Activation and Enhancement of the Performance of Iraqi Ca-Bentonite for Using as Drilling Fluid in Iraqi Oil Fields

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Abstract

   In this study, Iraqi bentonite taken from Trefawi area/ Al-Anbar region province/ Iraq, was activated to enhance its rheological and filtration properties and increase its quality by decreasing the non-clay minerals (impurities), in order to be used in Iraqi oil companies instead of commercial bentonite. Bentonite was characterized by X-ray diffraction (XRD), X-ray fluorescence (XRF) and particle size distribution (PSD) before and after activation to show the effects on its mineral and chemical properties. The rheological properties of bentonite were enhanced by using different weights (0.4, 0.5, 0.6, 0.7 and 0.8 gm) of sodium carbonate (Na_2CO_3), whereas the filtration properties were enhanced by using different weights (0.5, 1, 1.5 gm) of high viscous-carboxy methyl cellulose (CMC-HV) and different weights (0.5, 1, 2 gm) of low viscous-carboxy methyl cellulose (CMC-LV). The results showed that the rheological properties of Iraqi bentonite were enhanced and met the specifications of the American Petroleum Institute (API) when 0.7 gm of Na_2CO_3 was added. The filtration properties were also enhanced and satisfied API specification when 0.5 gm of CMC-HV and 2 gm of CMC-LV were added. Therefore, Iraqi bentonite has the potential to be used as drilling fluid in oil fields.

Keywords: Iraqi bentonite, bentonite Activation, Drilling fluid, Rheological properties, Filtration properties

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تنشيط و تحسين ادائية بنتونايت الكالسيوم العراقي لأستعماله كسائل حفر

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الخلاصة

في هذه الدراسة, البنتونايت العراقي المأخوذ من موقع طريفاوي\ محافظة الانبار\ العراق قد تحسن و تنشط تم تنشيطه لزيادة خواصه الريولوجية و خواصه الترشيحية و زيادة جودنه بتقليل المعادن الغير طينية (الشوائب) لكي يستعمل في شركات النفطية العراقية كبديل للبنتونايت الاجنبي.

البنتونايت العراقي تم تحليله معدنيا و كيميائيا و كذلك تحليل الحجم الحبيبي قبل و بعد التنشيط لمعرفة تأثير عملية التنشيط على خواص البنتونايت. الخواص الريواوجية للبنتونايت العراقي تحسنت بأضافة (0.4 , 0.5 , 0.6 , 0.7 و 0.8 غرام) من كاربونات الصوديوم, و خواصه الترشيحية تحسنت بأضافة (0.5 , 1 و 1.5 غرام) من كاربوكسي مثيل سيليلوز عالي اللزوجة و (0.5 , 1 و 2 غرام) من كاربوكسي مثيل سيليلوز واطى اللزوجة. النتائج اظهرت بأنه الخواص الريولوجية وللبنتونايت العراقي قد تحسنت عند

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اضافة 0.7 غرام من كاربونات الصوديوم, كذلك النتائج اظهرت بأنه الخواص الترشيحية للبنتونايت العراقي قد

تحسنت عند اضافة 0.5 غرام من كاربوكسي مثيل سيليلوز عالي اللزوجة و 2 غرام من كاربوكسي مثيل

سيليلوز واطئ اللزوجة. لذلك البنتونايت العراقي يمكن استعماله كسائل حفر .

1. Introduction

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. Aqueous drilling fluids (water-based mud) are an environment friendly and more economic than the non-aqueous type (oil-based mud and synthetic-based mud). In order to achieve the optimum performance of any mud during 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 fluid. Also, the clay surface chemistry and that of various drilling fluids must be controlled [1]. The ability of the drilling mud to perform its functions depends entirely on its viscosity. Without viscosity, all weighting materials and drill cuttings would settle on the bottom of the hole as soon as circulation is stopped [2].

Bentonite clay is considered as a suitable and promising material used as drilling fluid because it makes the drilling fluid viscous [3] and has optimal properties such as ion-exchange capacity, swelling, surface area, plastic viscosity, and thixotropy [4]. Bentonite is made of two building blocks; the aluminum octahedral sheet and the silica tetrahedral sheet [5]. Bentonite is a clay deposit consisting of smectite minerals usually dominated by montmorillonite which has a very wide range of industrial applications [6]. The montmorillonite lattice is negative in charge, owing primarily to isomorphous replacements of ions within the structure. This negative charge is balanced by cations, which are held on the surface of the flakes and clay, and can be readily exchanged. The cations that are most commonly found in nature are sodium and calcium [7]. Bentonite adsorbs water in the interlayer region and this adsorption process initiates swelling. The degree of swelling of the platelets depends on the type of cations in the interlayer region. If the interlayer cations are monovalent and strongly hydrated, such as Na^+ or Li^+, the inter-platelet repulsion will be strong and the swelling capacity will be high. Na+ content was found to be the most influential factor for enhancing the rheological properties of bentonite. In addition to the ability of Na^+ contained in bentonite to adsorb water, it also increases viscosity and forms thixotropic suspensions with a good gel strength. Unlike Na-bentonite, Ca-bentonite has low swelling capacity and forms unstable suspensions with high settling rates [8].

Calcium bentonite can be converted to sodium bentonite by treatment with sodium carbonate (a process called sodium activation). This activation, if conducted properly, can result in a bentonite that exhibits many of the characteristics of natural sodium bentonite [9]. By sodium activation or by introducing some polymer additives, it is possible to upgrade some Ca-bentonite to meet the API standard (30 cP minimum viscosity at 600 rpm; 15 cm^3 filtration loses, and 33 ml swelling index) [10].

A number of researchers attempted to enhance the performance of Iraqi bentonite in order to use it as drilling fluid. AL- Ajeel *et al*. (2012) tried to activate calcium bentonite (high grade calcium montmorillonite claystone) from Wadi Bashira region, Westren Desert, using sodium carbonate through a dry grinding procedure. They subsequently evaluated the product for use as drilling fluid. The results showed that the rheological properties of the activated sample were highly improved, but the sample failed to fulfill the API drilling fluid requirements [11]. Rasin *et al*. (2013) studied the activation conditions of Iraqi Bentonite from Qara Tappah formation at various ratios for converting it to the gelling form. Soda ash was used in the activation process with ratios of 2.5, 5 and 7.5 %. The best result for obtaining the gelling form in the limit of experimental work was found at the activation ratio of 7.5%, [12].

The aims of this study were to enhance the performance of Iraqi bentonite by enhancing the properties of its main mineral component (montmorillonite), decreasing its impurities (quartz and calcite), and enhancing its rheological and filtration properties in order to use it in Iraqi oil companies instead of commercial bentonite. Önal and Sarikaya (2017) [13] investigated the activation of local Turkish calcium bentonite of Kütahya Formation, which showed significant changes in crystal structure, chemical composition, and porosity with H_2SO_4 activation, realized by heating its acidic aqueous suspension at 97 °C for 6 hours [13]. Al-Essa (2018) studied the activation of Jordanian bentonite by hydrochloric acid at room temperature. The results demonstrated that bentonite was successfully activated and the adsorption efficiency was strongly affected by several parameters, such

as pH and temperature of the solution and adsorbent dosage. The efficiency was increased with the increase in the temperature of the solution and the adsorbent dose [14].
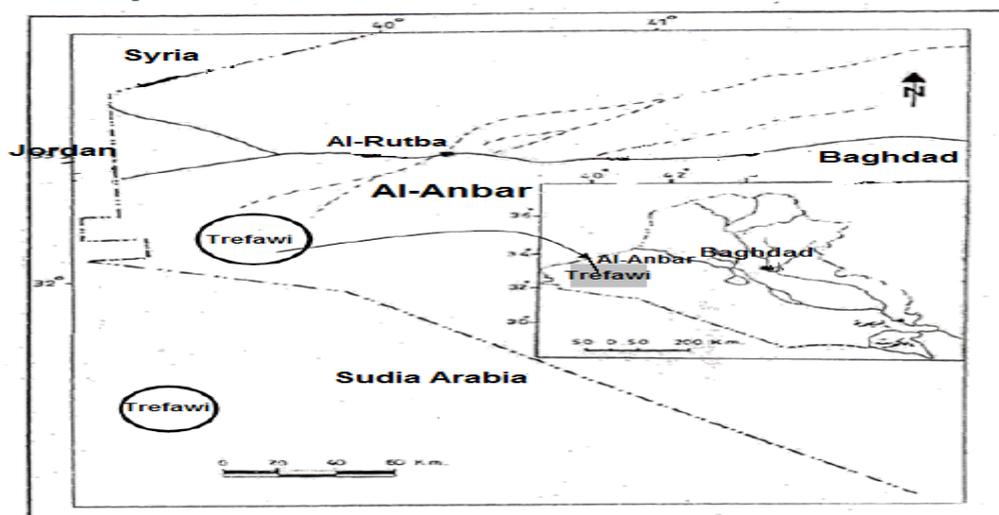
Figure 1 Geological Map of Trefawi Area.

2. Experimental Work
Determination of Drilling Fluid Properties
Rheological properties
This test was performed to measure the viscosity at 1, 2, 3, 6, 10, 20, 30, 60, 100, 200, 300 and 600 readings of the Viscometer, plastic viscosity, yield point, 10 min and 10 sec gel strengths. The equipment used was a viscometer (OFFITE model 900) while the materials were freshly prepared. The freshly prepared mud was poured into the sample cup of the viscometer. The rotor was allowed to rotate for few seconds for stabilization. Then the rotor sleeve was immense until the mud touched its scribed line. The mud button was pressed and the viscometer automatically carried out all the measurements above [2].

Filtration properties
The low pressure-low temperature filtration test, based on the API standard, was carried out at surface (room) temperature and 100 psi pressure for 30 minutes. The low pressure-low temperature filter press consisted of a cylindrical cell (3-inches in internal diameter (ID) and 5-inches high) to contain the formulated drilling mud. The bottom of the cell was fitted with a sheet No. 50 filter paper and filled with the clay mud sample to be measured. After the necessary connections, a pressure of 100 psi from an air compressor pump was supplied to the top of the cells. With a measuring cylinder placed beneath the cell, the filtrate through the filter paper was collected over a period of 30 minutes and recorded in ml; also the thickness of mud cake was measured in mm.

Density determination
The density of the mud was measured with a mud balance. The density was read at the left hand edge of the sliding weight and recorded.

pH determination
The pH test is a measurement of the concentration of hydrogen ions in aqueous solutions. This was performed by a pH meter after calibration. The probe was placed in the mud sample and the reading was taken after the needle was stabilized (the probe was washed clean before re-use). Also, pH was additionally tested by pH measurement papers.

Stability determination
The stability of the drilling fluid was measured by leaving the Solution of drilling fluid [22.5 gm of bentonite and 350 ml of distilled water] for 24 hrs in a 250 ml cylinder, as shown in Figure-2. The volume of the liquid separated from the drilling fluid was measured and applied in the following equation:

$$Drilling\ Fluid\ Stability\ \% = \frac{separated\ liquid\ volume}{250\ ml} * 100$$
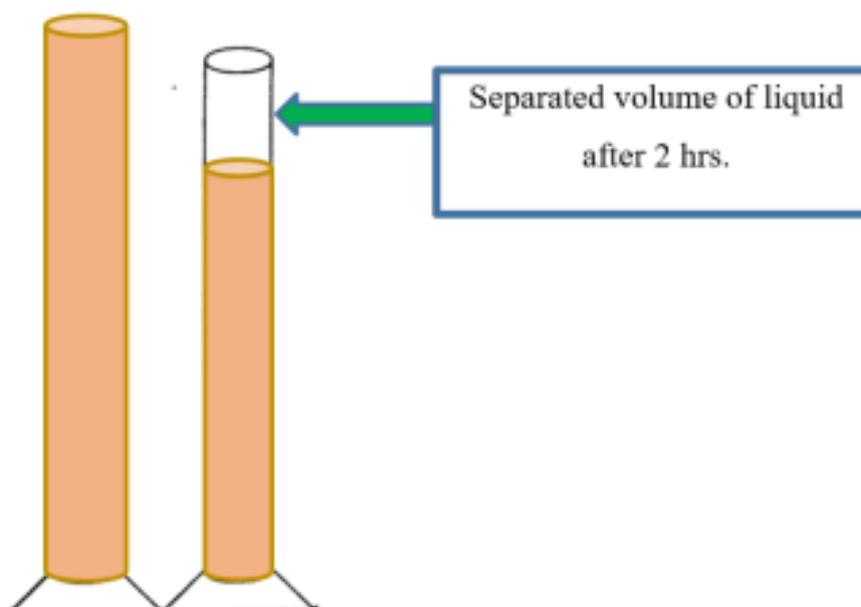
Figure 2-Stability Measurement of the Solution of Drilling Fluid [15].

Bentonite specifications for using as drilling fluid

Bentonite used for drilling fluids must meet the specifications set by the API, based on Wyoming natural sodium bentonite and the Oil Companies Materials Association (OCMA), which is used for lower quality clays, including Na-exchanged bentonites. These specifications are related to the viscosities of suspensions of fixed solids content, requiring the measurement of apparent viscosity, plastic viscosity, yield value, and the filtrate loss of a suspension at the same solids content. Specifications are shown in Table- 1.

Table 1 Specifications of Bentonite for Usage as Drilling Fluid [16].

Measurement	API	OCMA
Viscometer dial reading at 600 rpm	30 min	30 min
Yield point/plastic viscosity ratio	3 max	6 max
Filtrate volume	15 ml	16 ml
Residue>75µm	4 % max	2.5 % max
Moisture	10 % max	13 % max

Measurements of these specifications were made on the suspensions of 22.5 g of bentonite in 350 ml of water [16].

Bentonite characterization

Iraqi bentonite taken from Trefawi area in Akashat formation/AL-Anbar region/ Iraq was provided by the Iraqi geological survey company. In this study, Iraqi bentonite was grinded to powder and sieved to size <75µm (200 mesh) [17], then dried in oven at 180 ^{0}C for 12hr [18]. 22.5 gm of bentonite was mixed with 350ml [19] of distilled water for 20 minutes and left for 24 hr to hydrate [20]. Then, the rheological properties of mud were measured**.**

The mineralogical composition of the clay fractions (<75µm) of the original and treated montmorillonite-rich clay was determined using type 61007000 X-ray diffraction. The major elements were measured from the bulk samples and the bentonite fraction (<75µm) of the original and treated montmorillonite-rich clay using type1800 sequential XRF spectrometer. Also, bentonite was characterized by 2000s Malvern Mastersizer   to show the particle size distribution before and after treatment. XRD, XRF and particle size distribution analyses were carried out in the Iraqi Geological Survey/Central, Laboratories Department.

Bentonite enhancement

Enhancing the rheological properties of Iraqi bentonite

In this test, 0.4, 0.5, 0.6, 0.7 and 0.8 gm of Na_2CO_3 were mixed with 22.5 gm bentonite and 350 ml of distilled water for 20 minute in Hamilton Beach Mixer and left for 24 hs in a closed container to ensure good dehydration. After that, the rheological properties of the mixture were measured.

Enhancing the filtration properties of Iraqi bentonite

In order to enhance the filtration properties, 0.5, 1 and 1.5 gm of low viscous-carboxy methyl cellulose (CMC-LV) were added to the mixture of 0.7 gm of Na_2CO_3 and 22.5 gm of bentonite with 350 ml of distilled water. After that, 0.5, 1 and 2 gm of CMC-HV were added to the best result of CMC-LV addition.

3. Results and Discussions

Characterization of raw bentonite

XRD analysis showed that Iraqi bentonite contains montmorillonite and palygorskite as main minerals in addition to quartz and calcite as impurities (Figure-3).
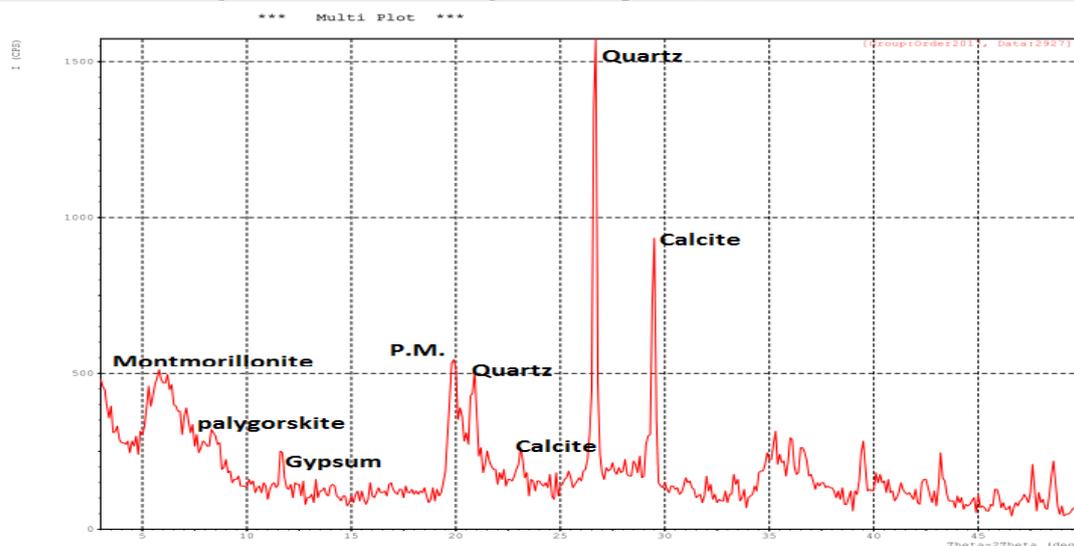
Figure 3-XRD diffraction analysis of Iraqi bentonite.

XRF analysis is shown in Table-2. The ratio of Al_2O_3/SiO_2 was 1/3, as expected for montmorillonite which is the main component of bentonite. The ratio of $(Na_2O+K_2O)/(CaO+MgO)$, based on previously reported approach [21], was found to be 0.143, confirming that Iraqi bentonite was of Ca-bentonite type**.**

Table 2 XRF Analysis of Iraqi bentonite

SiO_2 %	Fe_2O_3 %	Al_2O_3 %	CaO %	MgO %	SO_3 %	LOI %	Na_2O %	K_2O %
52.1	5.71	15.91	7.06	1.79	0.99	13.68	0.60	0.67

The results of PSD analysis are shown in Fig 4, where 10% of the particles had a size smaller than 5.354 μm, 50% smaller than 24.512 μm, and 90% smaller than 69.96 μm. The average particle size of Iraqi bentonite inside the powder was 36.0825 μm.

The specific surface area (SSA) of Iraqi bentonite diffraction was 0.449m²/g. The technique of wet laser diffraction was used to measure the specific surface area depending mainly on particle size [22].
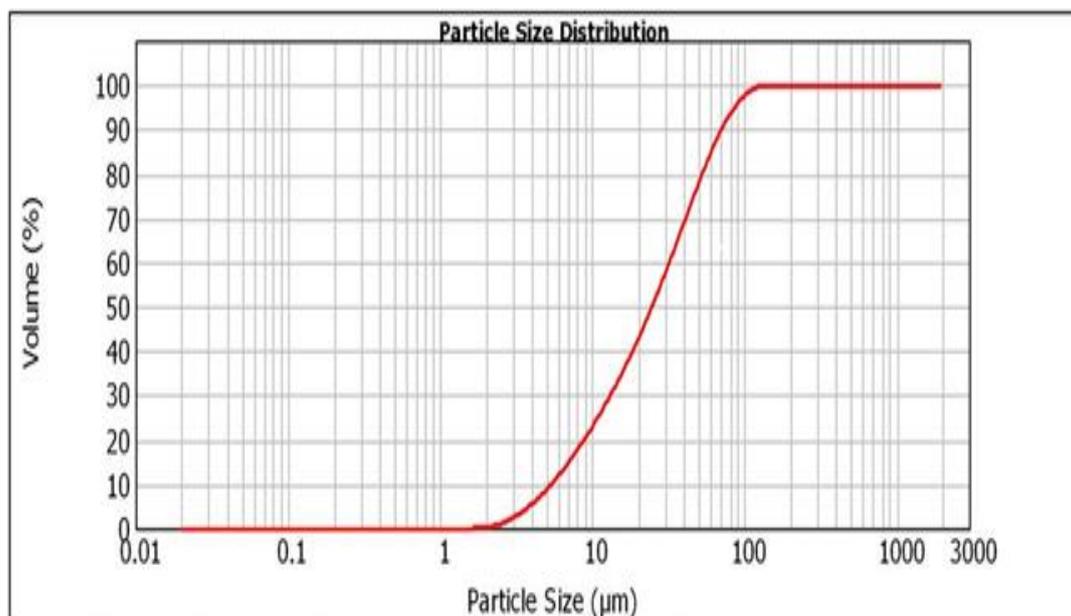
Figure 4-Particle size distributions for Iraqi bentonite**.**

The rheological properties of Iraqi bentonite and gel strength were very poor as compared with API specifications. The filtration loss was also very high and the stability was very low (Table-3).

The poor properties of Iraqi bentonite included its Ca - type. Accordingly, Iraqi bentonite is undesired for the use as drilling mud due to low adsorption and swelling values. Therefore, many processes of activation were carried out to enhance its properties.

Table 3-Rheological Properties of Iraqi Bentonite

Apparent Viscosity (AV), Cp	2.27
Plastic Viscosity (PV), Cp	2.35
Yield Point (YP), (lb/100ft²)	0.73
YP/PV, (lb/100ft²/cp)	0.31
10s gel Strength, (lb/100ft²)	0.8
10m gel Strength, (lb/100ft²)	1.9
Density, ppg	8.6
pH	7.1
$V_{7.5m}$,ml	27
V_{30m},ml	54
Thickness of Mud Cake, mm	2.13
Stability,2hs,%	76
Stability,4hs,%	67.2
Stability,24hs,%	50.8

Effects of Adding Na_2CO_3 on Rheological Properties

Apparent viscosity reflects the flow ability of drilling fluids and is related to the rate of penetration, whereas plastic viscosity is caused by the friction between the suspended particles and influenced by the viscosity of the base liquid [23]. Yield point is an important rheological parameter for drilling fluids and reflects the resistance to initial flow or the stress required to initiate fluid movement. Yield point to plastic viscosity is another important rheological parameter reflecting the capability of carrying drilling cuttings [24]. As shown in Table-4, Na_2CO_3 succeeded to enhance the Iraqi bentonite and its rheological properties satisfied the API specifications with the addition of 0.6 g of Na_2CO_3. The rheological properties and gel strength were increased when the concentration of Na_2CO_3 was increased. The best result of activation of the Iraqi bentonite was at 0.6 gm of Na_2CO_3, because when 0.7 gm of Na_2CO_3 was added, the value of YP/PV was approximately higher than the API

specifications, whereas adding 0.8 gm of Na_2CO_3 resulted in higher YP, YP/PV and gel strength values than those of the API specifications.

Table 4-Rheological Properties of the Directly-activated Iraqi bentonite by Na_2CO_3

S %	Wt. gm	AV cp	PV cp	YP (lb/100/ft²)	YP/PV (lb/100ft²/cp)	Gel Strength (lb/100ft²)	
						10 s	10 m
0.1	0.4	3.62	1.91	3.41	1.78	2	4.3
0.13	0.5	8.94	3.62	10.65	2.94	10.1	11.7
0.16	0.6	20.18	4.68	30.99	6.62	33.7	49.4
0.18	0.7	24.55	4.8	39.5	8.23	39.3	50.7
0.21	0.8	31.3	5	52.6	10.52	49.7	62.9

Figure-5 elucidates the rheological properties of the Iraqi bentonite directly-activated with different weights of Na_2CO_3. It shows that all the rheological properties were increased as the weight of Na_2CO_3 was increased. The increase in mass concentration has to improve the apparent viscosity because of the higher interaction between clay particles [25]. This refers to an increase of solid particles in liquid that increases electrochemical or attraction forces in the liquid [26]. The rheological properties were increased because of increasing Na^+ concentration which resulted in an increased cation exchange capacity between Na^+ and Ca^{++} and swelling capacity of the activated bentonite. Na_2CO_3 possibly interacted with Ca in the Iraqi bentonite, and the result of the interaction was the formation of Na-bentonite and $CaCO_3$, which is the white solid material deposited in the bottom of the drilling mud.
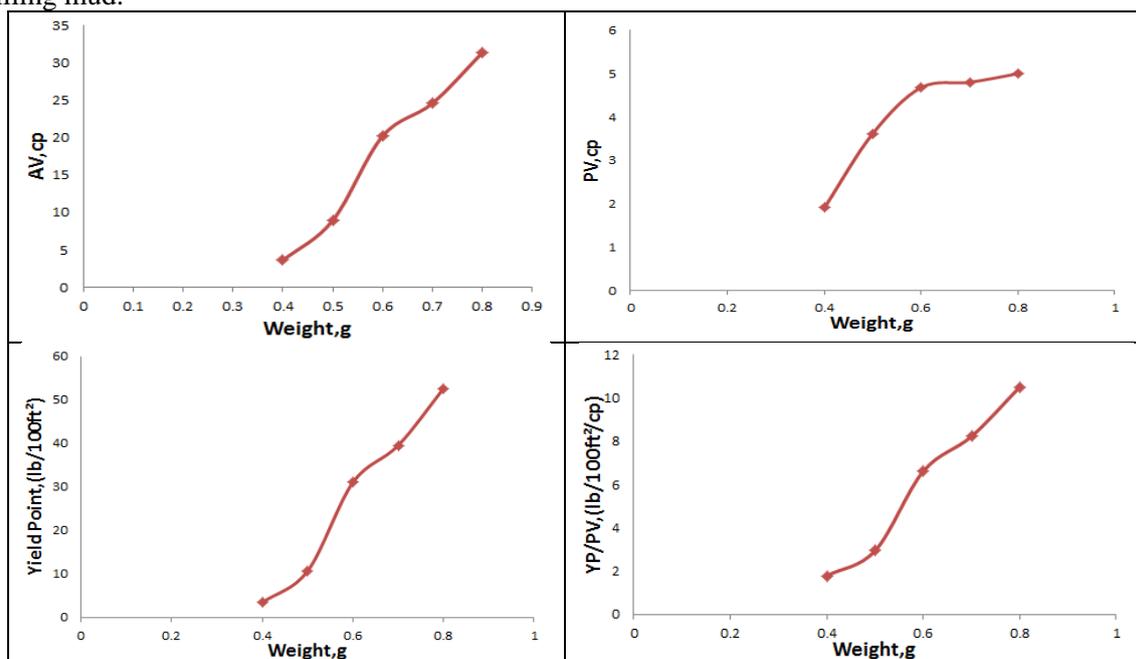
Figure 5-Rheological Properties of Iraqi Bentonite Directly-activated by Na_2CO_3.

Effects of Adding Na_2CO_3 on Stability Measurements

Table-5 manifests the stability of the activated Iraqi bentonite after directly adding different weight of Na_2CO_3. The table shows a large difference in the stability of the activated bentonite compared with that before activation. The remarkable enhancement in stability indicated that the substitution between Na and Ca cations made the Iraqi bentonite highly adsorbed in water. Therefore, the activation was successful.

Table 5-Stability of Iraqi Bentonite Directly-activated by Na_2CO_3

S %	Wt. gm	Stability %		
		1 hr	2 hr	24 hr
0.10	0.4	97.2	95.2	83.2
0.13	0.5	98.3	97.6	90.5
0.16	0.6	98.8	97.9	95.4
0.18	0.7	100	100	100
0.21	0.8	100	100	100

Effects of Adding Na2CO3 on pH, Density and Filtration Properties

As demonstrated in Table-6, the density was approximately constant and not affected by increasing the weight of Na_2CO_3. The pH value was increased from 8.8 to 9.92 when Na_2CO_3 addition was increased from 0.4 gm to 0.8 gm, because sodium carbonate dissolution in water causes the pH to increase. This high pH value is used to distinguish activated from non-activated materials [27]. The filtration property of drilling mud is the measure of the ability of its solid components to form a thin, low permeable filter cake. Low permeability decreases drilling difficulties because a thick filter cake restricts the passage of tools and allows an excessive amount of filtrate to pass into the formation, thus causing a cave [28]. Also, the results from this table reveal that the filtration volume had a high filter loss and that the mud cake was approximately thick because the activating material (Na_2CO_3) does not work on filtration enhancement. Therefore, filtration properties failed to meet the API standards.

Because the filtration properties were not enhanced, 1, 1.5 and 2 gm of CMC-LV were added to enhance the results of direct activation of Iraqi bentonite by Na_2CO_3 (0.7 gm of Na_2CO_3 were added to 22.5 gm bentonite with 350 ml of distilled water).

Table 6-Density, pH and Filtration Properties of Iraqi Bentonite Directly-activated by Na_2CO_3

S %	Wt. gm	Density ppg	pH	$V_{7.5m}$ ml	V_{30m} ml	Thickness of Mud Cake mm
0.10	0.4	8.5	8.8	27.3	54.6	3.6
0.13	0.5	8.55	9.15	20.3	40.6	3.2
0.16	0.6	8.55	9.27	16.4	32.8	4.7
0.18	0.7	8.55	9.48	14.1	28.2	5.2
0.21	0.8	8.55	9.92	11.5	23	6.5

Fig 6 shows the results of the swelling test of Iraqi bentonite before activation and after the best result of direct activation by Na_2CO_3. Also, this figure shows that the value of the swelling index of the best result of direct activation process was 20 ml, which is considered an accepted value. This value of swelling index provided the indication of the type of bentonite, since Na-bentonite has a high swelling capacity and Ca-bentonite has a low swelling capacity. From this figure, the value of swelling index of the best result of direct activation indicated that the activation process was successful and Iraqi bentonite was converted from Ca-bentonite to Na-bentonite, as indicated by the highest swelling capacity that the bentonite acquired after the direct activation process.

Blank bentonite

Direct activation by 0.7 gm of Na_2CO_3
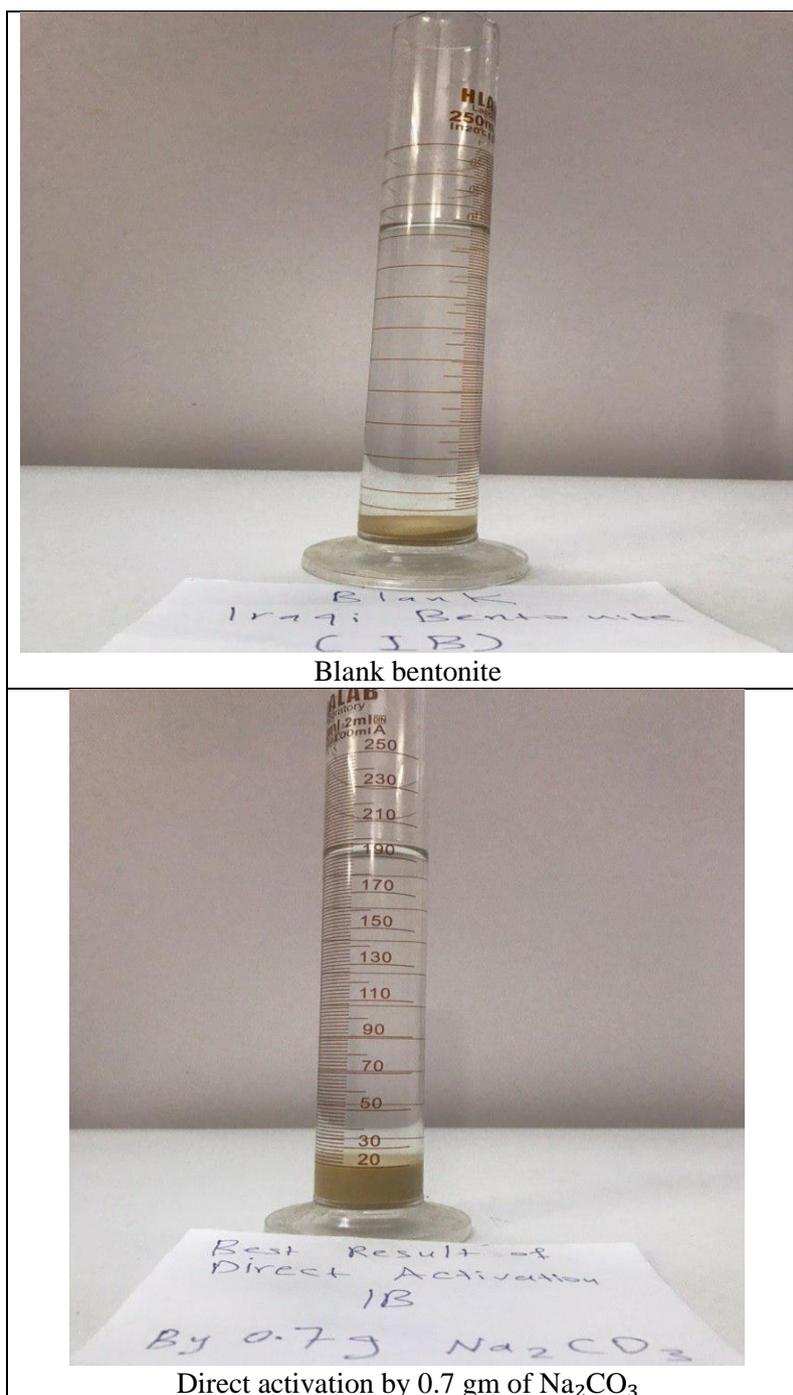
Figure 6-Swelling Test of Iraqi bentonite before Activation and after the Best Result of Direct Activation by Na_2CO_3

XRF **Characterization of Bentonite after Adding Na_2CO_3**

The results of XRF analysis (Table-7) show that the ratio of $(Na_2O+K_2O)/(CaO+MgO)$ in the activated bentonite was 1.07, confirming that the direct activation process was successful and the bentonite was converted from Ca-bentonite to Na-bentonite.

The results showed that 10% of particles had a sizes under 4.66 μm, 50% under 10.403 μm, and 90% under 21.791 μm (Figure-7). The decrease in particle size led to an increase in clay surface area. The value of the specific surface area was 0.577 m²/g. This value was higher than the value of clay before activation.

Table 7-Results of XRF Analysis of Direct Activation of Iraqi bentonite by 0.7g of Na_2CO_3

SiO_2 %	Fe_2O_3 %	Al_2O_3 %	CaO %	MgO %	SO_3 %	TiO_2 %	Na_2O %	K_2O %	P_2O_5 %
44.64	5.52	10.65	13.28	2.8	3.64	0.98	16.59	0.57	0.57
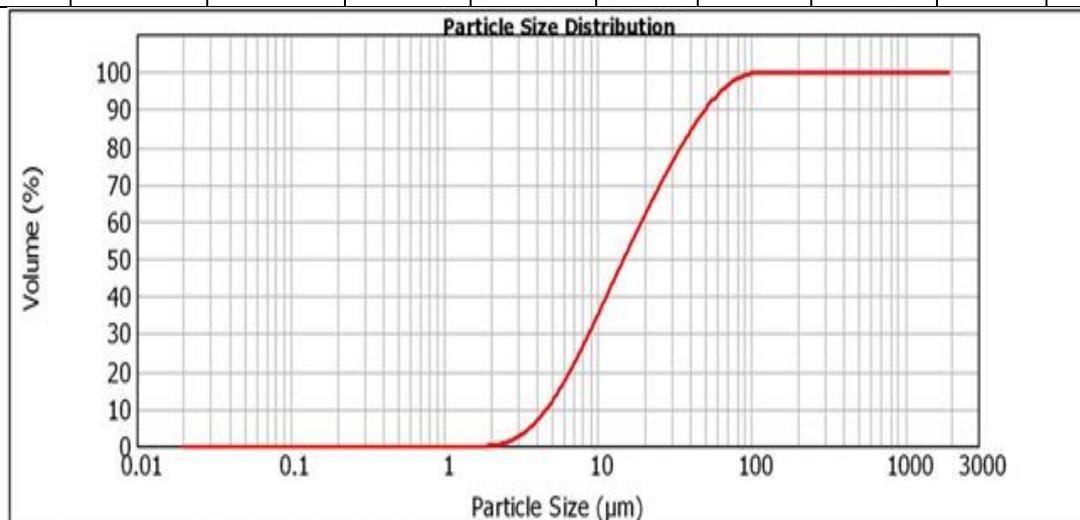
Figure 7-Particle Size Distribution of Directly-activated Iraqi bentonite by Na_2CO_3.

Effects of Adding CMC-HV on rheological properties

Table-8 shows the rheological properties of Iraqi bentonite after adding different weights of CMC-LV (filtration reducer material) and 0.7 gm of Na_2CO_3 (activation material) to the API standard mixture (22.5 gm of bentonite + 350 ml of distilled water). It reveals that the apparent viscosity did not satisfy the API specification and was decreased compared with that of the best mixture of direct activation of Iraqi bentonite by Na_2CO_3. 1 gm was adopted as the best result of adding CMC-LV to the best result of direct activation of Iraqi bentonite by Na_2CO_3. The purpose of adding CMC-LV was to enhance the filtration volume and the thickness of mud cake. In fact, the effect of CMC-LV was not only on the filtration properties but also on the rheological properties. Thus, different weights of CMC-HV were added to the mixture of 1 gm of CMC-LV and the best result of direct activated Iraqi bentonite by Na_2CO_3 in order to enhance the rheological and filtration properties.

Table 8-Rheological Properties after Adding CMC-LV to the Best Mixture of Direct Activation by Na_2CO_3

S %	Wt. gm	AV cp	PV cp	YP (lb/100ft²)	YP/PV (lb/100ft²/cp)	Gel Strength (lb/100ft²)	
						10 s	10 m
0.26	1	9.3	6.9	4.9	0.71	1	22.9
0.4	1.5	7.8	5.1	5.4	1.06	2.1	27.4
0.53	2	3.3	2.9	0.8	0.28	0.4	0.3

Figure-8 shows that the values of the rheological properties were decreased when the weight of the added CMC-LV was increased, because CMC-LV worked on reducing rheological properties and enhancing the filtration properties by reducing the volume of filtration and thickness of mud cake.
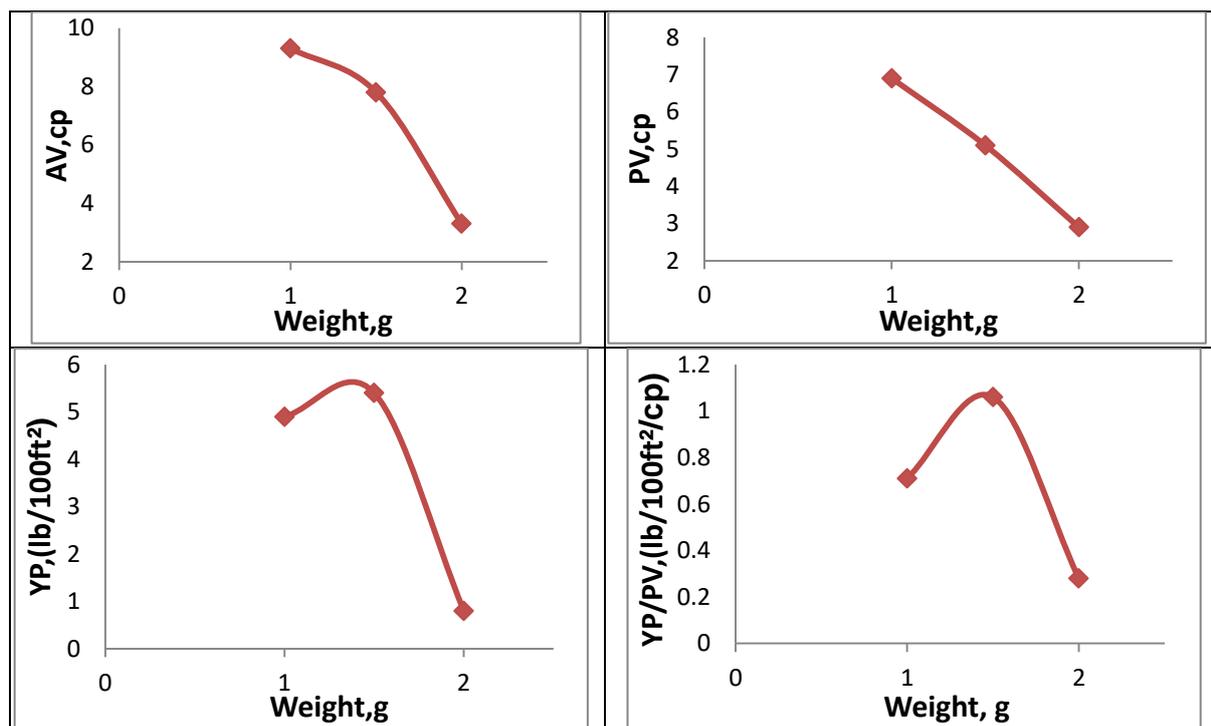
Figure 8-Rheological Properties of Iraqi bentonite after Adding CMC-LV to the Best Mixture of Direct Activation by Na_2CO_3.

Effects of Adding CMC-HV on pH, Density and Filtration Properties

Table-9 shows that the density and pH values were approximately constant and were not affected by the addition of CMC-LV. The filtration properties of Iraqi bentonite after adding different weights of CMC-LV and 0.7 gm of Na_2CO_3 to the API standard mixture were enhanced and satisfied the API specifications compared with those of the best result of direct activation of Iraqi bentonite by Na_2CO_3 without adding CMC-LV.

Table 9-Density, pH and Filtration Properties after Adding CMC-LV to the Best Mixture of Direct Activation of Iraqi bentonite by Na_2CO_3

S %	Wt. gm	Density ppg	pH	$V_{7.5m}$ ml	V_{30m} ml	Thickness of Mud Cake mm
0.26	1	8.55	8.5	6.9	13.8	0.61
0.4	1.5	8.6	8.55	5.6	11.2	0.53
0.53	2	8.61	8.57	5.5	11	0.51

Effects of Adding CMC-LV on Rheological Properties

Table-10 shows the rheological properties of Iraqi bentonite after adding 1 g of CMC-LV, 0.7 g of Na_2CO_3, and different weights of CMC-HV to API standard mixture (22.5 gm of Iraqi bentonite and 350 ml of distilled water). The results demonstrate that, as the weight of CMC-HV was increased, the rheological properties were increased and had an accepted value at the weight of 2 gm of CMC-HV. At the same time, the filtration properties satisfied the API specifications. Therefore, the best mixture was achieved when 1 gm of CMC-LV, 2 gm of CMC-HV, and 0.7 gm of Na_2CO_3 were added for enhancing the rheological as well as filtration properties. This indicates that the Iraqi bentonite is sufficient to be used as drilling fluid. The same weights of CMC-LV and CMC-HV can be used for the direct activation of Iraqi bentonite by NaOH.

Table 10-Rheological Properties after Adding CMC-HV and CMC-LV to the Best Mixture of Direct Activation by Na_2CO_3

S %	Wt. Gm	AV Cp	PV cp	YP (lb/100ft²)	YP/PV (lb/100ft²/cp)	Gel Strength (lb/100ft²)	
						10 s	10 m
0.13	0.5	14.4	8.5	5.6	0.67	0.3	0.7
0.26	1	16	11.76	8.48	0.72	0.5	11.5
0.53	2	37.81	22.8	30.02	1.32	7.2	46.6

Figure-9 shows that the apparent viscosity was increased when the weight of CMC-HV was increased. The best rheological properties were achieved when 2 gm of CMC-HV was added to the mixture (1 gm of CMC-LV, 0.7 gm of Na_2CO_3 , 22.5 gm of Iraqi bentonite and 350 ml of distilled water), which satisfied the API specification.
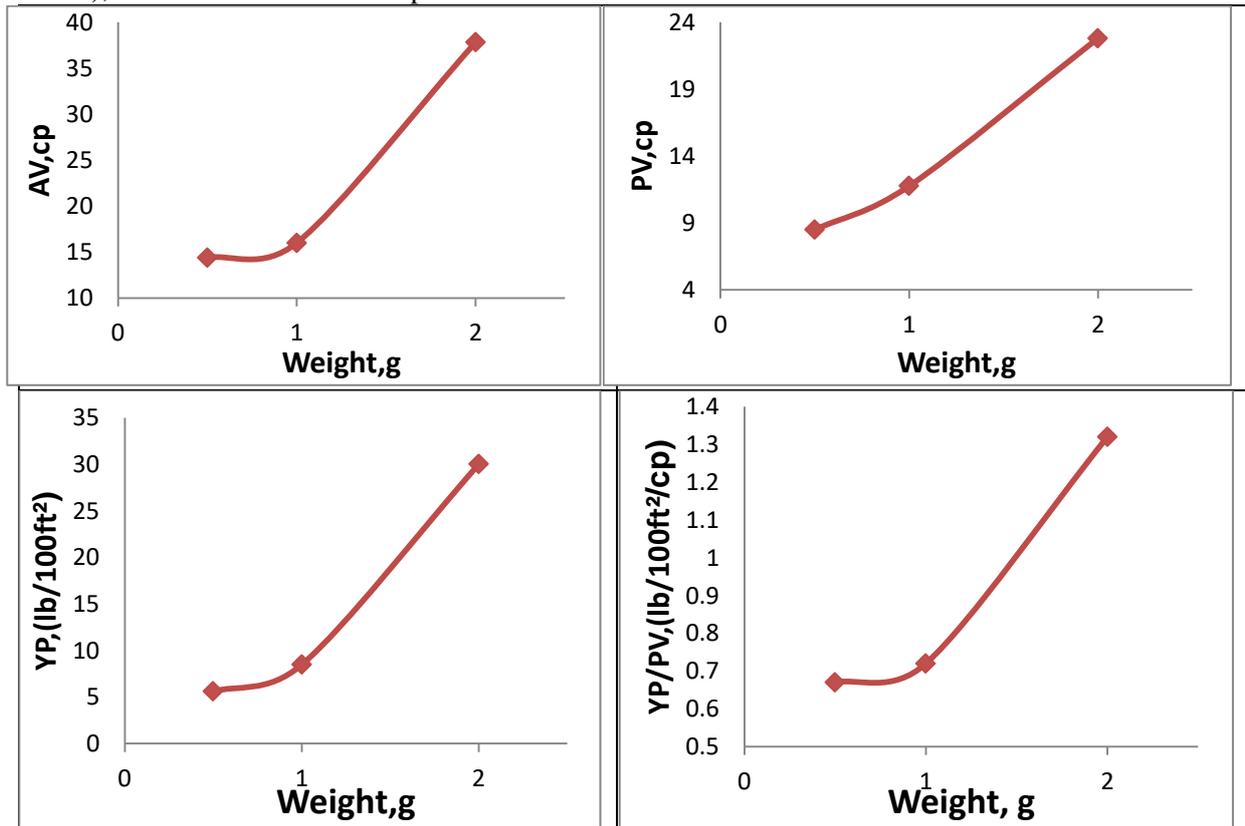
Figure 9-Rheological Properties of Iraqi bentonite after Adding CMC-HV and CMC-LV to the Best Mixture of Direct Activation by Na_2CO_3.

Effects of Adding CMC-LV on pH, Density and Filtration Properties

Table-11 depicts the density, pH, and filtration properties of Iraqi bentonite after adding 1 gm of CMC-LV, 0.7 g of Na_2CO_3, and different weights of CMC-HV to the API standard mixture (22.5 gm of Iraqi bentonite and 350 ml of distilled water). The table shows that the values of volume filtration and thickness of the mud cake meet the API specifications and, hence, they are accepted. and the properties of the produced mud cake were largely enhanced compared with those of the best mixture of direct activation of Iraqi bentonite by Na_2CO_3 without adding CMC-HV and CMC-LV.

Table 11-Density, pH and Filtration Properties after Adding CMC-HV and CMC-LV to the Best Mixture of Direct Activation of Iraqi bentonite by Na_2CO_3

S %	Wt. gm	Density ppg	pH	$V_{7.5m}$ ml	V_{30m} ml	Thickness of Mud Cake mm
0.13	0.5	8.5	9.5	6.7	13.4	0.54
0.26	1	8.55	9.6	5.1	10.2	0.58
0.53	2	8.5	9.6	3.9	7.8	0.67

Conclusions

This research was conducted to enhance and activate Iraqi bentonite (converting it from Ca-type to Na-type) in samples collected from Trefawi formation/ Al-Anbar region/ Iraq. The rheological and filtration properties were enhanced and the quality was increased in order to use the product in Iraqi Oil Companies instead of commercial bentonite.

Iraqi bentonite was successfully activated by adding Na_2CO_3 because of increasing the mass concentration which led to increase the amount of clay particles. Therefore, the rheological and stability properties were enhanced in a manner that fulfilled API specifications.

The filtration properties of Iraqi bentonite failed to enhance after adding Na_2CO_3.

The Filtration properties were enhanced by adding 1 gm of CMC-LV and 2 gm of CMC-HV to the mixture of the best result of direct activation by Na_2CO. As a result, Iraqi bentonite showed better properties to be used as drilling fluid in Iraqi oil companies instead of commercial bentonite, because its properties were enhanced in a manner that meets API specifications.

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