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Improvement of the Rheological Properties of Local Bentonite Clay Using New Blending Polymers for Water - based Drilling Fluids

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NEW composition polymers formulated from the reaction of different mixed polymers by using gamma (γ) radiation technology. A fixed ratio of polyvinylalchol (PVA), chitosan was mixed with different ratios of N-vinyl-2-pyrolidene (NVP) with and without diethyleglycal dimethylacrylate (DEDMA). The chemical structures of the prepared composition polymers were conformed using FT-IR and the molecular weight determination by (GPC). The results of the spectroscopic analysis indicate that they were prepared through right method and they have high purity. The new prepared composition polymers were evaluated as a viscosifier and filter loss additives for water-based drilling fluid formulated from local Egyptian clay to improve their rheological properties. The evaluation includes the study of rheological, filtration of the water – based mud treated with the new prepared composition polymers and the results were compared to the reference commercial water based- mud. The results of treatment of water-based mud with the prepared new composition polymers showed a good efficiency.

Keywords: Water-based mud, Poly vinyl alcohol (PVA), Chitosan, Rheological properties and Filtration properties.

During drilling of oil and gas wells, fluids are used to lubricate the drill bit, maintain hydrostatic pressure, transmit sensor reading, remove rock cuttings and inhibit swelling of reactive clay based shale formations[1-4] . Aqueous drilling fluids (water-based mud) are an environmental friendly and more economic than the non-aqueous type (oil – based mud and synthetic – based mud) [5-11]. In order to achieve the optimum performance of any mud during drilling operations, the physical as well as chemical properties of the mud must be carefully controlled ; viscosity, gel strength, fluid loss are of particular importance (parameters of drilling fluids). Also, the clay surface chemistry and that of various drilling fluids constitute must be controlled[12-14]. To control all these parameters simultaneously and restore the desired drilling fluid propertiesce it becomes necessary to use various chemicals as additives. Growing pressure is being placed upon oil and gas exploration industry to develop drilling fluid, additives with lower environmental impact. Long chain, high molecular weight chemicals

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are effective in increasing viscosity, flocculating molecule, reducing filter loss and stabilizing the formation. Various types of polymers are suitable for this purpose including bentonite extenders; biopolymers and cross-linkers polymers are also used and have good shear-thinning properties at low concentration [15-21].

Bentonite is the main constituent of the water-based drilling fluids due to high viscosity good swelling and lower filter loss. Local raw bentonite exhibit high filtration loss and do not develop sufficient viscosity so, they cannot meet the API (30cp minimum viscosity at 600rpm, 15cm3 filtration loses) standards[22]. By alkali activation or by introducing some polymer additives it is possible to upgrade row bentonite to meet the above standards and thus require appropriate activation formulations. This activation typically employs various additives such as inorganic salts like soda ash, Mgo salt; the inorganic salt improves the swelling or viscosity[23-25]. In the oil drilling fluid field, the polymer is usually selected to reduce fluid loss, increase cutting carrying capacity serve as emulsifiers and lubricants, especially as shale inhibition additives in water-based mud. Modification of bentonite with polymers (soluble in water) and similar compounds has been studied by different investigators and outstanding rheological behaviors such as viscosity, thixotroply, …etc. have been measured. Mechanisms governing activation can be usually advanced as ion exchange, ion adsorption and particle interaction (hetirocogulation)[26-28]. Organic compounds in particle – particular polymers, generally are more effective additives than inorganic salts. Polymeric materials are generally considered useful as viscosifiers agent and water loss additive when dissolved in appropriate solve system.

The interaction of non-ionic polymers with the clay surface is possible through two types of polymers. The amount of water bound the montmorillomite surface increases laniary with the concentration of oxygen or hydroxyls. There are two mechanisms, ion-dipole interactions, where the saturating cations on the clay surface serves as adsorption site for polar-non-ionic molecules. The second type of interaction involves hydrogen bonding either by the direct interaction between the adsorbed polymer clay surface and polymers [29-32] .

The aim of this work is to prepare a new composition polymers formulated from the reaction of different mixed polymers by using gamma (ɣ) radiation technology. A fixed ratio of polyvinylalchol (PVA), chitosan was mixed with different ratios of N-vinyl-2-pyrolidene (NVP) with and without diethyleglycal dimethylacrylate (DEDMA). The new prepared composition polymers was evaluated as a viscosifier and filter loss additives for water-based drilling fluid formulated from local Egyptian bentonite clay to improve their rheological properties. The evaluation includes the study of rheological, filtration of the water – based mud treated with the new prepared composition polymers and the results were compared to the reference commercial water based- mud.

Experimental Materials

Materials

All chemicals that were used throughout this investigation are of analytical grade and used as they are without more purification. Poly vinyl alcohol (PVA) with a molecular weight about 14000, vinyl pyrrolidone (PNVP) with average molecular weight 40000, chitosan and diethylene glycol dimethacrylate (DEDMA) were purchased from sigma Aldrich.

Preparation of the PVA/Ch/NVP Polymer through Radiation Method

Different samples were prepared from various components; full hydrolyzed poly vinyl alcohol (PVA), chitosan, N-vinyl-2-pyrrolidone (NVP) and diethylene glycol dimethacrylate (DEDMA). The preparation of PVA and chitosan solutions was aforementioned elsewhere[33-36]. The composition of each sample was listed in Table 1. The samples solutions were mixed and poured into test tubes of diameter 15 nm and then irradiated with gamma rays and exposed to 30 k Gy of a fixed dose rate 2.43 kGy/h. It was observed that, the samples extracted from gamma irradiation cell were characterized with light viscous with white foggy color. The extracted samples were casted on to Petri-plates (25 cm^2) and put in oven at 40 ^{o}C and 1 bar to dry. The drying process of samples continued for 5 days.

TABLE 1. The component of different samples during preparation.

Sample code	PVA (8%) (g/v)	Chitosan (1%) (g/v)	NVP (10%) (v/v)	DEDMA (1%) (v/v)	Mwt
S$_1$	5 ml	1.5 ml	4.5 ml	1ml	857
S$_2$	5 ml	1.5 ml	6.0 ml	1ml	859
S$_3$	5 ml	1.5 ml	4.5 ml	-----	891

Characterization of PVA/Ch/NVP

The chemical structures of the prepared polymers S1,S2 and S3 were confirmed by: FT-IR spectra of the superabsorbent composite were recorded on a Nicolet-380 Fourier Transform Infrared Spectrometer in a range of 4000-400 cm^1 using KBr pellets as shown in Fig. 1 .

Sample collection and preparation

The field sampling exercise was carried out during the dry season. Fresh samples of the local clay were collected from South Hamam Egypt. The samples were crushed to finer particles and sundried for 5 days to ease pulverizing and sieving. Then they were ground to powder with the aid of mortar and pastle, and then sieved with a rota shaker to obtain 63 μ fractions to Suit API specification for local bentonite [37].

Mineralogical studies

  X-ray diffraction (XRD)

Mineralogical composition of the local bentonite before and after treatment with the new prepared blending polymers S1,S2 and S3 as viscosifiers by X-ray diffraction (XRD) using a philips X-ray diffraction equipment model Pw 710 with mono chromator, Cu radiation (h = 1.542 A°) at 40 kV, 35 mA and scanning speed 0.02°/s. The reflection peaks between $2\phi = 2°-70°$, corresponding spacing (d, A°) and the relative intensities (I/I°) were obtained[38]. The diffraction charts and the relative intensities were obtained and compared with ICDD files (Table 2).

  X-ray fluorescence (XRF)

The samples studied are carried out to determine the chemical composition by (XRF) Spectrometry[37] and the results were listed in Table 3.

Tests for water-based mud

  Mud formulation

All sample were prepared according to American petroleum institute [API RP 13B-1 1997][22] and oil companies petroleum institute [OCMA specification No. DFCP-4 1983][39]. Mud was formulated as following:

1- The base component of water based mud was prepared by adding 6% of local bentonite mixed with 500 ml fresh water.

2- The samples were mixed in Hamiltan mixer for 20 min and cured overnight.

3- The samples were stirred for 15 min then the rheological and filtration properties were measured before adding the viscosifier.

4- Different concentrations of the new prepared blending polymers S_1, S_2 and S_3 were separately added to mud batches and stirred for 20 min and cured overnight.

5- Each sample was stirred for 5 min before the rheological and filtrations properties were measured. So we have five mud batches:

M_R: Water -based Mud formulated of 6% commercial bentonite (R).

M_0: Water -based Mud formulated of 6% Local non-treated bentonites.

Ms_1: Water-based Mud formulated of 6% Local non-treated bentonite and different concentrations of the prepared polymer S_1 ranged from 0.1 to 0.9 g (S_1).

Ms_2: Water-based Mud formulated of 6% Local non-treated bentonite and different concentrations of the prepared polymer S_2 ranged from 0.1 to 0.9 g (S_2).

Ms_3: Water-based Mud formulated of 6% Local non-treated bentonite and different concentrations of the prepared polymer S_3 ranged from 0.1 to 0.9 g (S_3).

Rheological properties

Rheological properties of the water-based mud were measured by using chandler engineering laboratory model (API) viscometer Chan 35 Model (3500). Apparent viscosity (AV), plastic viscosity (PV) and yield point (YP) Unit of: PV in centipoises (cP), AV in centipoises (cP) and YP in 1b/100 ft^2 were measured.

Determination of gel strength and thixotropy

The gel strength of the water-based mud is a measure of the minimum shearing stress necessary to produce slip-wise movement of fluid. Two readings are generally taken (1) after 10 sec (G10 sec) (2) after the mud in the cup has been rested for 10 min (G10 min). Thixotropy of the mud is the difference between the low reading after 10 sec, and 10 min.

Effect of temperature on the rheological properties

Viscosity of the water-based mud is a function of temperature more than pressure. It is necessary to measure viscosity at elevated bottom whole temperature. This is done by using the viscosity cup heater which is a thermostat-controlled unit for heating the mud sample directly on a viscometer with the selected concentration that meet the minimum API specifications for rheological properties (15 cp for apparent viscosity) and 13.5 ml for the filtration properties so for Ms_1 the selected concentration was 1.4 gm / 1000 ml , for Ms_2 was 0.6 gm / 1000 ml and for Ms_3 was 1 gm / 1000 ml

Filtration properties

All experimental data were carried out using Standard filter press fan model 300 multichamper for filtration at 100 psi after 30 minutes.

Results and Discussion

Characterization of PVA/Ch/NVP

The chemical structures of the prepared polymers S_1, S_2 and S_3 were confirmed by: FT-IR spectra of the superabsorbent composite were recorded on a Nicolet-380 Fourier Transform Infrared Spectrometer in a range of 4000-400 cm^{-1} using KBr pellets. Figure 1 (a, b, c) show the FTIR of the prepared compounds S_1, S_2 and S_3 respectively. In the present study, PVA, Ch, and NVP are compatible and miscible polymers via hydrogen bonds interactions between the CO, OH and NH_2 groups in the monomers in the amorphous regions of the blends. In the case of three samples, the band at 1670 cm^{-1} corresponded to the stretching vibration of C=O carbonyl group and at 1441cm^{-1} the vibration of C-N. The band at 1290 cm^{-1} was the absorption of C-O, and that at 2986 cm^{-1} was ascribed to the $-CH_2-$ group on the polymeric produced by polymerization of PVA, Ch, and NVP. The broad band at 3429 cm^{-1} was ascribed to the -OH groups as shown in Fig. 1 (a,b,c).
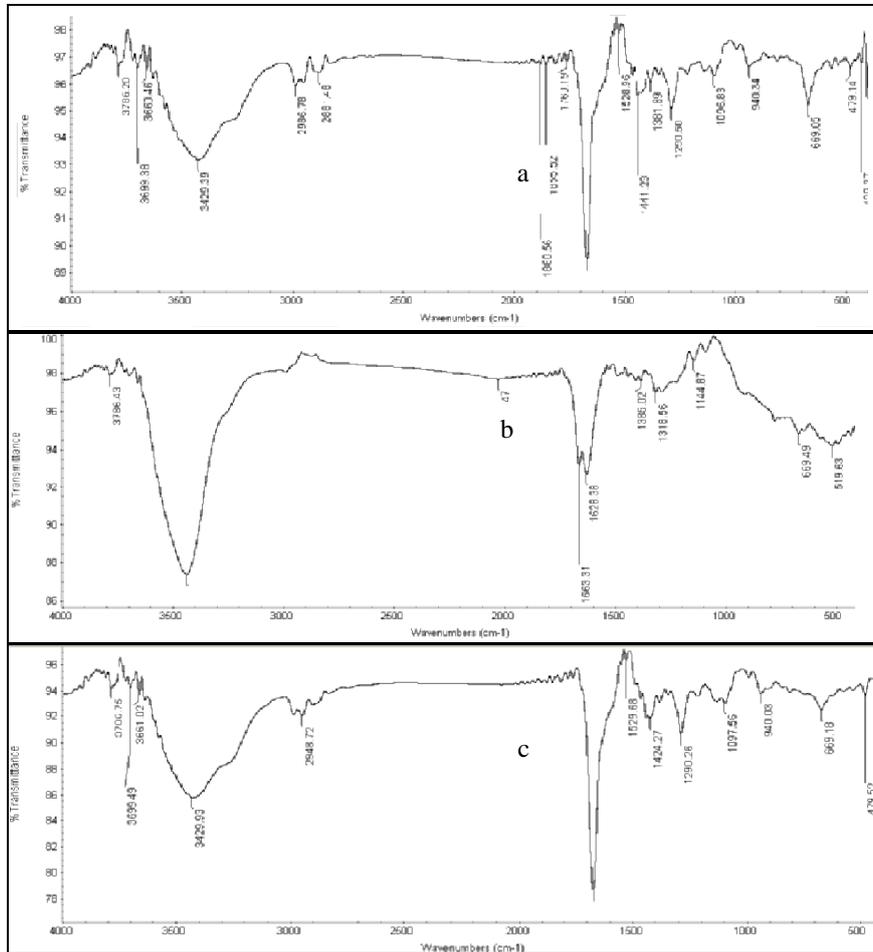
Fig. 1. FTIR spectra of a) S_1, b) S_2 and c) S_3.

Mineralogical studies

The diffraction charts and the relative intensities were obtained and compared with ICDD files as illustrated in Table 2.

TABLE 2. X-ray diffraction analysis for local bentonite .

Constituents :	Local bentonite
Major const :	Montmorillonite, Quartz
Minor const :	Kaolinite
Trace const :	–

X-ray fluorescence (XRF)

The chemical composition (XRF) spectrometry results were listed in Table 3.

TABLE 3. Chemical analysis for local-bentonite.

Elements	Local-bentonite %	Elements	Local-bentonite %
SiO_2	54.91	Na_2O	2.75
TiO_2	1.53	K_2O	1.03
$Al2O_3$	17.01	P_2O_5	0.16
Fe_2O_3	9.31	Cl	1.20

From the above results we can conclude that most of the studied samples of bentonite clay , were mainly montmorillonite .

X-ray diffraction
Mineralogical properties of the local raw bentonite clay mo after treatment with the prepared rheological modifiers (S_1, S_2 and S_3) using X-Ray Diffraction (XRD).

In addition to adsorption on to external surface, intercalation also takes place in phyllosilicates. To recognize the MMT intercalation with the new blending polymers S_1, S_2 and S_3, the XRD patterns of the MS_1, MS_2 and MS_3 samples were measured compared to the basel spacing of the local untreated clay Mo . The observed basal spacing (d_{001}) of MS_1, MS_2 and MS_3 are given in Table 4 and Fig. 2. The d_{001} value of each of MS_1 , MS_2 and MS_3 samples is higher in value than that of the local sample M_0 .The basel spacing (d_{001}) value of MS2 is higher than that of MS_1 and MS_3 which indicates that S_2 blending polymer was intercalated in a great amount than S_1 and S_2 blending polymers and it is also indicate that S_2 is attached strongly to the clay . This is because of the higher van dar walls and electrostatic interactions with the negatively charged silicate layers. The order of interaction was $S_2 > S_1 > S_3$, so the studied clay samples can not be used for the formulation of water based mud without treatment or activation .

TABLE 4. Basal spacing values (d_{001}) and diffraction angel of the local bentonite treated with S_1, S_2 and S_3.

Material	Basal spacing region d_{001} (Å)	Position (2Θ°)
M_0	12.95	5.91
MS_1	13.86	5.41
MS_2	14.05	5.81
MS_3	13.24	5.51
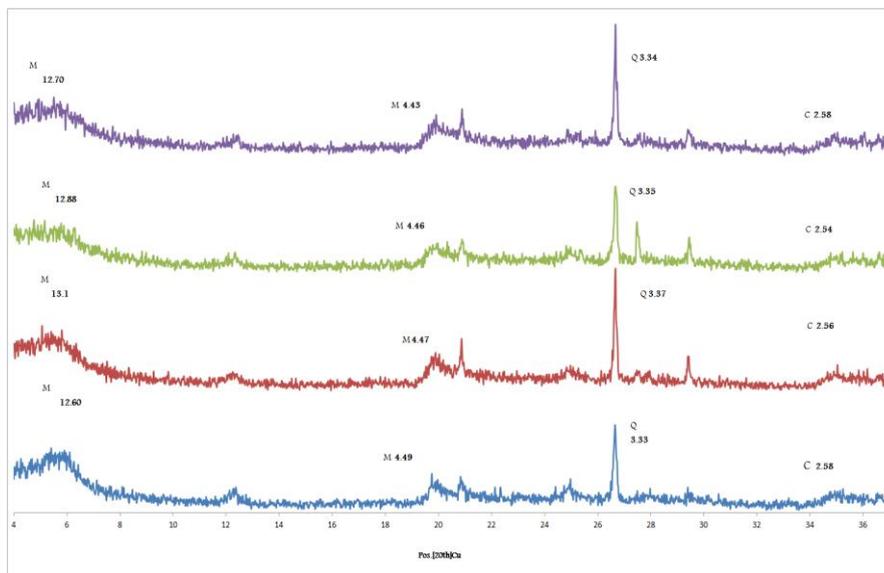
Fig. 2. X-ray diffraction analysis of MS$_1$, MS$_2$ and MS$_3$ compared to local M$_0$

Rheological and filtration properties of water-based mud treated with prepared polymeric compounds

The rheological properties of the reference mud formulated from commercial bentonite (Mr) and mud formulated with local non treated bentonite (Mo) at 60°F were illustrated in Table 5.

TABLE 5.   The rheological properties and filter loss of the reference mud (M$_R$) and local non treated bentonite mud (M$_0$).

Mud type	AV(cP)	AV(cP)	YP(1b/ 100ft^2)	Gel stranght (1b/100ft2)		Thixtropy (1b/100ft^2)	Filter loss Ml
				G10 sec.	G10 min.		
M$_R$	22.5	5	35	5	5	0	15
M$_0$	9	2	14	2	3	1	25

From the above results we can conclude that the performance of water-based muds formulated from local bentonite don't meet the API specification and the rheological properties need to modify . So on using the new three blending polymers S$_1$, S$_2$ and S$_3$ as rheological modifier for the local bentonite mud Mo, Tables 6, 7 and 8 illustrated the treatment of water – based mud formulated from the local bentonite with different concentration of the prepared blending polymers S$_1$, S$_2$ and S$_3$.

The rheological properties of the water-based mud formulated of 6% Local non-treated bentonite and different concentrations of the prepared polymer S_1 ranged from 0.1 to 0.9 g were illustrated in Table 6.

TABLE 6. The rheological properties of water based – mud formulated of local bentonite with different concentration of the new prepared polymer S_1 (MS_1) .

Mud type	Conc.of S_1(g)	AV(cP)	PV(cP)	YP(1b/100ft^2)	Gel strength(1b/100ft^2)		Thixtropy (1b/100ft^2)
					G10 sec.	G10 min.	
MS_1	0.1	9.5	2.5	12.5	10	12	2
	0.2	10	3	14	10	12	2
	0.3	11.5	4	15	11	13	2
	0.4	12.5	5	15	12	15	3
	0.5	13.5	4	19	12	16	4
	0.6	14.5	3	23	15	17	2
	0.7	15	2	26	16	18	2
	0.8	17.5	3	29	18	20	2
	0.9	18.5	2	33	20	23	3

From the above results we can conclude that water-based muds which consist of 6% Local non-treated bentonites and different concentrations of the prepared polymer S_1 ranged from 0.1 to 0.9 g. showed rheological properties : Apparent viscosity (AV) increase from (9.5 to 18.5 cP) , Plastic viscosity (PV) increase from (2.5 to 5 cP)

Yield point (YP) increased from (12.5 to 331b/100ft^2) as the concentrations of the prepared polymer S_1 increased from (0.1 to 0.9 g).

The gel strength G10$_{sec}$.ranged between (10 to 201b/100ft^2) while gel strength G10$_{min}$. ranged between (12 to 231b/100ft^2) and thixotropy was approximately constant at 2 1b/100ft^2

From the above result we can consider that (0.7 g) of prepared polymer S_1 as a selected concentration which represents the concentration at which rheological properties of the mud are compatable with API specification .

The rheological properties of the water-based mud formulated of 6% Local non-treated bentonite and different concentrations of the prepared polymer S_2 ranged from 0.1 to 0.9 mg (S_2) were illustrated in Table 7.

From the above results we can conclude that water-based muds which consist of 6% Local non-treated bentonites and different concentrations of the prepared polymer S_2 ranged from 0.1 to 0.9 g. The rheological properties: Apparent viscosity (AV) increased from (11.5 to 21.5 cP). Plastic viscosity (PV) increased from (3 to 5 cP) .

TABLE 7. The rheological properties of water based – mud formulated of local bentonite with different concentration of the new prepared polymer S_2.

Mud type	Conc. of S_2(g)	AV(cP)	PV(cP)	YP(1b/100ft^2)	Gel strength(1b/100ft2)		Thixtropy (1b/100ft^2)
					G10 sec.	G10 min.	
	0.1	11.5	3	17	10	11	1
	0.2	13.5	2	23	11	13	2
	0.3	15	2	26	12	14	2
	0.4	16	3	26	16	18	2
MS$_2$	0.5	17.5	3	29	18	20	2
	0.6	18.5	4	29	20	22	2
	0.7	19	3	32	22	24	2
	0.8	20	3	34	24	26	2
	0.9	21.5	5	33	24	26	2

Yield point (YP) increased from (17 to 331b/100ft^2) as the concentrations of the prepared polymer S_2 increased from (0.1 to 0.9 g). The gel strength $G10_{sec}$.ranged between (10 to 241b/100ft^2) while gel strength $G10_{min}$. ranged between (11 to 261b/100ft^2) and thixotropy was approximately constant at 2 1b/100ft^2. . From the above result we can consider that (0.3 g) of prepared polymer S_2 as a selected concentration represents the concentration at which the rheological properties of the water based mud are compatable with API specification .

The rheological properties of the water-based mud formulated of 6% Local non-treated bentonites and different concentrations of the prepared polymer S_3 ranged from 0.1 to 0.9 mg (S_3) were illustrated in Table 8.

From the above results we can conclude that water-based mud which consist of 6% Local non-treated bentonite and different concentrations of the prepared polymer S_3 ranged from 0.1 to 0.9 g. the rheological properties : Apparent viscosity (AV) increased from (10 to 18 cP) , Plastic viscosity (PV) increased from (2 to 3 cP) Yield point (YP) increased from (16 to 301b/100ft^2) as the concentrations of the prepared polymer S_2 increased from (0.1 to 0.9 g). The gel strength $G10_{sec}$. ranged between (10 to 121b/100ft^2) while gel strength $G10_{min}$. ranged between (12 to 151b/100ft^2) and thixtropy changed from 2 to 3 1b/100ft^2. From the above result we can consider that (0.5 g) of prepared polymer S_3 as a selected concentration represents the concentration at which the rheological properties of the mud are compatable with API specification .

TABLE 8. The rheological properties of water based – mud formulated of local bentonite with different concentration of the new prepared polymer S_3.

Mud type	Conc. of S_3 (g)	AV(cP)	PV(cP)	YP(1b/100ft^2)	Gel stranght (1b/100ft2)		Thixtropy (1b/100ft^2)
					G10min	G10sec.	
MS$_3$	0.1	10	2	16	10	12	2
	0.2	11	2	18	10	12	2
	0.3	12.5	2	21	11	13	2
	0.4	14	3	22	11	13	2
	0.5	15	2	26	12	13	1
	0.6	15.5	1	29	11	13	2
	0.7	16.5	2	29	12	13	1
	0.8	17	2	30	11	14	3
	0.9	18	3	30	12	15	3

Effect of temperature on the rheological properties of water-based mud

In our study, the rheological properties of water-based mud change with increasing temperature ranging between 60°F and 200°F. For water-based mud consisting of local bentonite and treated with the new blending polymers S_1, S_2, S_3 we selected 0.7 gm of S_1, 0.3 gm of S_2 and 0.5 gm of S_3 as optimum concentration for the coreesponding water-based mud formulation MS$_1$, MS$_2$ and MS$_3$ and then study the effect of temperature on the rheological properties as the temperature increasing ranging between 60 ^{o}F and 200 ^{o}F comparing the result with MR mud batch (Fig 3-5) showed that :

For M$_R$ .the apparent viscosity decreased from 19 cP to 10 cP while the plastic viscosity decreased from 15 cP to 7 cP and the yield point also changed from 8 lb/100 ft^2 to 6 lb/100 ft^2.

Effect of temperature on gel strength

For mud treated with imported viscosifier (M$_R$), Fig. 6&7 revealed that the gel strength G10 sec. decreased from 5lb/100ft^2 to 3lb/100ft^2 after the temperature raised from 60°F to 200°F. Also, G10 min decreased from 5lb/100ft^2 to 3lb/100ft^2 after 10 min. Mud treated with the new viscosifier as the temperature rose from 60°F to 200°F:

MS$_1$: The gel strength decreased from 13lb/100ft^2 to 9lb/100ft^2, after 10 sec, also it decreased from 13lb/100ft^2 to 9lb/100ft^2 after 10 min as the temperature raised from 60°F to 200°F.

MS$_2$: The gel strength decreased from 13lb/100ft^2 to 5lb/100ft^2, after 10 sec,also it decreased from 13lb/100ft^2 to 5lb/100ft^2 after 10 min as the temperature raised from 60°Fto 200°F.

MS$_3$: The gel strength decreased from 13lb/100ft^2 to 9lb/100ft^2, after 10 sec, also it decreased from 13lb/100ft^2 to 9lb/100ft^2 after 10 min as the temperature raised from 60°F to 200°F.

Fig. 3. Apparent viscosity-temperature relation of MS₁, MS₂ and MS₃ compared to reference mud sample (M_R).	Fig. 4. Plastic viscosity-temperature relation of MS₁, MS₂ and MS₃ compared to reference mud sample (M_R).
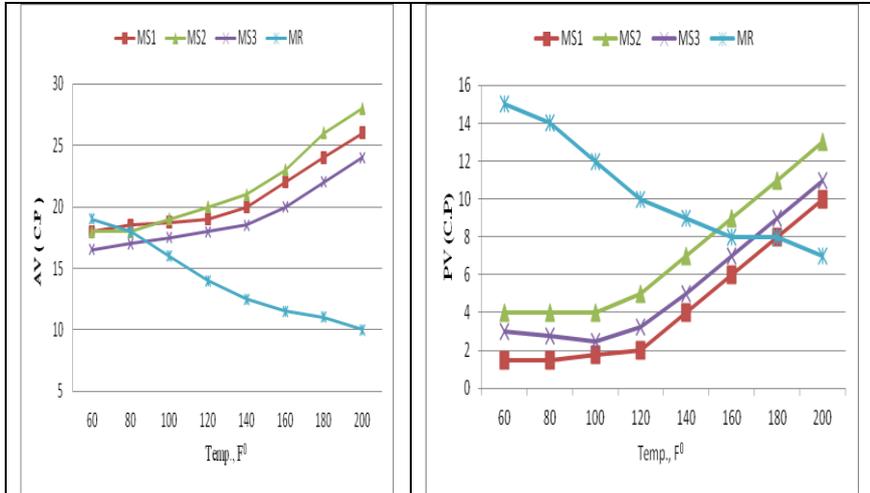
Fig. 3. Apparent viscosity-temperature relation of MS_1, MS_2 and MS_3 compared to reference mud sample (M_R).

Fig. 4. Plastic viscosity-temperature relation of MS_1, MS_2 and MS_3 compared to reference mud sample (M_R).

Fig. 5. Yield point -temperature relation of MS_1, MS_2 and MS_3 compared to reference mud sample (M_R).

MS_1: The apparent viscosity increased from 19.5 cP to 26 cP, plastic viscosity increased form 2 cP to 10 cP and yield point increased from 26 lb/100 ft^2 to 31 lb/100 ft^2.

MS_2: The apparent viscosity increased from 20 cP to 28 cP, the plastic viscosity increased from 5 cP to 13 cp and yield point increased from 23 lb/100 ft^2 to 38 lb/100 ft^2.

MS_3: The apparent viscosity increased from 16.5 cP to 24 cP, the plastic viscosity increased from 3 cP to 4 cP and yield point increased from 8 lb/100 ft^2 to 6 lb/100 ft^2.

Results of the rheology-temperature relation indicate that the new additives S_1, S_2 and S_3 satisfy the minimum requirements for API specification compared to imported viscosifier M_R.
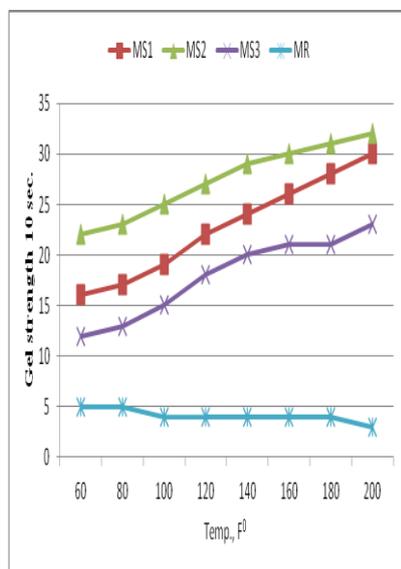
Fig. 6. gel strength10 sec.-temperature relation of (MS₁, MS₂, MS₃) compared to reference mud sample (M_R).
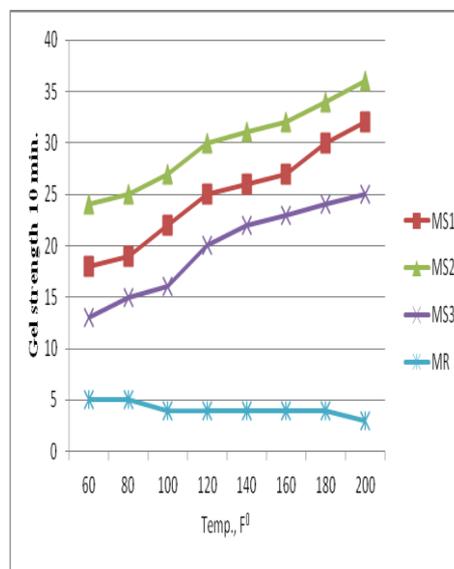
Fig. 7. Gel strength10 mints.-temperature relation of (MS₁, MS₂, MS₃) compared to reference mud sample (M_R).

TABLE 9. Thixtropy for MS1 , MS2 , MS3 compared to MR with increasing temperature .

Temp. ,Fº	MS_1	MS_2	MS_3	M_R
60	2	2	1	0
80	2	2	2	1
100	3	2	1	0
120	3	3	2	1
140	2	3	2	0
160	1	2	2	0
180	2	2	3	1
200	2	1	2	0

From Table 9 it is clear that thixotropy of water-based mud MS1 , MS2, and MS3 compared to the reference mud batch MR as the temperature increased the thixotropy increased for the mud batches treated with the new blending polymers while the thixotropy of the reference mud kept the value of thixotropy .

Relationship between shear stress and shear rate of water-based mud

For mud treated with imported viscosifier M_R: At 80 ºF the value of shear stress decreased from 36 to 4 1b/ft^2 as the shear rate decreased from 1020 sec^{-1} to 5.1 sec^{-1}. At 140 ºF the value of shear stress decreased from 25 to 3 1b/ft^2 as the shear rate decreased from 1020 sec^{-1} to 5.1 sec^{-1}. At 200 ºF the value of shear stress decreased from 20 to 2 1b/ft^2 as the shear rate decreased from 1020 sec^{-1} to

5.1 sec^{-1}.   MS$_1$: At 80 ^{o}F the value of shear stress decreased from 37.5 to 13 1b/ft^{2} as the shear rate decreased from 1020 sec^{-1} to 5.1 sec^{-1}. At 140 ^{o}F the value of shear stress decreased from 40 to 13 1b/ft^{2} as the shear rate decreased from 1020 sec^{-1} to 5.1 sec^{-1}. At 200 ^{o}F the value of shear stress decreased from 52 to 18 1b/ft^{2} as the shear rate decreased from 1020 sec^{-1} to 5.1 sec^{-1}. MS$_2$: At 80 ^{o}F the value of shear stress decreased from 39.5 to 13 1b/ft^{2} as the shear rate decreased from 1020 sec^{-1} to 5.1 sec^{-1}. At 180 ^{o}F the value of shear stress decreased from 41.5 to 9 1b/ft^{2} as the shear rate decreased from 1020 sec^{-1} to 5.1 sec^{-1}. At 200 ^{o}F the value of shear stress decreased from 56 to 18 1b/ft^{2} as the shear rate decreased from 1020 sec^{-1} to 5.1 sec^{-1}. MS$_3$: At 80 ^{o}F the value of shear stress decreased from 34 to 4 1b/ft^{2} as the shear rate decreased from 1020 sec^{-1} to 5.1 sec^{-1}. At 180 ^{o}F the value of shear stress decreased from 36 to 3 1b/ft^{2} as the shear rate decreased from 1020 sec^{-1} to 5.1 sec^{-1}. At 200 ^{o}F the value of shear stress decreased from 48 to 2 1b/ft^{2} as the shear rate decreased from 1020 sec^{-1} to 5.1 sec^{-1}. Figure 8 illustrated that the value of shear stress decreased as shear rate decreased at same temperature.
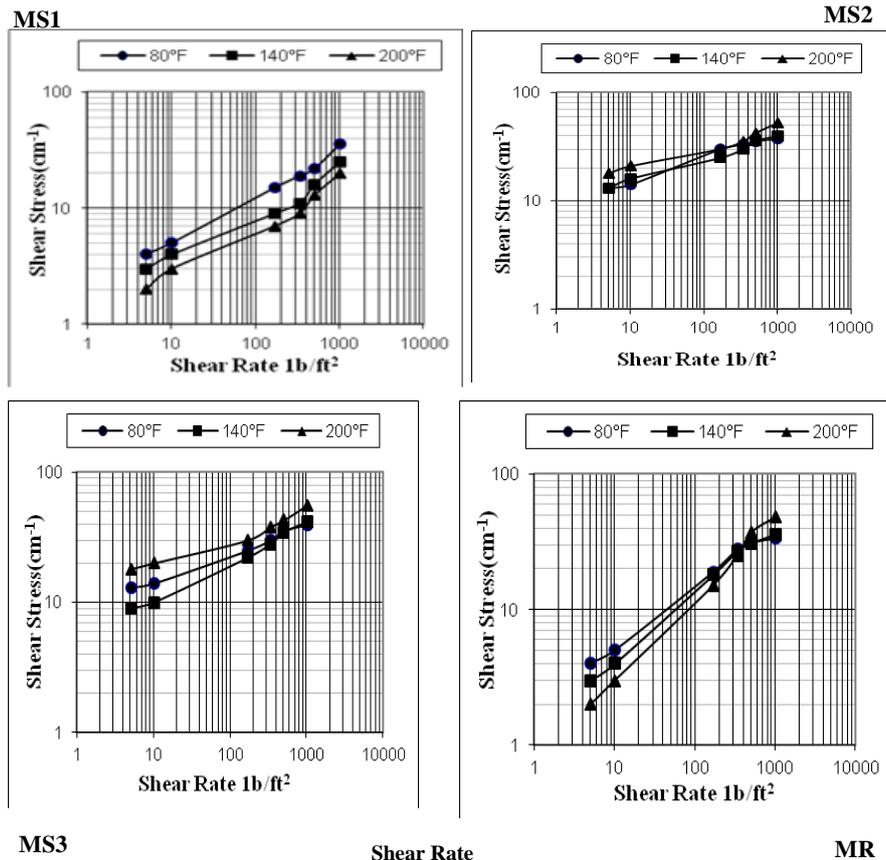
Fig. 8. shere rate – shear stress relationship of MS1 , MS2 , MS3 compared to MR .

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Effective viscosity of water-based mud

Plotting viscosity of mud versus the value of shear rate are illustrated in Fig. 9. The testing result showed that : the effective viscosity of the mud decreased with increased shear rate, these results are similar to field mud (M_R) formulated with the reference mud. From Fig. 9 we conclude that: the values of the effective viscosity verses the shear rate of water-based mud treated with the new prepared blending polymers S_1, S_2 and S_3 are extremely shear thining.
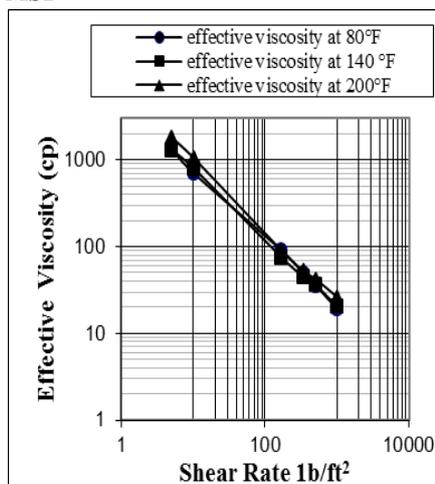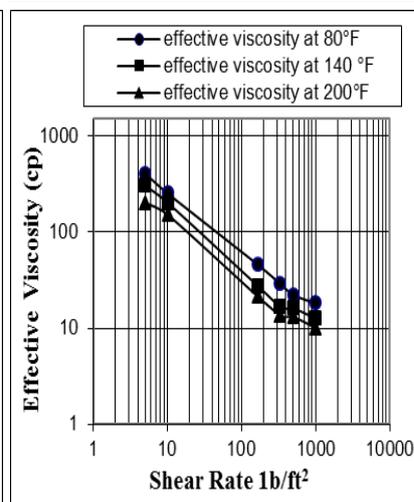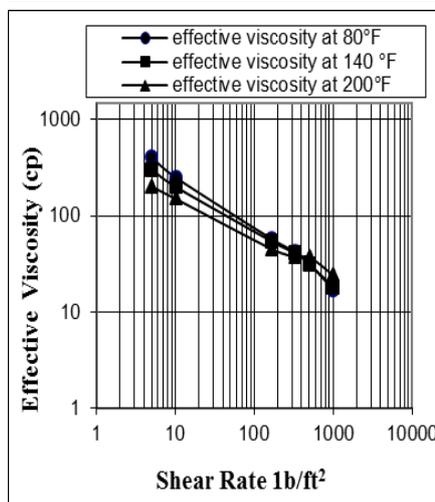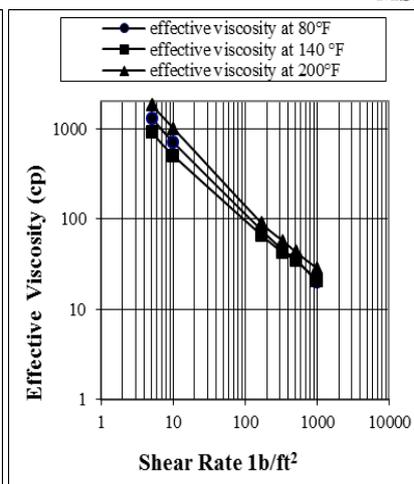
MS1   **MS2**

MS3   **MR**

Fig. 9. Effective viscosity of MS1 , MS2 , MS3 compared to MR with different temperature .

Filtration properties of water-based mud

As shown in Table 10 the stander filter loss at 100 psi after 30 min was measured and the corrected filter loss was determined for MS_1, MS_2 and MS_3 compared to M_R and Mo . The results of the filtration test showed that the higher filter loss for M_0 cannot meet API specification , while the filter loss of the mud batches MS_1, MS_2 and MS_3 was compatable to the API specification and less than reference mud sample M_R .

TABLE 10. Stander fluid-loss for MS_1 , MS_2 , MS_3 compared to M_R and M_0 .

Mud	Filter cake description	Fluid-loss (ml)
M_R	Filter cake thickness (mm) =1.4	15
M_0	Filter cake thickness (mm) =1.4	25
MS_1	Filter cake thickness (mm) = 0.9	14.5
MS_2	Filter cake thickness (mm) = 0.9	14
MS_3	Filter cake thickness (mm) = 0.9	13.5

Application of the power law model to the rotary viscometer data

The flow behavior index (n) and consistency index (K) values are calculated according to the power law model Herschel-Buckley model and is given by **:**

$\tau = \tau_p + k \cdot \gamma^n$ [40].

τ = shear stress

τ_p =yield stress or yield point

K=the consistency factor (viscosity in case of a newtonian or bingham fluid)

γ = share rate

n=the power of low exponent (rate index) or flow behavior.

Table 11 illustrated the flow behavior index (n) and the consistency index (k) of Mc and M_R .

TABLE 11 . The flow behavior index(n) and consistency index(K).

Mud type	Concentration of blending polymer g/500 cm3 base mud	Dial reading at 600 rpm	Dial reading at 300 rpm	Flow behavior index(n)dimensionless	Consistency index (K)lb.sec^n/ft^2
M_R	0	30	20	0.585	0.523
M_{S1}	0.7	30	28	0.470	1.401
M_{S2}	0.3	35	28	0.322	3.768
M_{S3}	0.5	30	26	0.322	3.768

Conclusion

The characterization of non activated clays collected from South Hamam , Egypt for the application as a drilling fluid (water-based mud) was investigated. Also, the activation compatibility for these clays was explained as an attempt to minimize the important cost of the imported bentonite to Egypt by a local solution. The following main conclusion can be drawn from the present study:

1. Most of the studied samples of bentonite clay, were mainly Na-montmorillonite:

2. The studied non – activated samples cannot be used as a drilling mud without activation.

3. The studied clay samples can be used after activation with the blending polymers S_1, S_2, and S_3, as drilling fluids for its rheological properties satisfied the API standard and OCMA specification .

4. The obtained results revealed that the activated samples may be expressed as medium grade bentonite clays and these grades of clay can be used as drilling fluids for shallow depth wells.

5. The structures of the samples S1 and S2 have similar structures (cross linked polymers) but differ in the amount of NVP which are 4.5 and 6, respectively. The structure of the other sample S3 was different from that of S1 and S2 because it is a linear polymer (without cross linker).

The effects of all the samples were studied and showed that the efficiency increases in the order of cross linked polymers more than linear polymer and decreases by increasing the amount of NVP in all samples, S2 > S1 > S3 and this result is compatable with the minorolegical study for the water based mud which formulated from local bentonite sample and treated with the blending polymers S_1, S_2, and S_3

6. Rheological , filtration properties of the water – based mud treated with the new prepared viscosifier performed a superior results compared to the commercial viscosifier .

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تحسين الخواص الريولوجية لخام البنتونيت المحلى بواسطة مزيج من البوليمرات الجديدة و ذلك لإستخدامه فى طفله الحفر ذات الاساس المائى

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تم تحضير بوليمرات جديدة من تفاعل مخاليط مختلفة من البوليمرات باستخدام تقنية اشعة جاما ، وتم ذلك بخلط نسب ثابتة من كحول البولي فانيايل والكيتوزان مع نسب مختلفة من ن-فانيايل 2-بيروليدين في وجود وفي عدم وجود داى اثيل جلايكال داى مثيل اكريلات وتم التعرف على التركيبات الكيميائية للبوليمرات الجديدة باستخدام طيف الأشعة تحت الحمراء وطيف الكتلة وتبين منها أيضا أنها فى حالة نقية جدا كما تم تقييم قدرة هذه البوليمرات على تحسين اللزوجة وكفاقد الرشح في طفلة الحفر ، كما تم قياس الخواص الريولوجية للبوليمرات الجديدة وقدرتها على الاحتفاظ بالسوائل تبين من خلالها أن اضافتها الى الطفلة يؤدي الى زيادة كفاءتها.