.)
50	75	55	20	35	10 / 18
60	46	31	15	16	8 / 10
70	47	33	14	19	9 / 11

Table (4-2): Filtration properties of original drilling mud

Time (minute)	Dial reading
1	1
5	2.6
7.5	4.6
30	9.6

Table (4-3): Rheological properties results after adding KCl at different Temperatures & concentrations

Temperatures (°C)	KCl concentrations (gm)	ϴ600 (RPM)	ϴ300 (RPM)	PV (cp)	YP ($lbs/100ft^2$)	Gel strength ($lbs/100ft^2$) (10 sec./10 min.)
50	0.75	70	52	18	34	24 / 30
	2.5	53	36	17	19	8 / 12
	5	29	19	10	9	2 / 5
60	0.75	84	66	18	48	29 / 41
	2.5	51	34	17	17	9 / 13
	5	29	19	10	9	2 / 5
70	0.75	64	47	17	30	20 / 30
	2.5	46	32	14	18	4/ 10
	5	25	17	8	9	4 / 5

Table (4 – 4): Filtration properties of original mud after adding KCl at different concentrations

Time (minutes)	Dial reading (at 0.75 gm of KCl)	Dial reading (at 2.5 gm of KCl)	Dial reading (at 5 gm of KCl)
1	1.4	2	1.6
5	4	3.6	4.8
7.5	4.8	4.8	5.4
30	9.6	9.6	10.8

Table(4-5) Rheology results for the NaCl at different Temperatures & concentrations

Temperatures (°C)	KCl concentrations (gm)	ϴ600 (RPM)	ϴ300 (RPM)	PV (cp)	YP (lbs/100ft^2)	Gel strength (lbs/100ft^2) (10 sec./10 min.)
50	0.75	37	26	11	15	11 / 15
	2.5	33	23	10	13	9 / 10
	5	130	120	10	110	92 / 116
60	0.75	40	28	12	16	12 / 15
	2.5	34	23	11	12	8 / 10
	5	123	113	10	103	101 / 106
70	0.75	40	29	11	18	12 / 16
	2.5	33	23	10	13	10 / 12
	5	130	122	8	114	103 / 114

Table (4 - 6): Filtration properties of original mud after adding NaCl at different concentrations

Time (minutes)	Dial reading (at 0.75 gm of NaCl)	Dial reading (at 2.5 gm of NaCl)	Dial reading (at 5 gm of NaCl)
1	1.6	1.8	2.1
5	3.8	3.9	4.1
7.5	4.8	4.9	5.2
30	9.7	9.8	11.2

4.1.1Result of the mud sample before contaminated:

Figures (4-1), (4 -2) and (4 -3) describe the effect of temperatures on the rheological properties of the original mud (bentonite mud).

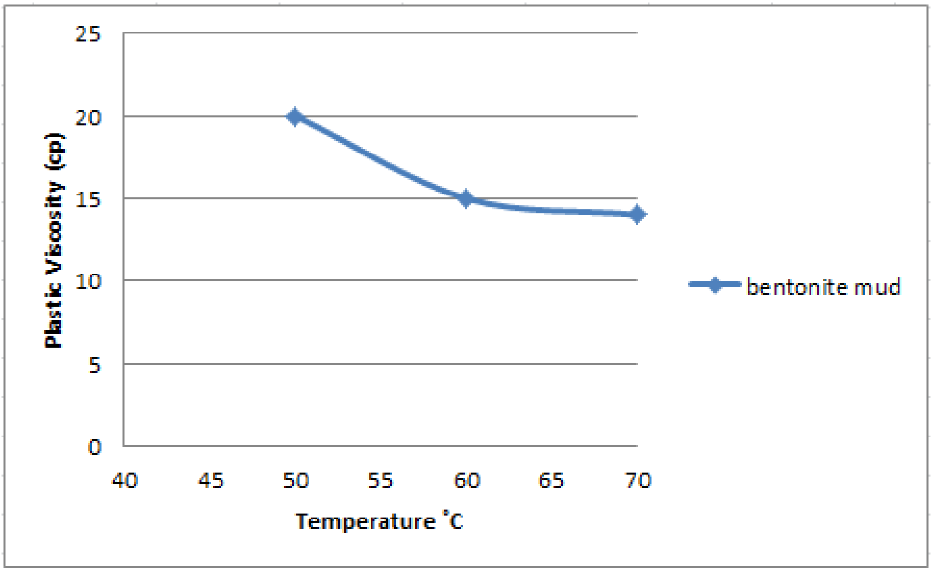

Fig.(4-1) : plastic viscosity against temperatures before salt contamination

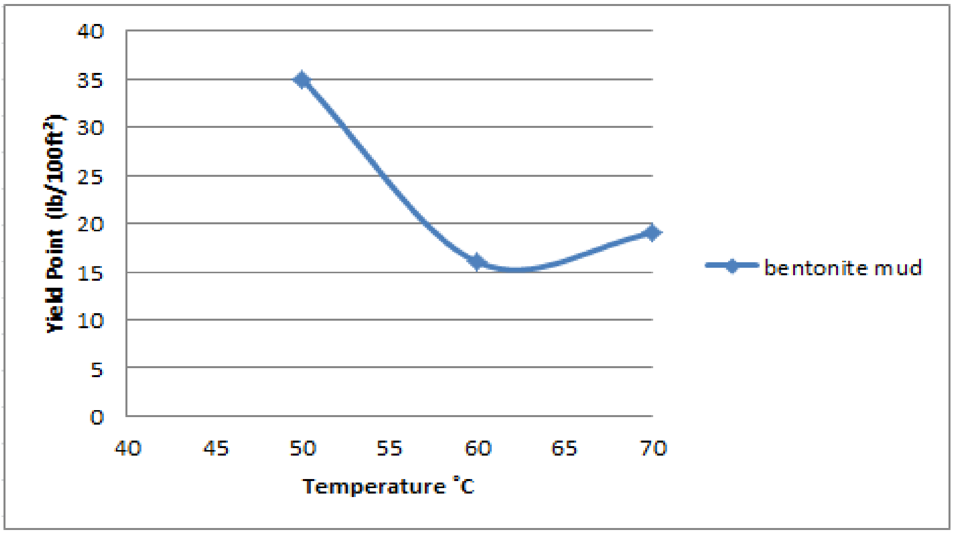

Fig.(4-2) : yield point against temperatures before salt contamination

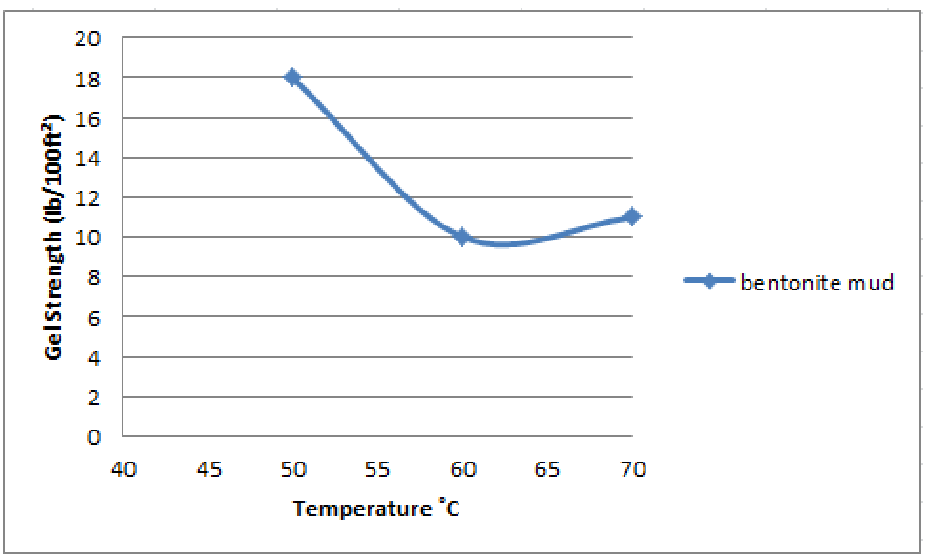

Fig.(4-3) : gel strength against temperatures before salt contaminations

4.1.2. Effects of adding KCl, at different temperature, on the rheological properties of the original mud:

Figures (4 - 4), (4 - 5) and (4 - 6) describe the effect of adding KCl, at different temperatures, on the rheological properties of the original mud (bentonite mud).

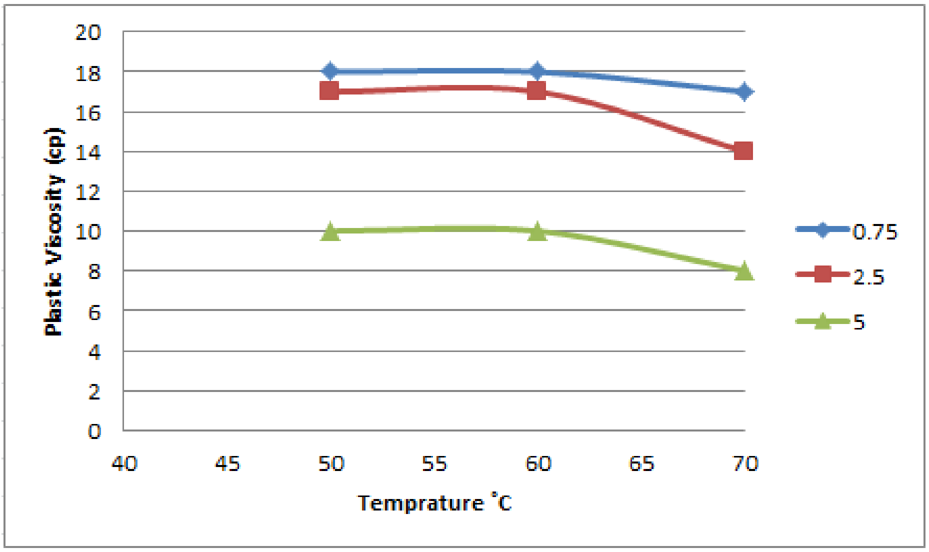

Fig.(4-4):Effect of adding KCl on the plastic viscosity of original mud at different concentrations and temperatures

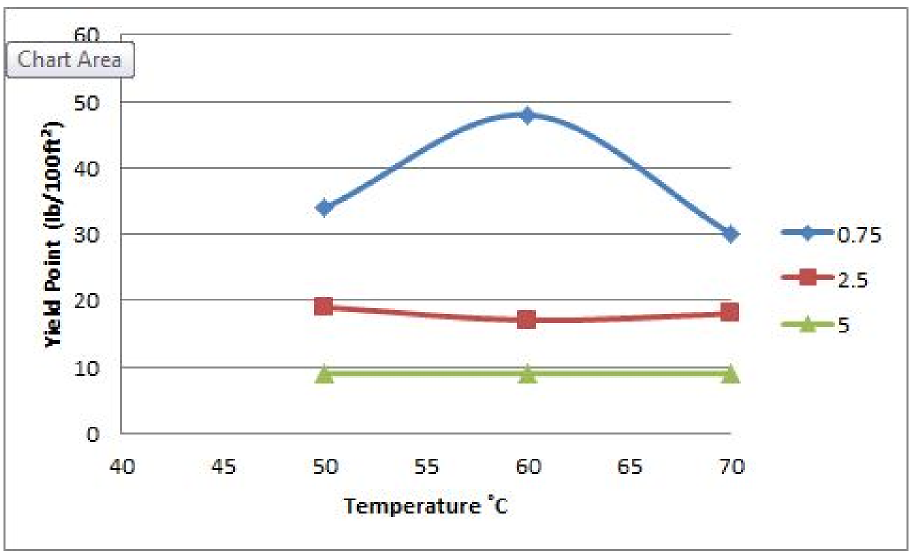

Fig.(4-5): Effect of adding KCl on the yield point of original mud at different concentrations and temperatures

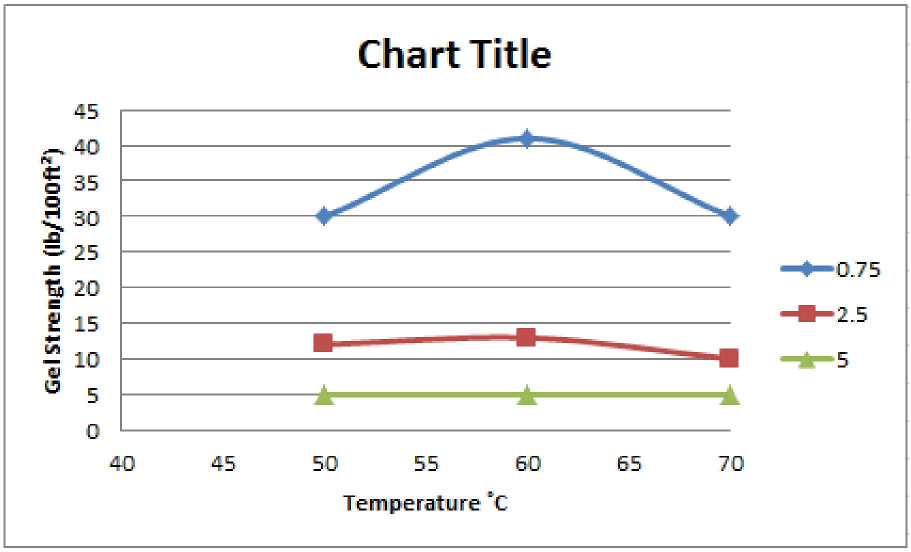

Fig.(4-6): Effect of adding KCl on the gel strength of original mud at different concentrations and temperatures

4.1.3Effects of adding NaCl, at different temperature, on the rheological properties of the original mud:

Figures (4 - 7), (4 - 8) and (4 - 9) describe the effect of adding NaCl, at different temperatures, on the rheological properties of the original mud (bentonite mud).

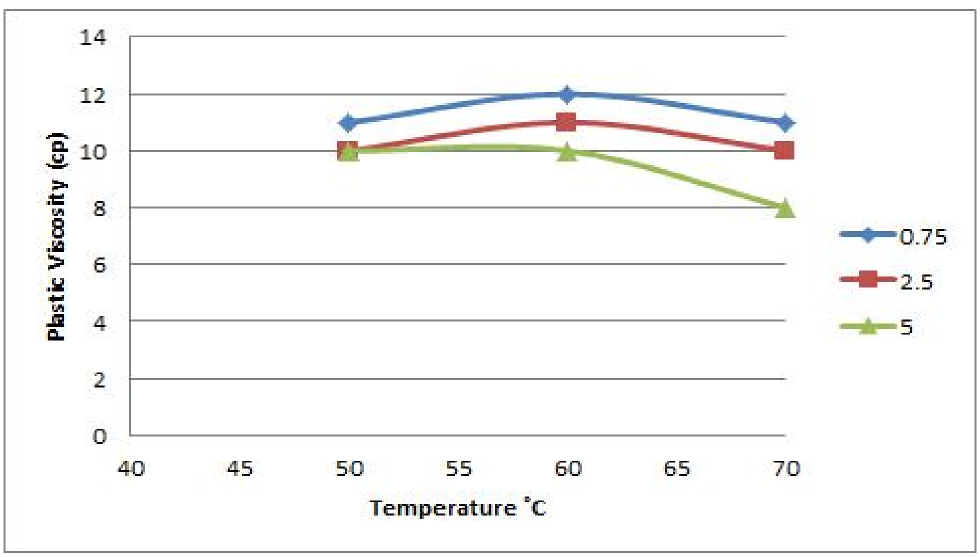

Fig.(4-7): Effect of adding NaCl on the plastic viscosity of original mud at different concentrations and temperatures

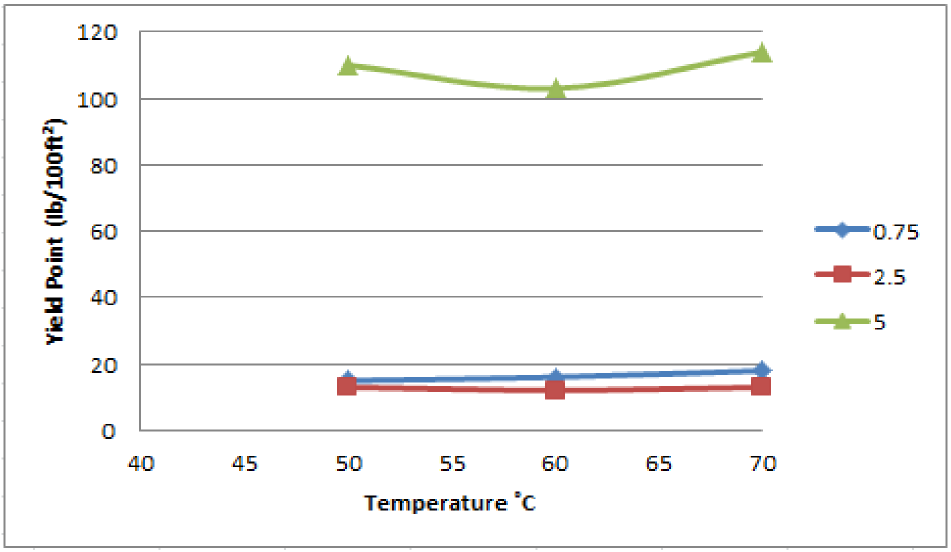

Fig.(4-8):Effect of adding NaCl on the yield point of original mud at different concentrations and temperatures

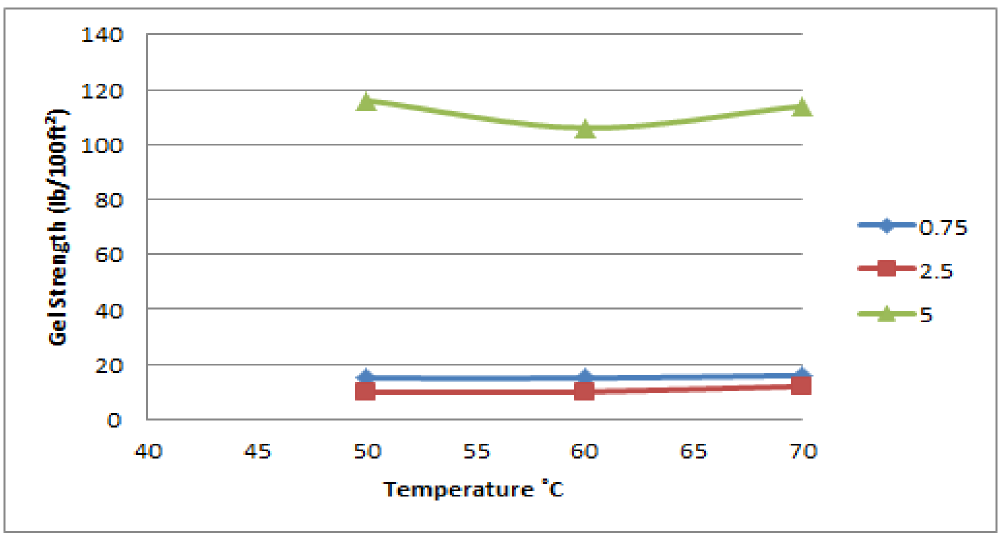

Fig.(4-9):Effect of adding NaCl on the gel strength of original mud at different concentrations and temperatures

4.2 Discussion:

- **Effect of temperature on the original drilling mud:**

  The results show that the plastic viscosity decreases as the temperature increases as shown in fig (4 -1).

  The effect on yield point and gel strength are the same, as shown in Fig (4-2) and Fig (4-3), where as the temperature increases the values of both yield point and gel strength changes .

- **Effects of KCl and NaCl on the original drilling mud:**

  Fig. (4-4) shows that as the KCl concentration increases the plastic viscosity of the original mud decreases.

  From Fig.(4-5) and Fig.(4-6) it can be noticed that as the KCl concentration increases the yield point and the gel strength decreases .

  Fig(4-4) shows that the filtration loss increases with the increases of KCl concentration.

  As the NaCl concentration increases the plastic viscosity decreases for the original mud, as shown inFig(4-8). Where from Fig.(4-7) and Fig.(4-8) it can be noticed that as the NaCl concentration increases the yield point and the gel strength decreases.

  Fig(4-6) shows that the filtration loss increases with the increases of NaCl concentration.

CHAPTER(5)

CONCLUSION AND RECOMENDATIONS

CHAPTER (5)

CONCLUSION AND RECOMENDATIONS

5.1. Conclusion:

The following points can be written from performed experiments:

1. Plastic viscosity decreases with the increases of the temperatures, yield point and gel strength changes with the increased of the temperatures.
2. As the concentration of salts (KCl, NaCl) increases the plastic viscosity decreases, yield point and the gel strength decreases.
3. Increases in the concentration of the salts (KCl, NaCl) the fluid loss into the formation increases.

5.2. Recommendations:

It is recommended to:

1. Identify the effects of salts under high temperatures, more than 70˚C, to see further effects on the rheological properties of water base mud.
2. Use five different concentrations of salts instead of three to give more comprehensive results.
3. Identify the effects of other contaminants under the same conditions of this study.

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بسم الله الرحمن الرحيم

Sudan University of Science And Technology

College of Petroleum Engineering & Technology

Petroleum Engineering Department

Experimental Studyto Recognize the Effects of Salts (potassium and sodium chloride)Contamination on Rheological Properties of Water Base Mud Under Different Temperatures

دراسة معملية لتاثير دخول الملح على الخواص التيارية لسائل حفر ذو اساس مائي تحت تاثير درجات حرارة مختلفة

Graduation Project Submitted to The College of Petroleum Engineering & Technology, Sudan University of Science & Technology.

Partial Requirement For BscDegree in Petroleum Engineering

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Dedication

Our exalted teachers,,,

Whom we met and a lot learned thought out our educational life ,,,

Thanking and very grateful for theirs great efforts ,,,

Guidance and assistance ,,,

Kind advice and encouragement ,,,

To them ,,,

We would like to dedicate and present this simple efforts on this study ,,,

Abstract

The drilling engineer must have a good estimate of how the stability of drilling fluid changes due to salt contamination encountered during drilling operation. a mud sample with different concentrations of sodium and potassium chloride salt (KCl,NaCl) was formulated in order to study they effect on the rheological properties of drilling fluid at ambient and elevated temperature conditions. This study shows that the drilling mud efficiency is affected with temperature as the result of thermal degradation. It was concluded that the rheological properties such as viscosity, yield point, and gel strength of drilling mud decrease as the concentration of KCl and NaCl salt increases. This indicates that with the KCl and NaCl salt contamination, there is an advanced decline in the performance of drilling mud and the salt affects the dispersion, hydration and flocculation behavior of the particles which make it incompetent for cutting suspender. Also, it was observed that when the concentration of salts increases in the drilling mud sample the fluid loss into the formation increases.

تجريد

يجب ان يكون لدى مهندس الحفر تقدير جيد لمدى أستقرارية سائل الحفر للتغيرات الناتجة من التلوث من جراء دخول الملح على سائل الحفر اثناء عمليات الحفر. تم تكوين عينة من سائل الحفر مع تراكيز مختلفة من املاح كلوريد البوتاسيوم وكلوريد الصوديوم وذلك لدراسة تاثيرهم على الخصائص التيارية لسائل الحفر تحت تاثير درجات الحرارة المختلفة .هذه الدراسة تظهر ان كفاءة سائل الحفر تتاثر بالتغير في درجات الحرارة . وتم التوصل الى ان الخصائص التيارية لسائل الحفر كاللزوجة ، مقاومة الجل ، نقطة الخضوع تقل بالزيادة في تراكيز كل من كلوريد الصوديوم وكلوريد البوتاسيوم. هذا يشير الى ان دخول هذه الاملاح يؤدي الى انخفاض في ادائية سائل الحفر وتم ايضا ملاحظة زيادة في فواقد سائل الحفرخلال التكوين مع زيادة تراكيز الاملاح المذكورة انفأ.

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CHAPTER (1)

INTRODAUCTION

INTRODAUCTION

1.1. Introduction:

In drilling operation, the drilling fluid system assuming that the condition of the hole is stable, the drilling fluid properties such as density, viscosity, filtration, etc. should not change during the drilling operation but in normal operation the drilling fluid properties are changed by contamination in the borehole, because the condition of the hole is unstable. This contamination can affects on the rheological properties of drilling fluid. Rheology refers to the flow behavior of all forms of matter. Certain rheologic measurements made on fluids, such as viscosity, gel strength, etc. help determine how this fluid will flow under a variety of different conditions. This information is important in design of circulating systems required to accomplish certain desired objectives in drilling operation. Drilling fluid tests are performed to evaluate the properties and characteristics of the fluid, and to determine its performance limitation .The rheological properties affected by contamination during drilling mud circulation .Actually we have several type of this contamination such as (salt ,cutting, Gypsum ,Anhydrite ,Cement, etc …)

Any change in rheological properties will change the performance of drilling mud .It is very important to treat drilling mud from any foreign material causes undesirable changes in mud properties. A good mud engineer should measure and maintain drilling fluid composition with regular tests of fluid composition and implements solutions to drilling-related problems. Drilling engineers select specific drilling fluid with most favorable properties for the job. Most of the drilling fluid functions are controlled by its rheological properties. A drilling fluid specialist or a “Mud Engineer” is often on site to maintain and revaluate these properties as drilling proceeds. The main factors governing the selection of drilling fluids types of formation to be drilled, The range of temperatures and pore fluids pressure exhibited by the formation. While, in addition to the above, selection of the drilling fluid can be informed through consideration of other factors such as - production concerns, environmental impact, safety . The most important factor that governs selection of drilling fluid is the “overall well cost” This study shows that the drilling mud efficiency is affected with contamination at different concentrations and different temperatures, to Evaluation the drilling mud.

1.2. Problem Statement:

Enter Nacl and kcl to the mud system as a result of drilling salt section or from formation saltwater flow , it considered to be a contamination to drilling fluid , and have the ability to effect on the drilling fluid properties .

1.3. Objectives of the study:

- To study the effect of salt contamination (Nacl, Kcl) on Rheological Properties of drilling fluids with different concentrations.
- To study the effect of salt contamination (Nacl, Kcl) on Rheological Properties of drilling fluids under different temperatures.
- To evaluate drilling mud before and after contamination.
  sub objective:
  To study the effect of filtration.

1.4. Methodology:

1. Prepare a water base drilling fluid using commercial bentonite.
2. Identify the rheological properties of the prepared mud before and after adding salts (NaCl and KCl), with different concentrations and temperatures.

CHAPTER (2)

LITERATURE REVIEW AND THEORATICAL BACKGROUND

CHAPTER (2)

LITERATURE REVIEW AND THEORATICAL BACKGROUND

2.1. Literature Review:

Olufemi et al. (2011)studied the effect of cutting on drilling fluid of oil base mud and found that drilling fluid viscosity, fluid loss and density are increased.

Khaled J. Hassiba1 and Mahmood Amani1in 2012 studied the effect of kcl and Nacl on the rheological properties of the water based mud under High Pressures and High Temperatures for DrillingOffshore and Deep Wells the shear stress-shear rate high when add Nacl and low of the shear stress-shear rate when add Kcl .

Joel, O.F α, Durueke, U.J σ & Nwokoye C.U ρ.(2012) Effect of KCL on Rheological Properties of Shale Contaminated Water-Based mud The rheological values using FANN viscometer with different concentration of KCl Test results indicated that the KCl inhibited the swelling tendencies of the shale and the rheological values reduced drastically.

Nagham Sami(2015) is found that the rheological and filtration properties of drilling mud are affected by magnesium salt contamination and concluded that magnesium salt contamination decreases the plastic viscosity ,yield point ,gel strength and makes the drilling mud has a poor filtration loss characteristic.

H. I. Kula and C. Vipulanandan, Ph.D., P.E.(no date) studied the effect of gypsum on resistivity of Water-Based mud the changes in electrical resistivity of drilling mud at room temperature was investigated. The results showed that the calcium sulfate decreased the resistivity of the drilling mud.

2.2. Drilling Fluids Background:

"In geotechnical engineering, drilling fluid is used to aid the drilling of boreholes into the earth. Often used while drilling oil and naturalgas wells and on exploration

drilling rigs, drilling fluids are also used for much simpler boreholes, such as water wells. Liquid drilling fluid is often called drilling mud. The three main categories of drilling fluids are water-based muds (which can be dispersed and non-dispersed), non-aqueous muds, usually called oil-based mud, and gaseous drilling fluid, in which a wide range of gases can be used.

The main functions of drilling fluids include providing hydrostatic pressure to prevent formation fluids from entering into the well bore, keeping the drill bit cool and clean during drilling, carrying out drill cuttings, and suspending the drill cuttings while drilling is paused and when the drilling assembly is brought in and out of the hole. The drilling fluid used for a particular job is selected to avoid formation damage and to limit corrosion.

2.2.1. Types of drilling fluid:

"Many types of drilling fluids are used on a day-to-day basis. Some wells require that different types be used at different parts in the hole, or that some types be used in combination with others. The various types of fluid generally fall into a few broad categories.(Wikipedia)

- Air
- Air/water
- Air/polymer
- Water
- Water-based mud (WBM)
- Oil-based mud (OBM)

2.2.2. Functions of drilling fluid:

The main functions of a drilling mud can be summarized as follows:

- Remove cuttings from the well.
- Suspend and release cuttings.
- Control formation pressures.
- Seal permeable formations.
- Maintain wellbore stability.
- Minimizing formation damage.
- Cool, lubricate, and support the bit and drilling assembly.
- Transmit hydraulic energy to tools and bit.
- Ensure adequate formation evaluation.
- Control corrosion (in acceptable level.
- Facilitate cementing and completion.
- Minimize impact on environment.

2.2.3. Composition of drilling fluid:

Water-based drilling mud most commonly consists of bentonite clay (gel) with additives such as barium sulfate (barite), calcium carbonate (chalk) or hematite.

2.2.4. Factors influencing drilling fluid performance:

Three factors affecting drilling fluid performance are:

1-The change of drilling fluid viscosity.

2-The change of drilling fluid density.

3-The change of mud PH.

2.1. 5. Properties of drilling fluid:

The properties of drilling fluids are:

- **Density (specific gravity):**

Density is defined as weight per unit volume. It is expressed either in ppg (lbs gallons) or pound per cubic feet or compared to the weight of an equal volume of water as specific gravity. Density is measured with a mud balance. One of the main functions of drilling fluid is to confine formation fluids to their native formations or beds".(Rabia_Hussain-Well Engineering&Construction)

- **Apparent Viscosity(AV) :**

Apparent viscosity is the ratio of stress to rate of strain of drilling fluid. And it can measure by using marsh funnel. Funnel viscosity is reported as seconds required for one quart of slurry to flow out a full funnel.

- **Plastic viscosity (PV):**

Plastic viscosity is that part of flow resistance, which is caused by mechanical friction. This friction occurs:

i. Between the solids in mud.
ii. Between the solids and liquids that surround them.
iii. With the shearing of the liquid itself.
iv. For practical field purpose, however the PV depends upon the concentration of mud solids.

- **Yield point (YP):**

Yield point is the second component of resistance to flow in a drilling fluid on account of the electro-chemical or attractive forces present in mud. These forces are as a result of negative and positive charges located on or near the particle surfaces. Yield point is a measure of those forces under flow conditions and depends upon:

i. Surface properties of the mud solids.
ii. Volume concentration of solids.
iii. The electrical environment of these solids.

- **Gel strength:**

The gel strength is shear stress of drilling mud that is measured at low shear rate after the drilling mud is static for a certain period of time. The gel strength is one of the important drilling fluid properties demonstrates the ability of the drilling mud to suspend drill solid and weighting material when circulation is ceased.

- **Filtration loss:**

The filtration property of a drilling fluid is indicative of the ability of the solid components of the mud to form a filter cake and the magnitude of cake permeability. The lower the permeability, the thinner is the filter cake and lowers the volume of filtrate from mud. Filtration property is dependent upon the amount and physical state of colloidal material in the mud. A thick filter cake is undesirable as it constricts the walls of the borehole and allows excessive amount of filtrate to move into the formation resulting in further problems such as caving, tight pulls, held ups, stuck ups etc.(Rabia Hussain-Well Engineering &Construction)

2.3. Drilling fluid contamination:

During drillingfluid circulation, the drilling fluid faces many problems and one of these problems is mud contaminants.A mud is said to be contaminated when a foreign material enters the mud system and causes undesirable changes in mud propertiessuch as density, viscosity, and filtration. Generally, water-based mud systems are the most susceptible to contamination. Mud contamination can result from overtreatment of the mud system with additives or from material entering the mud during drilling.

There are different types of contaminants of drilling mud such as:

Solids contamination:

Solids are materials that are added to make up a mud system (bentonite, barite) these solids are desirable to improve the performance of drilling mud. Another type of solids from the bore hole while drilling (cuttings). Excess solids, of any type, are the most undesirable contaminant to drilling fluids. They affect all mud properties, and must be removed by use of mechanical separating equipment (shakers, desanders, desilters, and centrifuges).

Calcium-ions contamination:

The sources of calcium ions are:Gypsum, Anhydrite, Cement, Lime, Seawater and Hard/brackish makeup water.

The calcium ion is a major contaminant to freshwater-based sodium-clay treated mud systems. The 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. It also causes added thinners to the mud system to become ineffective.

Biocarbonate and carbonate contamination: (HCO_3^{-}, CO_3^{-})

The contaminant ionsbiocarbonate and carbonate are from drilling a carbon dioxidebearing formation, thermal degradation of organics in mud, or over treatment with soda ash and bicarbonate. These contaminants cause the mud to have high yield and gel strength and a decrease in pH.

Hydrogen sulfide contamination:

The contaminant ions (HS^{-}, S^{--}) generally are from drilling an H_2S-bearing formation. Hydrogen sulfide is the most deadly ion to humans and is extremely corrosive to steel used during drilling operations.

Salt/saltwater flows:

The 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. Some actions for treatment are dilution with fresh water, the use of dispersants and fluid-loss chemicals, or conversion to a mud that tolerates the problem if the cost of treatment becomes excessive.(Rabia Hussain-Well Engineering&Construction)

CHAPTER (3)

LABORATORY EXPERIMENTS AND PROCEDURES

CHAPTER (3)

LABORATORY EXPERIMENTS AND PROCEDURES

This chapter describes in details the methodologies used to determine the rheological properties of the mud before and after adding the contaminants under effect of temperature changing.

3.1. Drilling mud preparation materials, equipments and procedures:

In order to prepare a drilling mud commercially available bentonite was used with water and some materials.

3.1.1. Drilling mud materials preparation:

The tables below describe the materials types, concentrations, additives and the function of each additive that used to formulate the drilling mud.

Table(3-1): Types of materials used in WBM preparation

Materials type	FUNCTION(S)	Material concentration (%)
Bentonite	Base fluid	7.14
Barite	Viscosity and Filtration control	2.00
Starch	Weighting agent	0.40
caustic soda	Fluid loss control	0.02

*(Nagham amer 2015)

Fig. (3-1) below shows the materials that used to formulate the water base mud which is used as the original mud for the experiments.

The principal additives used in formulating mud are as follows(Nagham Amer 2015):

•bentonite 7% % **Fig.(3-1-a**)

•barite 2% **Fig(3-1-b)**

•starch 0.4% **Fig.(3-1-c)**

•caustic soda 0.02% **Fig.(3-1-d)** was used to maintain on PH between(9-10.5) .

Fig(3-1-a)bentonite

Fig(3-1-b)barite

Fig(3-1-c)starch

Fig(3-1-d)caustic soda

3.1.2 Drilling mud equipments preparation:

1.Electronic scale:

It is a device used to measure weight or calculate mass. Scales using a balance beam compares masses by balancing the weight due to the mass of an object against the weight of known masses.**Fig. (3-2)**

Fig. (3-2): Electronic scale (Drilling fluids lab., CPET, SUST)

2.Mud Mixer:

This instrument used for mixing the mud components. As shown in **Fig(3-3)**it consist from crank connected to an electronic motor and fan to stir the components.

Fig. (3-3): Mud Mixer (Drilling fluids lab., CPET, SUST)

3.1.3 Drilling mud procedures preparations:

1.The weights of the components of mud (bentonite, barite, starch) were measured by the Electronic scale.

2.A certain amount of water was prepared(500 ml).

3.The components of the mud were added to the water in the mud mixture.

4.The mixing time between adding each components was from 2min to 3min , and for all mixture was for 5min.

5.After the mud mixing and ensuring that the mud is homogenous , the PH was measured. The ph was controlled between 9 to 10.5 by adding a certain amount of caustic soda(.02%)

3.2.Test equipments:

1.The heater with a thermometer:

Used to heat up the drilling mud, and with the thermometer we can heat to the wanted temperature.**Fig.(3-4)**

Fig.(3-4): heater (Drilling Fluid Lap.,CPET,SUST)

2. The API Filtrations Press:

Filter Press consists of a mud reservoir mounted in a frame, a pressure source, a filtering medium and a graduated cylinder for receiving and measuring filtrate. The basic unit has a cell assembly constructed of stainless steel and includes the required screen and gaskets.**Fig.(3-5)**

Fig.(3-5): API Filtrations Press (Drilling Fluid Lap.,CPET,SUST)

3.The 6 speeds Viscometer:

The Viscometer has 6speeds (model 35 viscometer).Fann produces a range of true coquette coaxial cylinder rotational viscometer. The test fluid is contained in the annular space or shear gap between the cylinders. Rotation of the outer cylinder is accomplished through precision gear. The viscous drag exerted by the fluid creates a torque on the inner cylinder or bob. **Fig.(3-6)**

Fig.(3-6): 6 speeds Viscometer (Drilling Fluid Lap.,CPET,SUST)

3.3 Test procedures:

3.3.1The rheological properties of the Original drilling mud Test:

plastic viscosity measurement procedure:

1. 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.
2. 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.
3. Stir the sample for about 5 seconds at 600 RPM, then select the RPM desired for the best.
4. Wait for the dial reading to stabilize (the time depends on the sample's characteristics).
5. Record the dial reading and RPM.

(PV) in (cp)= 600 RPM reading – 300 RPM reading

Gel Strength Measurement Procedures:

1. Stir a sample at 600 RPM for about 15 seconds.
2. Turn the RPM knob to the STOP position.
3. Wait the desired rest time (normally 10 seconds or 10 minutes).
4. Switch the RPM knob to the GEL position.
5. Record the maximum deflection of the dial before the Gel breaks, as the Gel strength in lb/100 ft2.

(lb/100 ft2 x 5.077 = Gel strength in dynes/cm2).

Yield point Measurement Procedures:

1. Obtain a recently agitated mud sample.
2. Using the 6 speeds viscometer, obtain dial readings at 300 and 600 RPM.

3. By means of the rheological calculations procedure, determine Plastic Viscosities, Yield Point and initial 10 sec. and final10-minute Gel Strength parameters.
4. Tabulate your results.

(YP) in (Ib/100ft2)= 300 RPM reading – (PV)

Filtration loss Measurement Procedures:

1. Detach the mud cell from filter press frame.

2. Remove bottom of filter cell, place right size filter paper in the bottom of the cell.

3. introduce mud to be tested into cup assembly, putting filter paper and screen on top of mud tighten screw clamp.

4. With the air pressure valve closed, clamp the mud cup assembly to the frame while holding the filtrate outlet end finger tight.

5. Place a graduated cylinder underneath to collect filtrate.

6. Open air pressure valve and start timing at the same time.

7. Report cc of filtrate collected for specified intervals up to 30 minutes.

The results of the rheological properties showed in Table(4-1)and for the filtration in Table(4-2).

3.3.1 The rheological properties of the drilling mud whit KCl test :

The procedures of adding the KCl to the drilling fluid:

1. The mixer was used after adding 0.75 g of KCl to the mud (400 ml) to ensure homogeneous mixture .

2. We took a sample from the mud in order to measure the filtration loss in the filtration press device and recorded the result.

3. Next we used the heater to heat up the remaining mud for three temperatures (50, 60 and 70°C). Then we took the sample that been heated to the 6 speeds viscometer to read 600 RPM reading, 300 RPM reading, 3 RPM @10 second reading and 3 RPM @10 minutes and recorded the result.

4. For another sample with same additives, we added 2.5 g and 5 g of KCl to the mud with same procedures as previous. We measured the filtration loss by API Filtration Press and recorded the readings.

5. The results of contamination by KCl showed in Table(4-3) and of the filtration showed Table(4-4-a), Table(4-4-b) and Table(4-4-c).

3.3.2 The Rheological properties of the drilling mud whit NaCl Test :

The procedures of adding the NaCl to the drilling fluid:

1. The mixer was used after adding 0.75 g of NaCl to the mud (400 ml) to ensure homogeneous mixture .

2. We took a sample from the mud in order to measure the filtration loss in the filtration press device and recorded the result .

3. Next we used the heater to heat up the remaining mud for three temperatures (50, 60 and 70°C). Then we took the sample that been heated to the 6 speeds viscometer to read 600 RPM reading, 300 RPM reading, 3 RPM @10 second reading and 3 RPM @10 minutes and recorded the result.

4. For another sample with same additives, we added 2.5 g and 5 g of NaCl to the mud with same procedures as previous. We measured the filtration loss by API Filtration Press and recorded the readings.

5. The results of contamination by NaCl showed in Table(4-5) and the filtration showed Table(5-4-a), Table(5-4-b) and Table(5-4-c).

CHAPTER (4)

RESULTS AND DISCUSSION

CHAPTER (4)

RESULTS AND DISCUSSION

4.1Experimental Results:

As mentioned earlier, a WBM (original mud) was prepared in the laboratory, and the tables below shows the rheological and filtration properties of the original mud before and after adding the salts (KCl and NaCl) at different concentrations and different temperature.

Table (4-1): Rheological properties of original drilling mud

Temperatures (°C)	ϴ600 (RPM)	ϴ300 (RPM)	PV (cp)	YP (lbs/100ft^2)	Gel strength (lbs/100ft^2) (10 sec./10 min.)
50	75	55	20	35	10 / 18
60	46	31	15	16	8 / 10
70	47	33	14	19	9 / 11

Table (4-2): Filtration properties of original drilling mud

Time (minute)	Dial reading
1	1
5	2.6
7.5	4.6
30	9.6

Table (4-3): Rheological properties results after adding KCl at different Temperatures & concentrations

Temperatures (°C)	KCl concentrations (gm)	ϴ600 (RPM)	ϴ300 (RPM)	PV (cp)	YP ($lbs/100ft^2$)	Gel strength ($lbs/100ft^2$) (10 sec./10 min.)
50	0.75	70	52	18	34	24 / 30
	2.5	53	36	17	19	8 / 12
	5	29	19	10	9	2 / 5
60	0.75	84	66	18	48	29 / 41
	2.5	51	34	17	17	9 / 13
	5	29	19	10	9	2 / 5
70	0.75	64	47	17	30	20 / 30
	2.5	46	32	14	18	4/ 10
	5	25	17	8	9	4 / 5

Table (4 – 4): Filtration properties of original mud after adding KCl at different concentrations

Time (minutes)	Dial reading (at 0.75 gm of KCl)	Dial reading (at 2.5 gm of KCl)	Dial reading (at 5 gm of KCl)
1	1.4	2	1.6
5	4	3.6	4.8
7.5	4.8	4.8	5.4
30	9.6	9.6	10.8

Table(4-5) Rheology results for the NaCl at different Temperatures & concentrations

Temperatures (°C)	KCl concentrations (gm)	Θ600 (RPM)	Θ300 (RPM)	PV (cp)	YP ($lbs/100ft^2$)	Gel strength ($lbs/100ft^2$) (10 sec./10 min.)
50	0.75	37	26	11	15	11 / 15
	2.5	33	23	10	13	9 / 10
	5	130	120	10	110	92 / 116
60	0.75	40	28	12	16	12 / 15
	2.5	34	23	11	12	8 / 10
	5	123	113	10	103	101 / 106
70	0.75	40	29	11	18	12 / 16
	2.5	33	23	10	13	10 / 12
	5	130	122	8	114	103 / 114

Table (4 - 6): Filtration properties of original mud after adding NaCl at different concentrations

Time (minutes)	Dial reading (at 0.75 gm of NaCl)	Dial reading (at 2.5 gm of NaCl)	Dial reading (at 5 gm of NaCl)
1	1.6	1.8	2.1
5	3.8	3.9	4.1
7.5	4.8	4.9	5.2
30	9.7	9.8	11.2

4.1.1Result of the mud sample before contaminated:

Figures (4-1), (4 -2) and (4 -3) describe the effect of temperatures on the rheological properties of the original mud (bentonite mud).

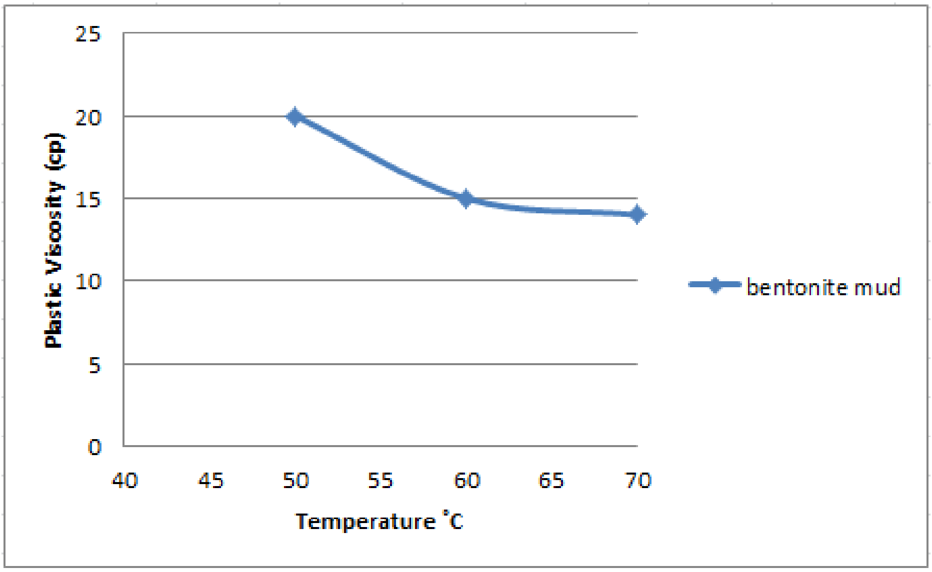

Fig.(4-1) : plastic viscosity against temperatures before salt contamination

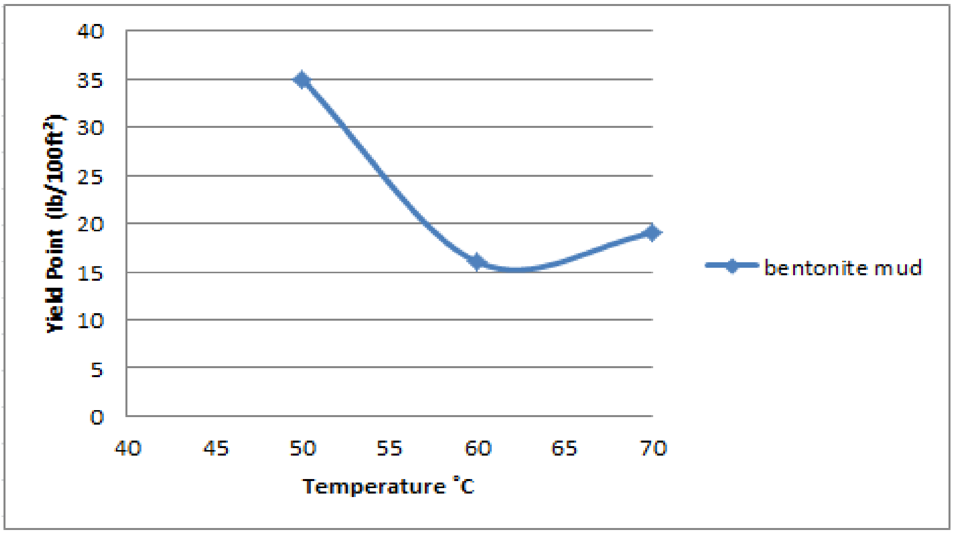

Fig.(4-2) : yield point against temperatures before salt contamination

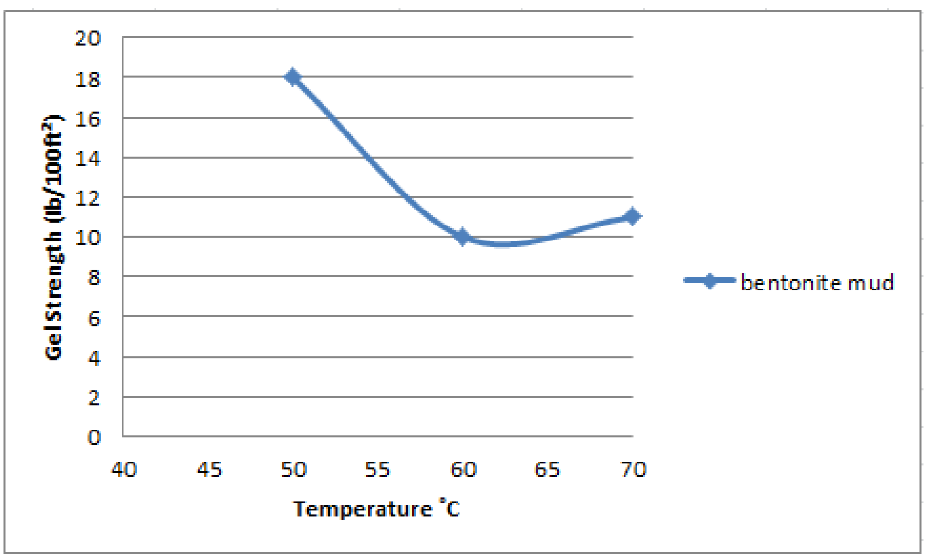

Fig.(4-3) : gel strength against temperatures before salt contaminations

4.1.2. Effects of adding KCl, at different temperature, on the rheological properties of the original mud:

Figures (4 - 4), (4 - 5) and (4 - 6) describe the effect of adding KCl, at different temperatures, on the rheological properties of the original mud (bentonite mud).

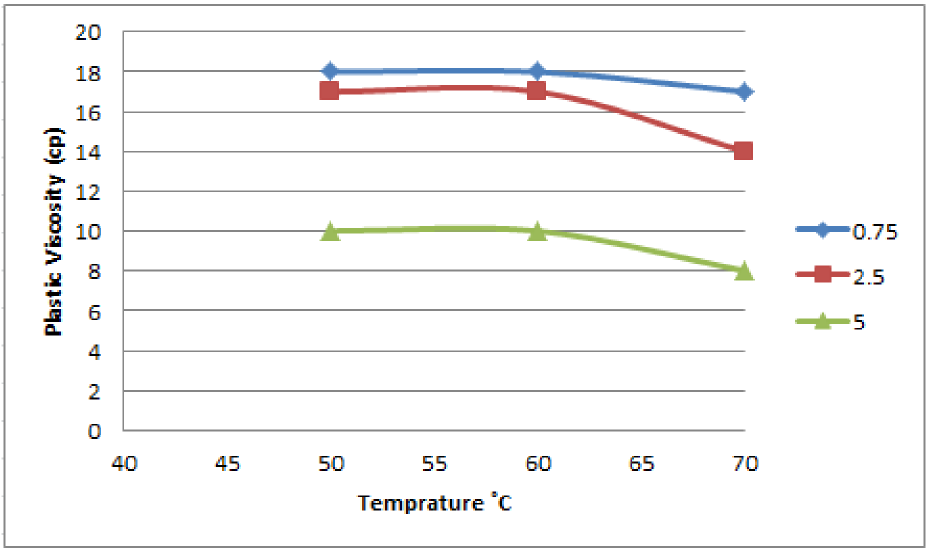

Fig.(4-4):Effect of adding KCl on the plastic viscosity of original mud at different concentrations and temperatures

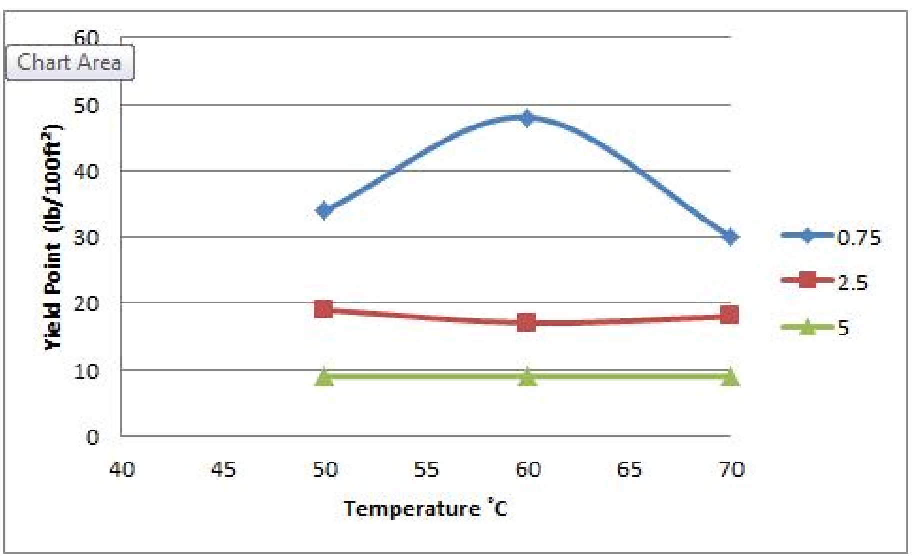

Fig.(4-5): Effect of adding KCl on the yield point of original mud at different concentrations and temperatures

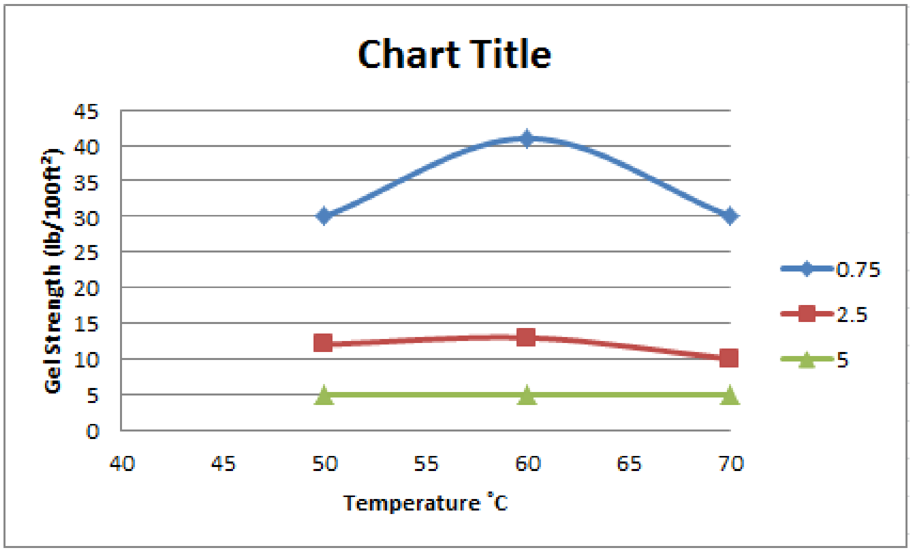

Fig.(4-6): Effect of adding KCl on the gel strength of original mud at different concentrations and temperatures

4.1.3Effects of adding NaCl, at different temperature, on the rheological properties of the original mud:

Figures (4 - 7), (4 - 8) and (4 - 9) describe the effect of adding NaCl, at different temperatures, on the rheological properties of the original mud (bentonite mud).

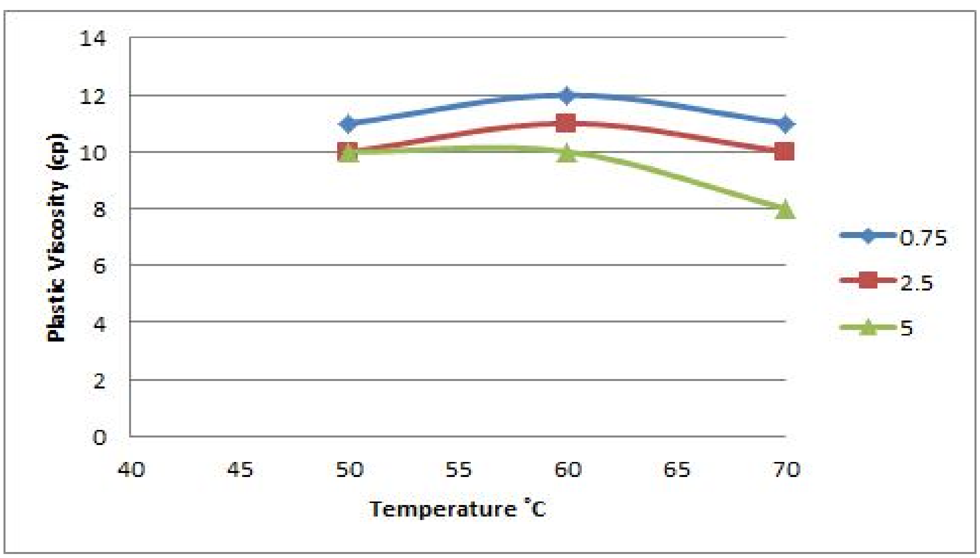

Fig.(4-7): Effect of adding NaCl on the plastic viscosity of original mud at different concentrations and temperatures

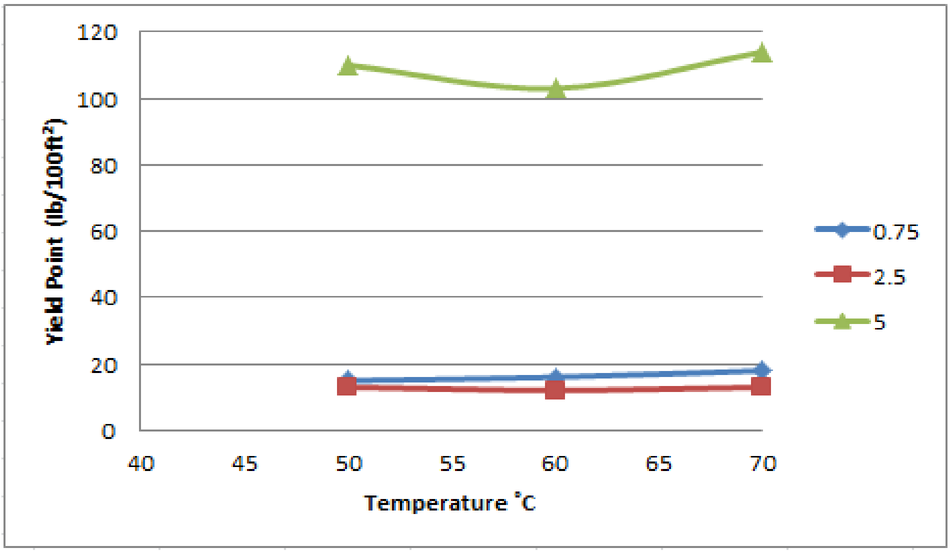

Fig.(4-8):Effect of adding NaCl on the yield point of original mud at different concentrations and temperatures

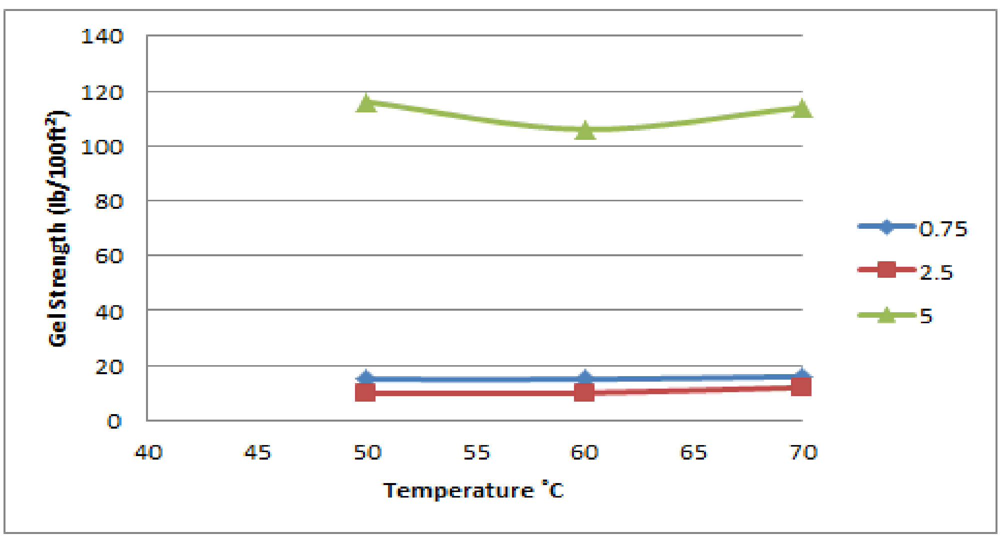

Fig.(4-9):Effect of adding NaCl on the gel strength of original mud at different concentrations and temperatures

4.2 Discussion:

- **Effect of temperature on the original drilling mud:**

  The results show that the plastic viscosity decreases as the temperature increases as shown in fig (4 -1).

  The effect on yield point and gel strength are the same, as shown in Fig (4-2) and Fig (4-3), where as the temperature increases the values of both yield point and gel strength changes .

- **Effects of KCl and NaCl on the original drilling mud:**

  Fig. (4-4) shows that as the KCl concentration increases the plastic viscosity of the original mud decreases.

  From Fig.(4-5) and Fig.(4-6) it can be noticed that as the KCl concentration increases the yield point and the gel strength decreases .

  Fig(4-4) shows that the filtration loss increases with the increases of KCl concentration.

  As the NaCl concentration increases the plastic viscosity decreases for the original mud, as shown inFig(4-8). Where from Fig.(4-7) and Fig.(4-8) it can be noticed that as the NaCl concentration increases the yield point and the gel strength decreases.

  Fig(4-6) shows that the filtration loss increases with the increases of NaCl concentration.

CHAPTER(5)

CONCLUSION AND RECOMENDATIONS

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CONCLUSION AND RECOMENDATIONS

5.1. Conclusion:

The following points can be written from performed experiments:

1. Plastic viscosity decreases with the increases of the temperatures, yield point and gel strength changes with the increased of the temperatures.
2. As the concentration of salts (KCl, NaCl) increases the plastic viscosity decreases, yield point and the gel strength decreases.
3. Increases in the concentration of the salts (KCl, NaCl) the fluid loss into the formation increases.

5.2. Recommendations:

It is recommended to:

1. Identify the effects of salts under high temperatures, more than 70˚C, to see further effects on the rheological properties of water base mud.
2. Use five different concentrations of salts instead of three to give more comprehensive results.
3. Identify the effects of other contaminants under the same conditions of this study.

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