Chemical, Petroleum and Environmental Engineering

Improvement of the Rheological and Filtration Properties of Drilling Mud Using the Syrian Clay

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ABSTRACT

Drilling fluid properties and formulation play a fundamental role in drilling operations. The Classical water-based muds prepared from only the Syrian clay and water without any additives((Organic and industrial polymers) are generally poor in performance. Moreover, The high quantity of Syrian clay (120 gr / l) used in preparing drilling fluids. It leads to a decrease in the drilling speed and thus an increase in the time required to complete the drilling of the well. As a result, the total cost of drilling the well increased, as a result of an increase in the concentration of the solid part in the drilling fluid. In this context, our study focuses on the investigation of the improvement in drilling mud Prepared from the Syrian clay by reducing the clay concentration to (50 gr / L). And compensate for the remaining amount (70 gr / l) of clay by adding (natural and industrial polymers) The rheological properties and filtration are measured at different concentrations of polymers .. In light of the experiments, we determine the polymers' concentrations that gave good results in improving the flow properties and controlling the Filter. It is polymers that have given good results:

،HEC ،HEC and Xanthan Gum PAC and HEC ،CMCHV ،PolyAcryl Amid ،Xanthan Gum .

Keywords. Syrian clay; Drilling fluids; Rheological property; Filtration control

تحسين الخواص الجريانية والارتشاحية لسوائل الحفر المحضرة من الغضار السوري

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الخلاصة

.تلعب خصائص سائل الحفر دوراً أساسياً في عمليات الحفر. سائل الحفر ذو الاساس المائي التقليدي المُعد من الغضار السوري والماء فقط دون أي إضافات (البوليميرات العضوية والصناعية) يكون ضعيفًا بشكل عام في الأداء. علاوة على ذلك ، فإن الكمية الكبيرة من الغضار السوري(120 غرام/لتر) المستخدمة في تحضيرسوائل الحفرتؤدي إلى تقليل سرعة الحفر وبالتالي ازدياد الزمن اللازم لانجازحفر البئر وبالنتيجة النهائية لحفر البئرنتيجة ازدياد تركيز الجزء الصلب في سائل الحفر. في هذا السياق، تركز دراستنا على تحسين سائل الحفر المحضر من الغضار السوري من خلال تقليل تركيز الغضار إلى (50 غرام /لتر).

ونعوض عن الكمية المتبقية (70 غرام/لتر) من الغضار بإضافة (البوليمبرات الطبيعية والصناعية) و يتم قياس الخصائص الريولوجية وفاقدالرشح للسائل عند التراكيز المختلفة من البوليمرات. وعلى ضوء التجارب نحدد تراكيز البوليميرات التي اعطت نتائج جيدة في تحسين الخواص الجريانية والتحكم بفاقد الرشح ، ومن البوليميرات التي أعطت نتائج جيدة نذكر:

HEC ،HEC and Xanthan Gum، HEC and PAC ، CMCHV، PolyAcryl Amid ، Xanthan Gum .

الكلمات الرئيسية: الغضار السوري ، سوائل الحفر ، الخواص الجريانية ، التحكم بالراشح

1. INTRODUCTION

One of the most important elements of drilling operations is drilling mud, as it has many functions through which an oil or gas well is drilled as quickly as possible and with minimal problems. In the event of a malfunction in one of the jobs, this leads to the emergence of a specific problem during drilling Such as stubborn digging of pipes, loss of drilling fluid inside the rock layers, kicks, or a burst of oil or gas. **(Baroid Fluids HandBook .2005)**

A drilling fluid is any fluid which is circulated through a well in order to remove cuttings from a wellbore. This section will discuss fluids which have water which can be used as drilling fluids.

A drilling fluid must fulfill many functions in order for a well to be drilled successfully, safely, and economically. The most important functions are **(Omland,and T.H., Albertsen.2006).**

: (1). Cuttings removal. An important function of the drilling fluid is to carry rock cuttings removed by the bit to the surface. The drilling flows through treating equipment where the cuttings are removed and the clean fluid is again pumped down through the drill pipe string.t. (2) Cooling and lubrication. As the bit drills into the rock formation, the friction caused by the rotating bit against the rock generate heat. The heat is dissipated by the circulating drilling fluid. The fluid also lubricates the bit. (3) Suspend cuttings. There are times when circulation has to be stopped. The drilling fluid must have that gelling characteristics that will prevent drill cuttings from settling down at the bit. This may caused the drill pipe to be stuck. (4) Pressure control. The drilling mud can be the first line of defense against a blowout or loss of well control caused by formation pressures. (5) Data source. The cuttings that the drilling mud brings to the surface can tell the geologist the type of formation being drilled (6) To wall the hole with impermeable filter cake. This will give a temporary support to the wall of the borehole from collapsing during drilling..

Polymers are used in many types of drilling fluids and can control properties such as viscosity, fluid loss control, flocculation/deflocculating (Thinning), shale inhibition, lubricity, polymer drilling fluids. These fluids contain polymers as PolyAcryl Amid, PolyAnionic Cellulose and Xantan Gum **(Wood, Brad Billion.1999)**

The main advantages of using polymer drilling fluids are: (i) high rate of penetration (ROP) in hard formations, (ii) shear thinning/lower emergency shutdown (ECD), (iii) good borehole cleaning, (iv) easy to run, (v) it gives probably made its most significant contribution to the drilling industry in high temperature/high pressure applications, (vi) polymer fluids can handle contamination and can be treated to minimize corrosion, (vii) lubrication drilling pipe and torque reduction (viii) it is an environmental compatibility **(Omland,and T.H., Albertsen.2006).**

The properties of the mud which allow it to fulfil these functions are its velocity, viscosity, density, and gel strength.

The drilling fluid is chosen based on the type and locations of the excavated layers, the pressure of the layers and the type of fluids in them (oil, gas) The properties of drilling fluid (density, viscosity, yield point, gel strength) are controlled by chemical additives.

The density of the drilling fluid is carried out through the pressure of the drilling fluid column inside the well, which must be greater than the pressure of the layers. The viscosity of the drilling

fluid is responsible for carrying rock cuttings from the bottom of the well to the surface. Yield point is responsible for carrying the crumbs while the liquid is moving inside the well.The gel force is responsible for carrying the rock cuttings while the drilling fluid stops rotating as the drilling fluid turns from a liquid to a gelatinous state **.**

This paper describes the laboratory evaluation adding the polymers in order to develop the performance of the drilling mud preparing by incorporation of the Syrian clay. Syrian clay has a weak ability for controlling (i) the rheological properties (e.g. viscosity, yield point, and gel strength), (ii) filter controlling, (iii) carrying capacity, and (iv) weak ability in cuttings removal and suspend.

Actually, the drilling mud prepared in the field requires a large quantity of the Syrian clay (about 120 g/l) during the preparation step. This excessive quantity may generate major problems related to (i) increase the solids content, (ii) reduce the rate of penetration (ROP),
 (iii) increase the drilling time, (iv) increase the time of execution of well (v) increase the total cost of drill a well and (iv) increase the filter cake which will altered the formation production. Therefore, improving the specifications of drilling fluid reduces drilling problems and thus reduces the total cost of drilling the well In this paper, we will improve the specifications of drilling fluid by adding polymers.

one of the most successful used is the adding of polymers/material not only to improve the properties of drilling mud, but also to reduce the large quantity of the Syrian clay. This paper focuses on the investigation of the improvement in drilling mud used in the Syrian field. Several polymers were added at different concentrations and their influence on the rheological properties and filtration is investigated. Finally, in order to design efficient processes, the analysis of results is used to achieve the optimum performance.

2. THEORETICAL BACKGROUND

There are many types of alkaline liquids used in drilling oil and gas wells, depending on the type of well that is to be drilled and the type of rock layers.It is classified according to the base liquid used for water, oil and air . The types of drilling fluids are given in the following sections.

2.1 Types of drilling fluids

 (i) Water-base mud :This fluid is the mud in which water is the continuous phase. This is the most common drilling mud used in oil drilling. Water may be fresh or salt treated with some salts such as sodium chloride, potassium chlorine and calcium chlorine. Polymers may be added to improve the flow characteristics and reduce leaching loss.

(ii) Oil-based mud:This drilling mud is made up of oil as the continuous phase. Diesel oil is widely used to provide the oil phase. This type of mud is commonly used in swelling shale formation

(iii) Air and foam :There are drilling conditions under which a liquid drilling fluid is not eh most desirable circulating medium. Air or foam is used in drilling some wells when these special conditions exist. Air "drilling fluid" is mainly used in dry hard rocks where hole stability is not Problem. Foam is used when drilling formations that cause a total loss of drilling fluid and formations that have a low bed pressure (**Omland,and T.H., Albertsen.2006).**
. Scientific research is still ongoing to develop the performance of various drilling fluids and make them more economical, by using natural or industrial polymers.

2.2. Composition drilling mud

1-Water (continuous phase): It can be fresh water, OR Salt (Potassium chloride, Calcium Chloride, Potassium Formats, sodium Formats) (**Cameron,snd C., Florence, 2005)** 2-Reactive

solids: Sodium Montomorillonit or Bentonite, Attapulgite, SALT GEL, Natural or synthetic polymers

3- Inert solids: Barite (barium sulfate): It used to increase mud density up to maximum of 22 ppg [8].Hematite (iron oxide): It used to increase mud density up to maximum of 25 ppg

(iii) Calcium Carbonate: It used to increase fluid density up to maximum of 14.0 ppg . It also used as bridging agent in drill-in, oil and synthetic fluid.

(iv) Lost Circulation Material: Materials used to seal rocky cracks, which cause a loss of drilling fluid(Mica Fiber, wood, paper,plastic)

(v) Formation solids: Sand, Limestone, Dolomite.

4-Soluble chemicals: (NaOH), (KOH), [Ca(OH)$_2$], (Na$_2$CO$_3$), (NaHCO$_3$), Zinc Oxide (ZnO), Viscosity reducers (mud thinner) adds anionic (negative) charges to the mud, Neutralizes positive.

2.3 Clay types
The elements that go to make up clay minerals make up 80% of the mass of the earth. The clay types are:

2.3.1 Smectite:
A common smectite is Montomorillonit and Bentonite. Weathering product from Feldspar. Hydrates and swells in contact with water are very good. Its structure is composed of two sheets of silica with one sheet of aluminum in between, as show in **Fig. 1**(a). This three sheet structure is called a clay platelet. The outer silica sheet (tetrahedral) is composed of units of four oxygen atoms (O^{2-}) and one silicon in a pyramid shaped network with the silicon atoms in the center of the pyramid **(Sawhney, B.L. 1989)**. The combinations of these units form a sheet (1 to 2180microns) as oxygen atoms are shared at the base. The degree of substitution is high **(Grim, R. E., 1968).**

(a)   (b)   (c)
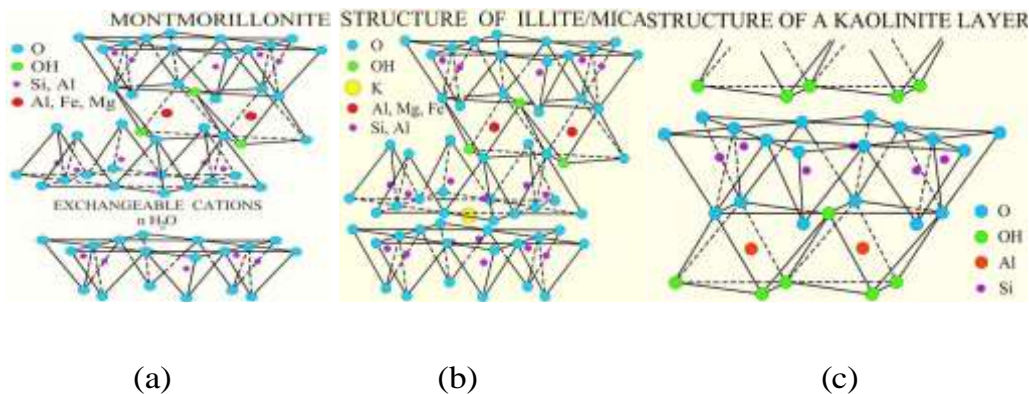
Figure 1. structure of Smectite.

2.3.2 Illite:
The structure is similar to that of Montomorillonit, as shown in Figure 1(b). However, substitution of aluminum has been made for silicon (Si^{4+}) in the outer sheet as well as magnesium (Mg^{2+}) for aluminum (Al^{3+}) in the inner sheet. This deficit of positive charges is satisfied with potassium in the lattice. **U.S. Geological**
Hydration of this clay is very low because of potassium (K$^+$) ion. The ionized dimension of

the potassium ion is so small it has very little water associated with it, so that it snug-fits into the base of the oxygen network on the outer sheet. The small volume of water surrounding the potassium ineffect places the net positive charge very close to the surface in the platelet or layer and strongly supplements the van der Waals forces in boding the platelets very close together. Thus, only a small amount of water can become associated with the clay.

2.3.3 Kaolinite

Kaolinite is composed of to sheet: a silicon and aluminum sheet, as shown in **Fig.1**(c). The tetrahedral oxygen is strongly bonded Face-to-Face with the octahedral hydroxyls. There is little or no cation on the surface, therefore hydration and swelling are prevented.

2.3.4 Chlorite:

Fig.2 (a) shows the structure of Chlorite. It is clay with three-sheet platelets separated by a brucite sheet. The brucite sheet is basically the same as the aluminum octahedral sheet except that the predominate metal atom is magnesium. The substitutions of aluminum for magnesium resulte in a net positive charge.
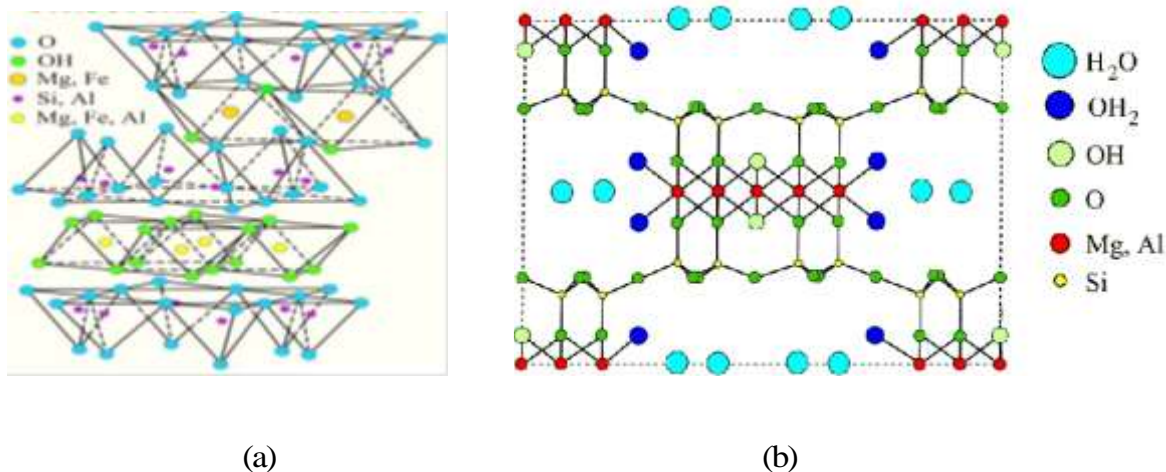

(a)   (b)

Figure 2. structure of Chlorite and Attapulgite.

2.3.5 **Attapulgite:**

Fig 2(a) shows the structure of Attapulgite. It is another class of clay that when hydrated has a small water envelope. It builds viscosity when sheared and has a "haystack" appearance. Attapulgite is used in building viscosity in salt water systems because of its needle type structure. The use of Attapulgite is excluded form use in all shell operation due its toxicity.

2.3.6 . Mixed-layer clays

Mixed-layer clays are combination of different clay platelets stacked together such as montmorillonite-illite, chlorite-smectite, ..etc.. Mixed-layer clays can form by weathering involving the removal or uptake of cations (e.g. K), hydrothermal alteration, or removal of

hydroxide interlayers, and, in some cases, may represent an intermediate stage in the formation of swelling minerals from non-swelling minerals or visa versa **(MacEwan, D. M.C. and Ruiz-Amil, A, 1975 13,8).**

The characteristics of the clay will be influenced by the most reactive clay. summarizes the composition of the Syrian clay. As shown in **Table 1.**

Table 1. Show composition of the Syrian clay.

Oxides	SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	H_2O	Na_2O	TiO_2
%(W/W)	46.6	14.4	7.2	6.7	12	12.8	0.13	0.19

The Syrian clay has a little content of (SiO_2, Al_2O_3), high content of the detrimental oxides as (MgO, CaO). Moreover, the very low hydration of this clay will cause the following problems: (i) add a big quantity of it for preparing drilling mud; (ii) carry cuttings out of the hole is a bad; (iii) suspend cuttings during the stopped is not a good; (vi) increase the solids content; (iv) reduce a rate of penetration (ROP); (v) increase the drilling time; (vi) increase time execution of well; and (vii) increase the total cost of drill a well.

3. Materials and methods
3.1 Materials

Different materials were used in the experiments. These materials and their most important physical properties are presented as follows:

1-Syrian Clay: It is used as viscosifier. The bulk density is 2500 kg/m³.

2-Soda Ash: sodium carbonate (Na_2CO_3) is used primarily to remove calcium contamination particularly that due to anhydrite. The bulk density ranges from 460 to 600 kg/m³. It is readily soluble in water.

3-Caustic soda: sodium hydroxide (NaOH) is used to control pH in water based mud. Its bulk density is 1200 kg/m³. It is soluble in water up 42 g/100 ml at 0°C.

On the other hand, caustic soda is used to maintain the proper drilling fluid pH. Consequently, it provides the alkaline environment necessary for the correct degree of dispersion of clays and the full ionization, solubility of dispersants, and of some polymers. Maintaining a high also aids corrosion control and reduces contamination by calcium or magnesium which are precipitated as hydroxides **(Drilling Engineers Workbook.2003).**

4-Xanthan Gum: This water-soluble biopolymer, slightly anionic and highly branched is used as a primary viscosifier in all types of water-based muds. It is one of the few polymers that develop progressive gel strengths, allowing weighting agents to be easily suspended without the need for very high viscosities. It is particularly suitable for use in workover and completion fluids and water flood operations. It produces a minimum of formation damage. Indeed, it is completely broken down by acids or oxidizing agents, rapidly soluble in freshwater, seawater or brines. Temperature stability in laboratory is up to 130°C. Temperature stability in the field can be reached at up 160°C. The stability can be extended by up to 20°C by the use of temperature stabilizer. The bulk density is 840 kg/m³ **(Dowell IDF Fluids Services.2000).**

5-CarboxyMethylCellulose-High Viscosity (CMC_{HV}): This modified natural polymer, which has a high molecular weight, is used to well increase viscosity as well as control fluid loss. Temperature stability in the field can be reached at up 120°C. The bulk density is 600 kg/m³. It is soluble in freshwater and saltwater.

6-PolyAnionic Cellulose (PAC) as fluid loss reducer: This viscosifier is a high performance, which functions as a combined viscosifier and fluid loss reducing agent for all types of water– based mud The bulk density ranges between 500 and 800 kg/m^3. It is soluble in water.Temperature stability in laboratory may be achieved up to 150°C. Temperature stability in the

field can be reached at up 180°C. The stability can be extended by up to 20°C by the use of temperature stabilizer. The viscosifier acts as a combined viscosifier and field loss reducing and gives a shear thinning fluid with a good yield point to plastic viscosity ratio. Moreover, it is effective in freshwater, seawater, and all common brines, including magnesium chloride and shows a good resistance to calcium.

7-HydroxyEthylCellulose (HEC): This viscosifier is a multipurpose viscosity agent for use in freshwater, seawater and complex brine systems. It is a linear polysaccharide polymer based on a cellulose backbone. It is widely recognized as being the least damaging viscosifier for clear brines since the material is nonionic its viscosifying characteristics are unaffected by common contaminants or dissolved salts. It is rapidly soluble in freshwater; seawater or brines Temperature stability is up to120°C. The bulk density ranging from 360 to 610 kg/m^3 (**Dowell IDF Fluids Services**.**2000**)

8-Poly Acryl Amide: This polymer is used as a primary viscosifier in all types of water-based muds. The Temperature stability is up to 200 $^\circ$C. It is also used as filtration control.

3.2. Rheological tests of the drilling fluids

Measurement of Rheological characteristics(gel strength, plastic viscosity and yield point) and density and filter press were performed on samples prepared from the Syrian clay, which are the recommended tests from the American Oil Institute(API). (**Badrul,and M.J., Chiou,2007).**
The drilling fluid density measurement test consists of essentially filling the cup with a mud sample and determining the rider position required for balance, as shown in **Fig 3.**

Figure 3. Density meter of mud.

In viscosity measurement, a rotational viscometer was used. **Fig 4** shows the Fann rotational viscometer employed in this study. Rotational viscometer can provide a more meaningful measurement of the rheological characteristics of the mud than marsh funnel. The mud is sheared at a constant rate between an inner bob and outer rotating sleeve. Six standard speeds plus a variable speed setting are available with the rotational viscometer. Only two standard speeds are possible with most models designed for field use (**Badrul,and M.J., Chiou,2007)**

Figure 4. the Fann rotational viscometer.

The rheological parameter called the gel strength (G_s) given in Equation (1), measured in units of lbf/100 sq ft or 0.48 kg/ms², **(Badrul,and M.J., Chiou,2007).**

$$G \; = \; \theta_3 / \theta_3^{/} \tag{1}$$

Where: θ_3 is the torque readings from instrument dial at 3 rpm after (10 minute) of stopping,

and $\theta_3^{/}$ is the torque readings from instrument dial at 3 rpm after (10 second) of stopping.

Another rheological parameter called the plastic viscosity, ($_p$), measured in units of centipoises (cP). The plastic viscosity is defined as follows Eq (2) :

$$\eta_p = \theta_{600} - \theta_{300} \tag{2}$$

where θ_{600} and θ_{300} are the torque readings from instrument dial at 600 rpm and 300 rpm,

respectively.

The rheological parameter yield point, (Y_b), is the most important measured in units of

(lb/100 ft²). It is defined as follows as Eq (3):

$$Yp = \theta_{300} - \eta_p \tag{3}$$

A relatively simple criterion below was suggested to control the fluid drilling as Eq (4):

$$\xi = Yp / \eta_p \tag{4}$$

Values of $_t$ far above unity must be verified allowing the utilization of fluid drilling.

The parameter Carrying Capacity Index (CCI) for drilling mud is given in Equation (5). There are only three hole cleaning variables that can be controlled at the rig: mud density, annular velocity, and plastic viscosity and rheological parameter yield as Eq (5) (**Drilling Engineers Workbook**.2003)

$$CCI = \frac{\rho_f.K.\bar{v}}{400000} \tag{5}$$

where ρ_f is the mud density, v is the annular velocity, and K is a constant relative to drilling mud.

The annular velocity can be defined by the Equation as Eq (6):

$$\bar{V} = \frac{352190}{D_B.\rho_m} \tag{6}$$

ρ_m is the pressure gradient (kPa/m) and D_B is the diameter of bit (e.g. 215. 9 mm).
On the other hand, the constant relative to drilling mud, (K), can be defined as follows as Eq (7):

$$K = 511^{(1-n)}(\eta_p + YP) \tag{7}$$

where the exponent n is given as Eq (8)

$$n = 3.32\log(\frac{2.\eta_p + YP}{\eta_p + YP}) \tag{8}$$

If the (CCI) is equal to 1 orgreaterthe hole cleaningis assumed to be adequate.
The filter press is used to determine the filtration rate through a standard filter paper measured in units of (cm 3/30 min). The API filter press is shown in **Fig** 5. API filtration testis an indication of the rate at which permeable formations are sealed by the deposition of a mud cake after being penetrated by the bit. Cake buildup during drilling is desirable as it protects the formation from being contaminated by fluid invasion. Thus it reduces formation damage   during drilling operation (**Drilling Data Hand Book. 2004)**.
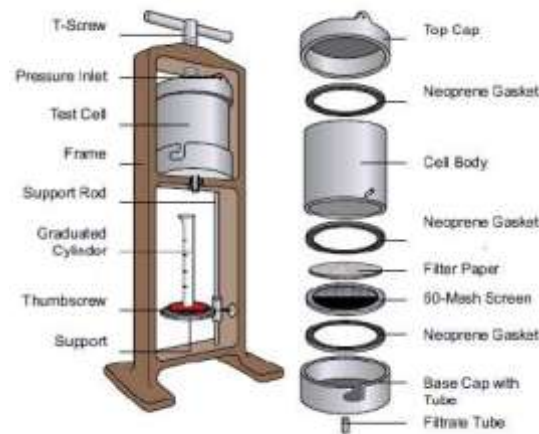
Figure 5. The API filter press.

4. EXPERIMENTAL SECTION

In preparing the mud slurry, 120 g of Syrian clay is added slowly to 1000cm^3
Of distilled water. Then 5 g of Soda Ash and 3 g of Caustic soda are added. Then the mixture was stirred at 1200 rpmfor30 min. Then the procedures are repeated for different polymer and electrolyte concentrations. Mixed solutions were prepared at least 24h prior to application, in order to allow the polymer chains to completely unfold for optimized contact.

4.1. Water based mud preparation

It involves two stages, the preparation of the drilling mud fluids and the rheological
tests of these drilling fluids.

4.1.1 Drilling mud fluids preparation (stage 1)

samples of the drilling mud fluids were prepared including one blank sample which

consists of Syrian clay without any additive. Table 2 shows the composition of the prepared mud samples.

Table 2. composition of samples.

samples	composition
1 Blank	1000cm^3 of distilled water + 120 g of the Syrian clay + 5 g of Soda ash + 3 g of Caustic soda + 12 g of *CMC$_{LV}$[as filtration control age]
2 Xanthan Gum	1000cm^3 of distilled water + 50 g of the Syrian clay + 3 g of Soda ash + 3 g of Caustic soda + different concentration of Xanthan Gum (0.5, 1, 1.5 ,2 ,2.5 ,3, 3..5 ,4 , and 4.3 g)
3 Poly Acryl Amid	1000cm^3 of distilled water + 50 g of the Syrian clay + 3 g of Soda ash + 3 g of Caustic soda + different concentration of Poly Acryl Amid (0.5, 1, 1.5, and 2 g)
4 **CMC$_{HV}$	1000cm^3 of distilled water + 50 g of the Syrian clay + 3 g of Soda ash + 3 g of Caustic soda + different concentration of CMC$_{HV}$ (0.5, 1, 1.5 ,2 ,2.5 ,3, 3..5 ,4 ,4.5 ,5 and 5.5 g)
5 ***PAC	1000cm^3 of distilled water + 50 g of the Syrian clay + 3 g of Soda ash + 3 g of Caustic soda + different concentration of CMCHV (0.5, 1, 1.5 ,2 ,2.5 ,3, 3..5 ,4 ,4.5 and 5 g)
6 HEC	1000cm^3 of distilled water + 50 g of the Syrian clay + 3 g of Soda ash + 3 g of Caustic soda + different concentration of HEC (3, 3.5 ,4 , and 4.4 g)
7 HEC + Xanthan Gum	1000cm^3 of distilled water + 50 g of the Syrian clay + 3 g of Soda ash + 3 g of Caustic soda + 1.5 g of Xanthan Gum + different concentration of HEC (3, 3.5 ,4 , and 4.4 g)
8 HEC + Xanthan Gum	1000cm^3 of distilled water + 50 g of the Syrian clay + 3 g of Soda ash + 3 g of Caustic soda + 2.5 g of Xanthan Gum + different concentration of HEC (3, 3.5 ,4 , and 4.4 g)

4.1.2 Rheological tests (stage 2)

The rheological characteristics of the blank sample drilling mud summarized in **Table 3**. show that the blank sample has a weak carrying capacity index and low yield point. Besides, it has a high gel strength and high filtration rate.

**Table 3**. The rheological and filtration characteristics of the blank (classical) sample drilling mud.

CCI	Filtration rate (cm³/30min)	Gs	$\xi = \dfrac{Y_b}{\mu_p}$	Y_b (lb/100ft²)	μ_p (cP)
2.18	14	12/15	1.62	13	8

4.1.3 Experimental results

(i) Effect of one polymer additive concentration (sample 2, 3, 4, 5, and 6)

In the formulation, the polymer additives, such as Xanthan Gum, Poly Acryl Amid, Carboxyl Methyl Cellulose High Viscosity (CMCHV), Poly Anionic Cellulose (PAC), and Hydroxy Ethyl cellulose (HEC), are used to obtain the desired rheological properties and filtration control character. The results are presented in Figure 6 and in Table 4. It could be seen that the concentration of the polymer additives had a significant effect on the rheological parameters and filtration rate for the drilling mud fluids prepared in this study.

According to the experimental results, as shown in **Fig 6** and **Table 4**, one of the key factors to maintain acceptable rheological properties and filtration rate for this kind of drilling fluids is to select the proper proportion of polymer additives and Syrian clay. It was found that the favorable values of CCI, YP, Gs, and filtration rate could be obtained when the concentration of polymer additives and Syrian clay was kept within the range of (4.3 g): (50 g) in the case of Xanthan Gum (**Fig** 6(a)), (1.5, 2 g): (50 g) in the case of PolyAcryl Amid (**Fig** 6(b)), and (3.5-4.4 g): (50 g) in the case of Carboxyl Methyl Cellulose High Viscosity (CMCHV) (**Fig** 6(c)). It is clear from a perusal of all these curve plots that high these concentrations resulted in an improvement in the classical drilling mud fluids in terms of rheological properties and filtration rate. On the other hand, the results obtained from the PAC and HEC polymer additives experiments showed that these polymers did not show any beneficial effect to the results   (**Fig** 6(d, e)).
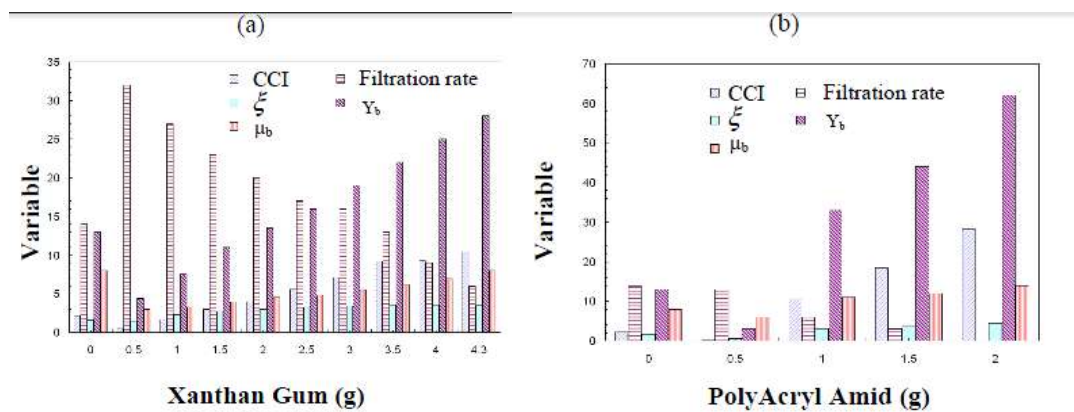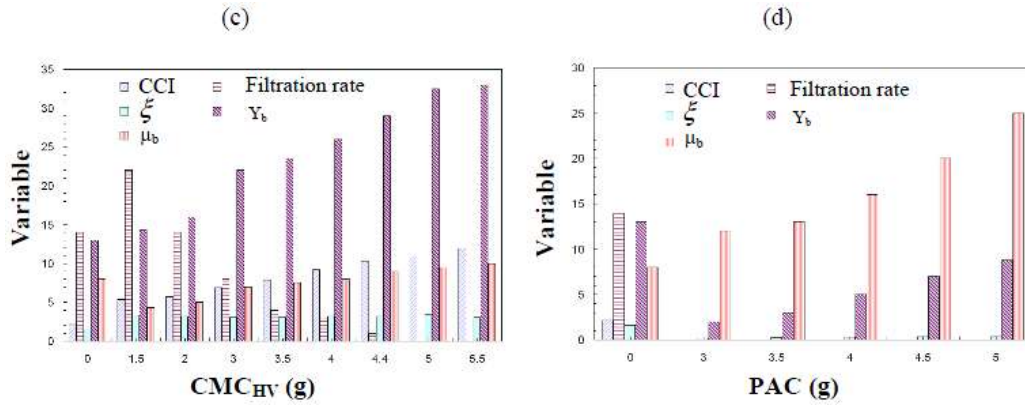
Figure 6. The results Effect of one polymer.

Table 4. Gel strength drilling fluids with different polymer concentration.

Xanthan Gum		PolyAcril amid		CMC$_{HV}$		PAC		HEC	
g	Gs	g	Gs	g	Gs	g	Gs	g	Gs
0.5	5/7.6	0.5	4/5	1.5	9/14	3	1.5	3	2/7
1.5	6/9	1	7/8	2	10/16	3.5	1.5/6	3.5	4/17
2	7/10	1.5	8/9	3	16/32	4	2/7	4	5/19
2.5	8/10.5	2	13/14	3.5	17/35	4.5	2.5/8	4.4	8/33
3	10/11			4	21/33	5	3/9		
3.5	10/12			4.5	23/35				
4	11/13			5	25/38				
4.4	12/15			5.5	27/42				
5	14/17								

 (ii) Effect of two polymer additives concentration (sample 7, 8, 9, 10, 11, and 12)

Various types of water-based muds such as HEC/Xanthan Gum/Syrian clay, Xanthan Gum
/CMC$_{HV}$/ Syrian clay, and CMC$_{HV}$/ Xanthan Gum/Syrian clay have been tried in this area.
The rheological parameters including plastic viscosity, carrying capacity index, gel strength
and yield point of the mud for different concentrations of the HEC (3 g, 3.5 g, 4 g, 4.4 g) at
different fixed concentrations of Xanthan Gum were compared with that of blank (or
398classical) mud prepared from only Syrian clay without any additive (Figure 7(a, b, c, d),
Table 5. The rheological properties display a significant increase in carrying capacity index,
plastic viscosity, and yield point as concentration of the HEC polymer increased from 3 g to 4.4
g atdifferent fixed concentrations of Xanthan Gum (except at 1.5 g of Xanthan Gum).
On the other hand, it was found that the favorable values of CCI, Y$_P$, G$_s$, and filtration rate
could be obtained when the concentration of two polymers additives and Syrian clay was kept
within the range of (3, 3.5 g of Xanthan Gum)/(2 g of CMC$_{HV}$)/(50 g of Syrian clay)
(**Fig 7**(e)), and (3, 3.5 g of CMC$_{HV}$)/(2 g of Xanthan Gum)/(50 g of Syrian clay)
(**Fig 7**(f)).In all cases, as shown in **Fig 7**(b, c, d, e, f), it was found that the filtration properties
show that filtration rate is increased by decrease in the concentration of the polymer additive.
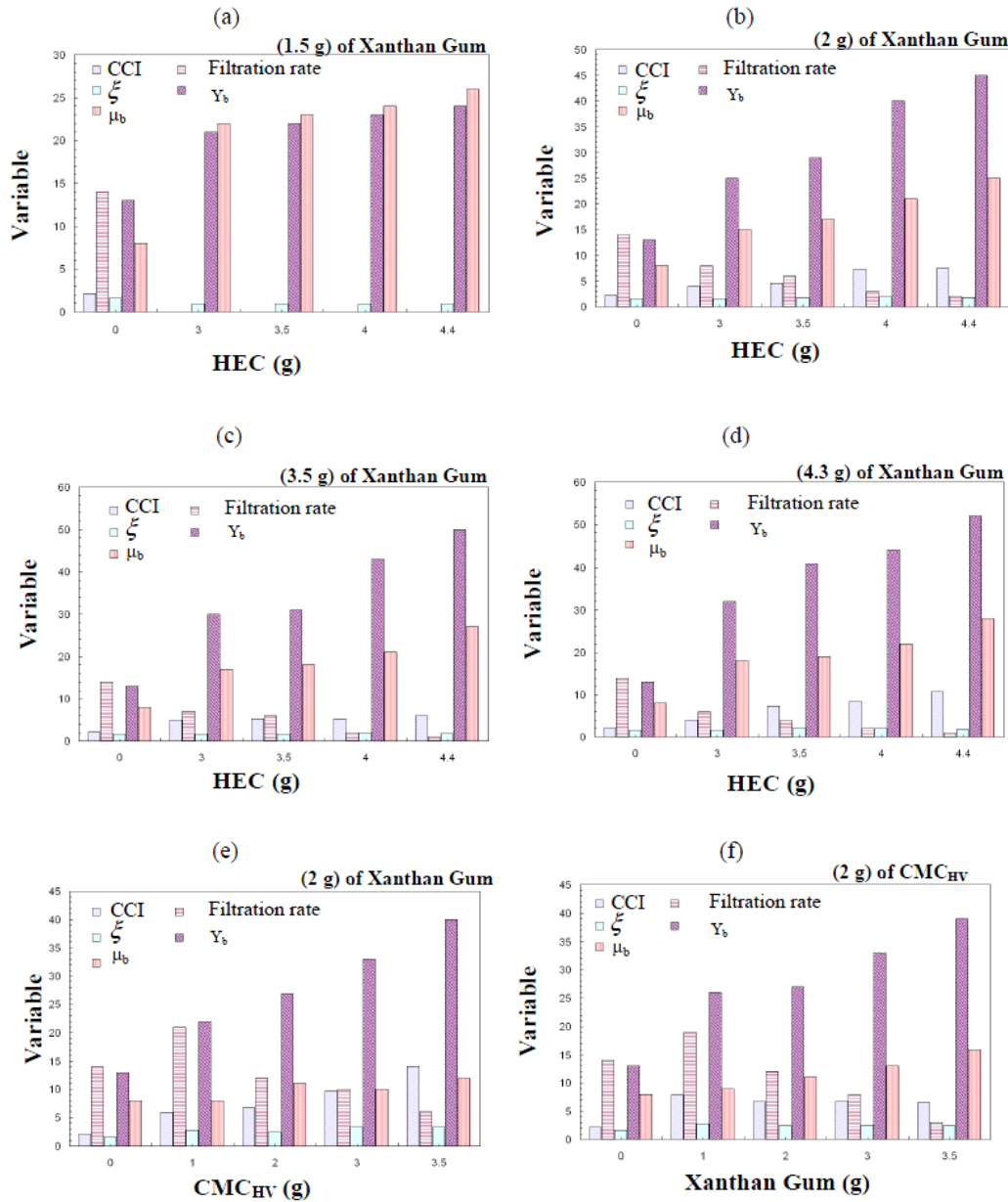
Figure 7. The results Effect of two polymer.

Table 5. Gel strength drilling fluids with two different polymers concentration.

HEC(1.5)g of xanthan Gum		HEC(2)g of xanthan Gum		HEC(3.5)g of xanthan Gum		HEC(4.3)g of xanthan Gum		CMCHV(2)g of xanthan Gum		Xanthan Gum (2)g of CMC$_{HV}$	
g	Gs	g	Gs	G	Gs	g	Gs	g	Gs	g	Gs
3	11/35	3	14/30	3	15/30	3	17/29	1	11.5/12	1	12/12
3.5	15/38	3.5	16/31	3.5	16/31	3.5	24/30	2	14/14	2	14/14
4	16/39	4	28/38	4	18/33	4	26/33	3	17/19	3	24/25
4.4	18/40	4.4	31/38	4.4	31/38	4.4	38/43	3.5	17/18	3.5	27/30

4.2 Salt water based mud preparation

 The salt content of make-up water will greatly affect the viscosity of clay mud, as well as wall cake thickness, water loss and mixing ability. Salty water has a minimal effect on polymers. Salt may be added to increase mud weight without adding solids, and is a very effective method of increasing mud weight in most conditions **(Falode,and O.A., hinola**.**2005).**

. Indeed, salt may be added to the water phase in order to enhance emulsion stability (electrical effect and water activity) and to increase both density and viscosity.Hard water contains dissolved calcium and/or magnesium, which make it difficult to mix and hydrate clay and to get a good yield from the clay. It is well documented that, in areas with wellbore stability problems, polymers are usually supplemented with a salt that supplies a cation to help stabilize the formation. For example, the following are some salt/polymer muds that have been used: (i) Xanthan Gum/K$_+$: it is used in wells that do not have severe shale problems. It does impart excellent low-shear-rate viscosity to the mud for good suspension of cuttings and carrying capacity. As mentioned earlier, Xanthan Gum has a limited temperature stability and lubricating agents can be added. (ii) Sized Salt: several horizontal wells have been drilled using a fluid originally developed as a completion fluid**. (Mondshine, T.C., 1989**). It contains sized sodium chloride particles for bridging and a polymer blend for excellent cuttings suspension and carrying capacity. It is a saturated salt system and cannot be formulated for low mud weights. Inasmuch as the salt is easily dissolved in water and breakers are added to destroy the polymer, it is a relatively non damaging fluid (**Caenn,andR., Chillingar**.**1996)**

In the next section, the rheological behaviour and filtration rate of three mud systems (Xanthan Gum, HEC, and HEC/Xanthan Gum)/NaCl/Syrian clay) whose compositions are reported in **Table 6**. are studied.

4.2.1 Experimental results

The rheological characteristics of the blank sample salt water based drilling mud summarized in **Table 7**. show that the blank sample has a weak carrying capacity index and low yield point. Besides, the gel strength and filtration rate in this case are lower than that obtained for blank sample prepared from only water without salt.

Table 6. Composition of salt sample.

samples	composition
1 Blank	1000cm^3 of distilled water + 120 g of the Syrian clay + 5 g of Soda ash + 3 g of Caustic soda + 12 g of *CMC$_{LV}$[as filtration control age] + 300 g of NaCl
2 Xanthan Gum	1000cm^3 of distilled water + 50 g of the Syrian clay + 3 g of Soda ash + 3 g of Caustic soda + different concentration of Xanthan Gum (0.5, 1, 1.5 ,2 ,2.5 ,3, 3..5 ,4 , and 4.3 g) + 300 g of NaCl Mud density(10.4ppg)
3 HEC	1000cm^3 of distilled water + 50 g of the Syrian clay + 3 g of Soda ash + 3 g of Caustic soda + different concentration of HEC (1.5 ,3 ,3.5 and 4.5 g) + 300 g of NaCl Mud density(10.4ppg)
4 HEC + Xanthan Gum	1000cm^3 of distilled water + 50 g of the Syrian clay + 3 g of Soda ash + 3 g of Caustic soda + 1.5 g of Xanthan Gum + different concentration of HEC (1.5 ,3 ,3.5 and 4.5 g) + 300 g of NaCl Mud density(10.4ppg)
5 HEC + Xanthan Gum	1000cm^3 of distilled water + 50 g of the Syrian clay + 3 g of Soda ash + 3 g of Caustic soda + 2 g of Xanthan Gum + different concentration of HEC (1.5 ,3 ,3.5 and 4.5 g)) + 300 g of NaCl Mud density(10.4ppg)
5 HEC + Xanthan Gum	1000cm^3 of distilled water + 50 g of the Syrian clay + 3 g of Soda ash + 3 g of Caustic soda + 3 g of Xanthan Gum + different concentration of HEC (1.5 ,3 ,3.5 and 4.5 g)) + 300 g of NaCl Mud density(10.4ppg)

Table 7. the rheological and filtration characteristics of the blank(classical) sanple salt water based drilling mud

CCI	Filtration rate (cm^3/30min)	Gs	$\xi = \dfrac{Y_b}{\mu_p}$	Y_b (lb/100ft^2)	μ_p (cP)
2.18	14	5/10	1.2	10	8

Fig 8. and Table 8. show the experimental results for these three mud systems (Xanthan Gum, HEC, and HEC/Xanthan Gum)/NaCl/Syrian clay). The experimental results indicated that the favorable values of CCI, Y$_P$, G$_s$, and filtration rate could be obtained when the concentration of polymer additives and Syrian clay was kept within the range of (4.5 g)/(300 g of NaCl)/(50 g of Syrian clay) in the case of Xanthan Gum (**Fig 8**(a)), (4.5 g)/(300 g NaCl)/(50 g of Syrian clay) in the case of Carboxyl Methyl Cellulose High Viscosity (CMC$_{HV}$)
(**Fig 8**(b)), and (1.5-4.5 g of CMC$_{HV}$)/(1.5-3 g of Xanthan Gum)/(300 g of

NaCl)/(50 g of Syrian clay) (**Fig 8**(c, d, f)). It is clear from a perusal of all these curve plots

that high these concentrations resulted in an improvement in the classical drilling mud fluids in terms of rheological properties and filtration rate.
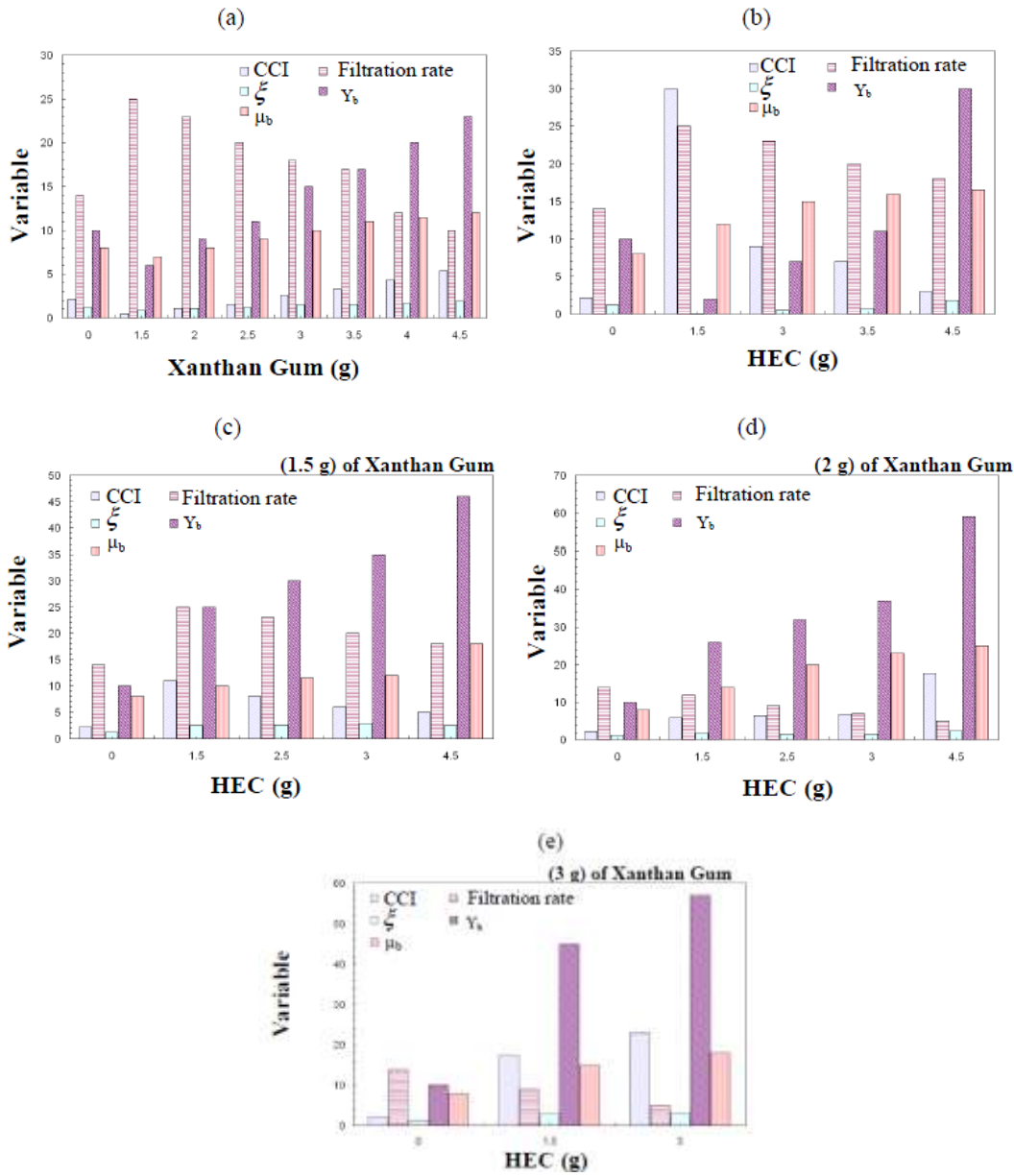
(a)

(b)

(c)

(d)

(e)

Figure 8. the experimental results for these three mud systems.

Table 8. Gel Gel strength of drilling fluids with different polymers concentration in case of salt water based drilling mud.

xanthan Gum		HEC		HEC (1.5)g of xanthan Gum		HEC (2)g of xanthan Gum		HEC (3)g of xanthan Gum	
g	Gs	g	Gs	G	Gs	g	Gs	g	Gs
1.5	5/10	1.5	5/6	1.5	5/7	1.5	4/8	1.5	12/15
2	6/11	3	6/10	2.5	6/8	2.5	5/9	3	14/15
2.5	7/13	3.5	10/15	3.5	7/9	3.5	7/10		
3	8/14	4.5	12/17	4.5	9/11	4.5	9/12		
3.5	10/15								
4	11/17								
4.5	13/20								

5 . CONCLUSIONS

1-The Syrian clay was not an effective for preparing drilling mud because it has a weak ability in carrying capacity, yield point, cuttings removal, and suspend cuttings and filtration control.
2-The polymer Xanthan Gum with water based mud had a good ability improving the carrying capacity index and yield point. The optimum concentration is 4.3 g.
3-The polymer Xanthan Gum with salt mud had a good ability to improve the carrying capacity and yield point. The optimum concentration is 4.3 g with adding a material for filtration control.
4-The polymer PolyAcryl Amid with water base mud had a good ability to improve the carrying capacity and yield point and reduce the gel strength. The optimum concentration is 1.5 g.
5-The polymer CMC$_{HV}$ with water based mud gave good results in improving the carrying capacity and yield point. The optimum concentration is 4.4 g.
6-The polymers PAC and HEC with water based mud did not show any beneficial effect to the results.
7- Both the polymers HEC and Xanthan Gum had a good ability in improvement the drilling mud properties with following forms:
Xanthan Gum 3 g/l, HEC 2.5 g/l, ،Xanthan Gum 3.5 g/l HEC + 2.5 g/l

8-The polymers $_{CMCHV}$ and Xanthan Gum both gave a good results of Improvement The drilling mud Properties with following forms :
Xanthan Gum 2 g/l (CMC$_{HV}$) + 3 g/l

Xanthan Gum 3.5 g/l (CMC$_{HV}$) + 2 g/l

9-adding the polymer (HEC) with salt mud gave a good results of Improvement The Rhological Properties and filter controlling, with concentration 4.5 gr
10-adding the polymers HEC and Xanthan Gum wit salt mud gave a good results of Improvement The drilling mud Properties. with following form:
Xanthan Gum. 3 g/l HEC + 1.5 g/l

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LIST OF ABBREVIATIONS

HEC: Hydroxy Ethyl cellulose
CMCHV: Carboxyl Methyl Cellos
PAC: Poly Acryl Amid
CCI :Carrying Capacity Index
YP: yield point
η_p : plastic viscosity

G: gel strength

ρ_f : mud density

v : the annular velocity.
K : constant relative to drilling mud.

ρ_m : the pressure gradient .
D_B : the diameter of bit.