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FULL LENGTH ARTICLE

Improving the performance of clay from Gabal Um Qumar as drilling mud

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Abstract The main component of water base drilling fluids to perform common properties that facilitate safe and satisfactory drilling is bentonite operations. This paper represents composition and treatment capability of clays collected from clayston quarries in Gabal um Qumar north Cairo-Ismailia Desert Road, Egypt for its application as water base drilling mud. Chemical analysis, XRD and particle size distribution showed that these clays consist of montmorillonite. The rheological properties of the prepared suspension from these clay samples and its activation products by using chemicals and polymers were investigated. Results of untreated samples indicate that they cannot be used as a drilling mud but after activation processes by soda ash, Carboxi Methyl Cellulose (CMC) and Drispac Polymer significant changes were observed in yield and rheological properties. Accordingly this type of clay after activation by polymer can be classified as sub-bentonite and classified between bentonite grade and medium bentonite grade that can be used as drilling mud for medium depth wells.

1. Introduction

Gabal Um Qumar lies north of the Cairo-Ismailia Desert Road, about 32 km from Cairo (Fig. 1). The oldest rocks exposed in the area are of Oligocene age, represented by gravels, sand and sandstone with scattered silicified wood fragments and small outcrops of weathered basalt sheets.

The Oligocene is overlain unconformably by Lower Miocene sediments composed of sand and sandstone interbedded by claystone beds, with lateral changes into carbonate facies. The Lower Miocene sediments are unconformable overlain by Middle Miocene deposits composed of sandy limestone and dolostone interbedded with some clay. Both the Lower and Middle Miocene sediments have been considered as marine facies deposited in a shallow sublittoral to reefal environment [1]. Unconformable overlying the Middle Miocene beds are deposits of Upper Miocene age composed mainly of gravels and sand, and are considered as non-marine facies. Miocene sediments which are exposed to the north of Cairo Suez road are represented by Fossiliferous marine sediments belonging to Lower and Middle Miocene and non-marine fluviatile sediments belonging to Late Miocene [2]. Attia [3] stated that Miocene sediments unconformable overlie the Oligocene sediments and basalt flows while they are overlain unconformable

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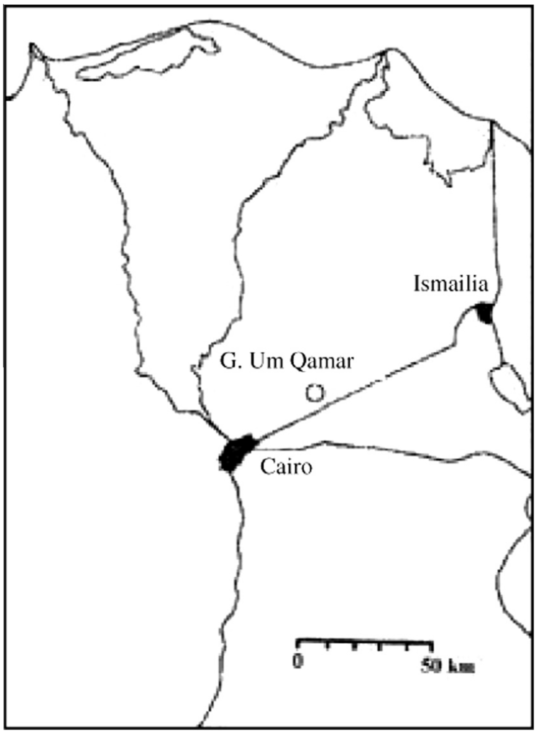

Figure 1 Location map of the Gabal Um Qumar north of the Cairo-Ismailia Desert Road.

by Quaternary sediments, and he studied mineralogically, petrologically and chemically the Miocene clays from Gabal Hamza and Gabal Um Qumar, N.E. Cairo, the deposits consist essentially of Na-Montmorillonite in addition to quartz, albite, calcite and dolomite as common impurities. He also stated that these deposits can be used as catalytic agent in petroleum refining, bleaching agents, construction engineering, pelletization of iron ore and as binding material. Bentonites are used worldwide as drilling fluid additives, their main functions are the viscosities of the mud in order to reduce the fluid loss to the formation, a good quality bentonite should contain mainly montmorillonite [4–8].

Drilling fluids are primary water-bentonite suspensions, they are important for the oil, gas and geothermal drilling industries because they perform various functions as transporting rock cuttings to surface, lubricating the drill bit, applying hydrostatic pressure in the well bore to ensure well safety and minimize fluid loss across permeable formations by forming a filter cake on the walls of the well bore [9–18]. It was shown that sufficient sodium is required to obtain a well dispersed bentonite suspension. Also it is found that the physical properties of bentonite are affected by the Na/Ca ratio and that bentonite swelling was readily improved by the addition of small amounts of soda ash [19–23]. Different types of chemicals and polymers were used in designing drilling mud to meet some functional requirements such as the appropriate mud rheology, density, mud activity and fluid loss control property [17,24–26].

The present study aims to evaluate clays of Gabal Um Qumar to use these clays as drilling fluid. The lithostratigraphic, chemical analyses and rheological properties outlines of the studied succession will be discussed.

2. Lithostratigraphy

The deposits of the bentonite in the region with a single layer topped with rocky cover of limestone and at the bottom followed by a sandy limestone. The loess is a constituent of the ore which has been studied from the showdown in quarries and the initial estimate of the quantities of bentonite in the limited length of the outcrop samples was collected, including tests of about 38 million cubic meters, equivalent to about 85 million tons. The stratigraphy of Gabal Um Qumar belongs to the marine, Early Miocene sediments overlain by Middle and Late Miocene sediments. Early Miocene sediments at Gabal Um Qumar unconformable overlie the Oligocene basalt. The Miocene sediments in Gabal Um Qumar can be represented from base to top as follows:

- The Early Miocene deposits consist of sandy limestones and sandstones with marl intercalations, highly fossiliferous.
- The Middle Miocene deposits unconformable overly the Early Miocene deposits and consist essentially of clays overlain by limestone. The clay bed underlies the limestone bed and consists of gray, soapy, Ferruginous in parts, clay ranging in thickness from 8 m. to 10 m.
- The Late Miocene deposits are represented by non-marine gravels, flint fragments and reddish brown sands, they unconformable overly the Middle Miocene deposits and attain a thickness of 20 m.

Twenty four representative samples were collected from Gabal Um Qumar, tests were carried out on the different samples to determine their chemical nature and rheological properties.

3. Experimental work

3.1. Chemical and mineralogical studies

Only 12 samples of clay from Gabal Um Qumar Cairo-Ismailia Road were subjected to chemical and mineralogical analyses, the mineralogical composition of the samples was determined by X-ray powder diffraction (XRD) analysis and the chemical composition of the samples (major and trace elements) was determined using X-ray fluorescence techniques (XRF). Table 1 gives the chemical composition of the studied samples, the montmorillonite mineral which mostly exist in the clay component in the samples, the results of X-ray analysis showing that the often type is Na-Montmorillonite, but Ca-Montmorillonite exists in few isolated locations. Table 2 shows the percentage of clay components in the samples and the proportion of the contents of montmorillonite minerals.

3.2. Beneficiation and processing

Twenty four representative samples were collected from Gabal Um Qumar, tests were carried out on the different samples to determine their rheological properties including apparent viscosity, plastic viscosity, and yield point, gel strength, thixotropy and filtration characteristics. Drilling fluids are subjected to varying condition during circulation from the surface to

Table 1 Chemical analyses of the studied samples.

Sample no.	SiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	TiO_2	P_2O_5	LOI	Total
1	53.05	23.21	7.33	0.03	1.75	1.11	1.01	1.45	1.43	0.08	9.33	99.79
2	60.25	18.30	7.34	0.02	1.89	0.49	1.51	1.27	1.58	0.05	7.83	100.55
3	48.37	25.33	9.63	0.03	1.38	0.49	1.30	1.03	1.87	0.13	10.18	99.73
4	50.69	24.60	8.33	0.04	1.32	0.46	1.23	1.11	2.01	0.14	9.83	99.75
5	50.19	25.72	7.33	0.03	1.43	1.09	1.34	0.96	1.67	0.46	10.24	100.48
6	53.83	21.01	8.17	0.02	1.87	1.51	1.30	1.34	1.52	0.13	9.03	99.74
7	51.98	24.62	7.11	0.03	1.74	1.09	1.01	1.24	1.54	0.06	9.55	99.97
8	51.80	22.78	8.84	0.08	1.74	0.61	1.33	1.26	1.56	0.11	9.64	99.75
9	51.03	23.27	9.25	0.16	1.26	1.50	1.02	1.33	1.01	0.07	9.35	99.23
10	53.73	21.05	8.69	0.14	1.30	1.03	1.67	1.20	1.16	0.10	8.10	98.16
11	49.16	23.93	9.65	0.13	0.75	1.47	1.32	0.92	1.26	0.52	9.27	98.37
12	49.95	24.70	8.20	0.13	0.92	0.72	1.48	0.97	1.25	0.09	9.76	98.18
Average	52.00	23.21	8.32	0.07	1.45	0.96	1.29	1.17	1.49	0.16	0.00	0.00

Table 2 Percentage of clay component of the studied samples.

Sample no.	Clay component %	Montmorillonite minerals	
		Type	%
1	99.8	Ca-Mon.	53
2	99.8	Na-Mon.	40
3	99.8	Na-Mon.	53
4	99.6	Na-Mon.	32
5	98.0	Na-Mon.	50
6	99.8	Ca-Mon.	43
7	99.8	Ca-Mon.	36
8	90.8	Na-Mon.	40
9	85.4	Ca-Mon.	40
10	95.6	Na-Mon.	36
11	98.0	Ca-Mon.	44
12	83.8	Na-Mon.	37

down hole. Therefore, these conditions should be simulated properly through API standard and performance tests. To evaluate local clays as a viscosifier material, used to increase the viscosity of the water to formulate the water base mud system for drilling fluids, certain conditions must be satisfied relevant to material preparation which are as follows:

1. Local clay should be ground to optimum particle size distribution for API mud grad size.
2. The percentage of dry particles passing from 100 meshes must be 98% at least.
3. The moisture content must be less than 15%.
4. The percentage of wet particles retained on 200 meshes as a residue must be 2.5% maximum.

All the above material conditions as grinding and particle size distribution shall be satisfied by using appropriate grinders to beneficiate the local clay in accordance with specification [27,28].

3.3. Mud formulation and preparation

Four group field mud batches were prepared using local clay from Gabal Um Qumar as a viscosifier for various tests. Group one was prepared for different concentrations starting from 6% to 23.5% clay. Group two were prepared from 6.4% to 10% local clay soda ash. Group three were prepared for different concentrations of local clay from 6% to 8% and treated by CMC (Carboxi Methyl Cellulose). Group four were prepared from 4% to 6.4% and treated by drispace polymer. Chemicals and polymers were added gradually to permit testing under varying percentage. The mud preparation and testing program was incorporated for water base drilling fluids.

4. Discussion of results

4.1. Chemical analysis (Table 1)

XRF Values obtained in XRF analysis showed that the Al_2O_3/SiO_2 ratio was 1/2 as expected for montmorillonite which is the main component of clay under study. The ratio of $[(Na_2O + K_2O)/(MgO + CaO)]$ for the samples was generally found to be confirming that the samples were Na-bentonite.

Table 3 Rheological properties of untreated clays.

Sample no.	Yield lb/bbl	Mud wt. lb/ft^3	Wt %	AV. cp	PV. cp	YP. lb/100ft^2	Gel		Thix.
							10′	10″	
1	29.5	71.0	17.0	17.0	5.0	23.0	13.0	15.0	2.0
2	24.8	70.0	22.5	15.0	3.0	20.0	12.5	12.5	0.0
3	32.6	70.5	16.5	16.0	2.0	25.0	13.0	13.0	0.0
4	21.8	69.0	23.5	14.0	4.0	19.0	12.0	13.0	1.0
5	24	68.0	23.0	15.0	7.0	16.0	10.0	10.0	0.0
6	28.4	69.5	21.5	15.0	6.0	18.0	14.0	18.0	4.0

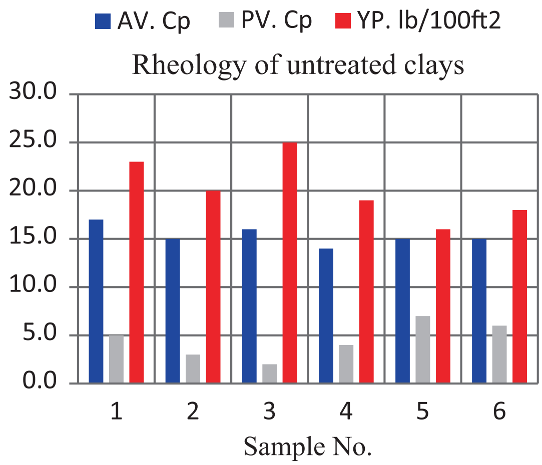

Figure 2 Rheology of untreated clays.

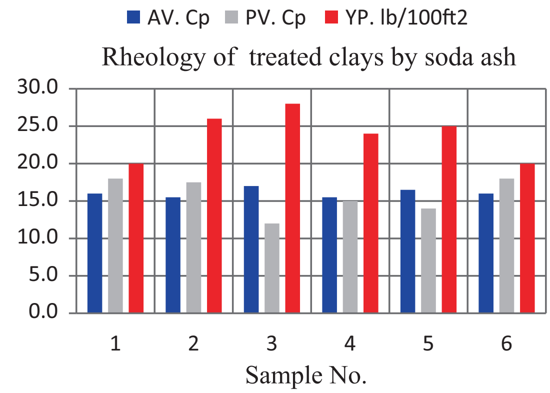

Figure 5 Rheology of clays treated by soda ash.

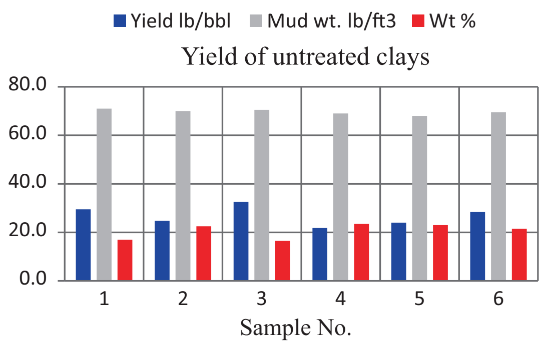

Figure 3 Yield of untreated clays.

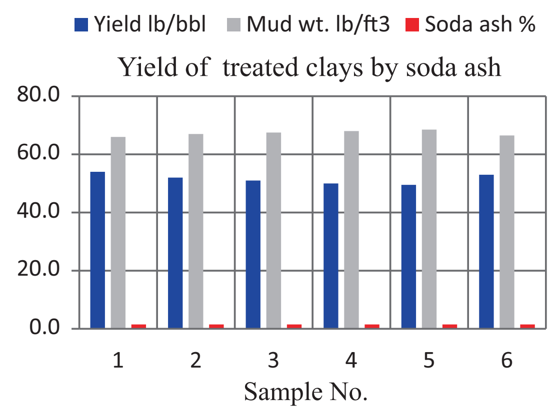

Figure 6 Yield of clays treated by soda ash.

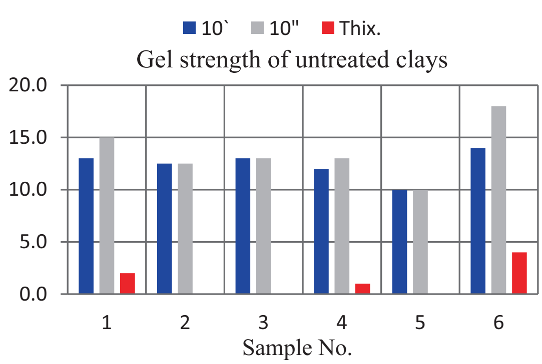

Figure 4 Gel strength of untreated clays.

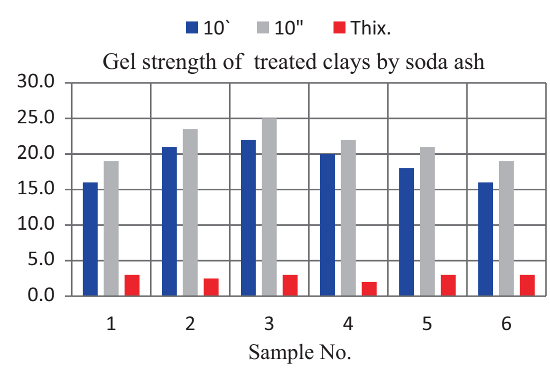

Figure 7 Gel strength of clays treated by soda ash.

Table 4 Rheological properties of clays treated by soda ash.

Sample no.	Yield lb/bbl	Mud wt. lb/ft^3	Soda ash %	AV. cp	PV. cp	YP. lb/100ft^2	Gel		Thix.
							10′	10″	
1	54	66	1.5	16.0	18.0	20.0	16.0	19.0	3.0
2	52	67	1.5	15.5	17.5	26.0	21.0	23.5	2.5
3	51	67.5	1.5	17.0	12.0	28.0	22.0	25.0	3.0
4	50	68	1.5	15.5	15.0	24.0	20.0	22.0	2.0
5	49.50	68.5	1.5	16.5	14.0	25.0	18.0	21.0	3.0
6	53	66.5	1.5	16.0	18.0	20.0	16.0	19.0	3.0

Table 5 Rheological properties of clays treated by CMC.

Sample no.	Yield lb/bbl	Mud wt. lb/ft^3	CMC %	AV. cp	PV. cp	YP. lb/100ft^2	Gel		Thix.
							10′	10″	
1	68	65	1.0	17.0	12.0	10.0	10.0	11.0	1.0
2	67	65.2	1.0	15.0	9.0	18.0	13.0	15.0	2.0
3	62	66.7	1.0	16.5	10.0	15.0	11.0	11.0	0.0
4	69	64.9	1.0	15.5	10.5	11.0	12.0	13.0	1.0
5	66	65.3	1.0	16.0	9.5	14.0	11.0	12.0	1.0
6	65	65.5	1.0	15.0	8.5	15.0	13.0	14.0	1.0

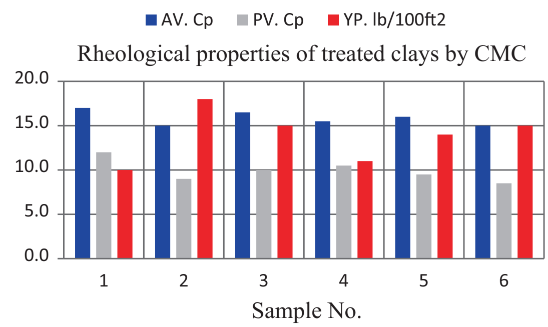

Figure 8 Rheology of clays treated by CMC.

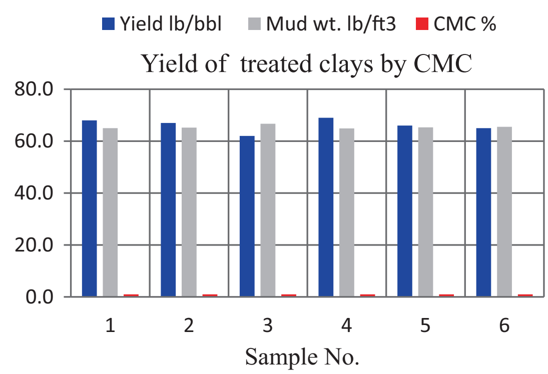

Figure 9 Yield of clays treated by CMC.

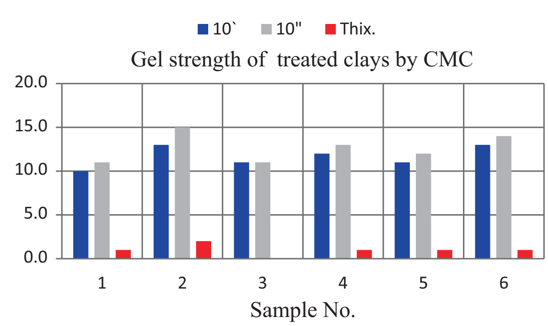

Figure 10 Gel strength of clays treated by CMC.

4.2. Mineralogical studies

Mineralogical analysis for local clay studied samples showed that they are essentially montmorillonite as expected. XRD patterns of samples indicate that the main constituents are montmorillonite, Quartz and Kaolinite in decreasing order of their abundance. It is clear from Table 2 that the number of samples containing Na-Montmorillonite is 7 samples representing approximately 58% of the total number of samples where the number of samples containing the Ca-Montmorillonite is 5 samples representing approximately 42% of the total number of samples.

4.3. Rheology studies

4.3.1. Rheology and gel strength of untreated clay

Apparent viscosities of untreated samples range between 14 and 17 cp, with plastic viscosity from 2 to 7 cp, where yield point changes from 16 to 25 lb/100ft^2 due to weight percentage of clay that varies from 16.5% to 23.5% which leads to yield changing from 21.8 to 32.6 lb/bbl as shown in Table 3 and Figs. 2 and 3. Gel strength after 10 s changes from 10 to 14 lb/100ft^2 and after 10 min from 10 to 18 lb/100ft^2 where thixotropy ranges between 0 and 4 lb/100ft^2 when the concentration of the clay varies from 16.5% to 23.5% as weight fraction of clay as shown in Table 3 and Fig. 4.

4.3.2. Rheology and gel strength of clay treated by soda ash

Rheology, yield and Gel strength of clay treated by soda ash were measured and the results illustrated in Table 4 and Figs. 5–7 show the following:

Apparent viscosity changes from 15.5 to 17 cp. Plastic viscosity ranged from 12 to 18 cp where yield point ranged between 20 and 28 lb/100ft^2. Gel strength after 10 s changes from 16 to 22 lb/100ft^2 where gel after 10 min changes from 19 to 25 lb/100ft^2 and thixotropy varies from 2 to 3 lb/100ft^2. The above results were obtained when 1.5% soda ash adds to 10% of the weight percentage of the local clay which leads to an increase in the yield from 49.50 to 54 lb/bbl.

4.3.3. Rheology and gel strength of clay treated by CMC

Rheological properties including viscosity, yield point and gel strength in addition to yield value of clay treated by CMC were measured and the results show that the apparent and plastic viscosities change from 15 to 17 cp and from 8.5 to 12 cp, respectively. The yield point varies from 10 to 18 lb/100ft^2. Gel strength ranges between 10 and 13 lb/100ft^2 and between 11 and 15 lb/100ft^2 after 10 s and 10 min, respectively. Results of clay treated by 1.0% CMC added to 8% of the weight percentage of the local clay show an increase in the yield from 62 to 69 lb/bbl (Table 5) and (Figs. 8–10).

Table 6 Rheological properties of clays treated by polymer.

Sample no.	Yield lb/bbl	Mud wt. lb/ft^3	Polymer	AV. cp	PV. cp	YP. lb/100ft^2	Gel		Thix.
							10′	10″	
1	86.5	64.9	0.5	15.5	10.0	10.0	11.0	13.0	2
2	86	65.0	0.5	16.0	9.0	15.0	13.0	15.0	2
3	84	66.0	0.5	16.5	9.5	13.0	12.5	12.5	0
4	87	64.8	0.5	15.5	8.5	16.0	10.0	12.0	2
5	85	65.5	0.5	15.5	8.0	14.0	11.0	11.0	0
6	85	65.0	0.5	15.0	7.5	17.0	12.0	13.0	1

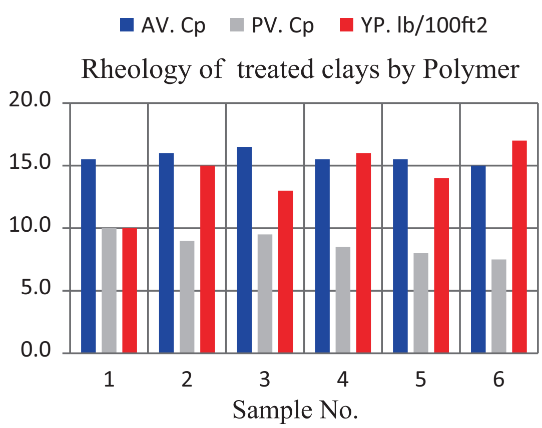

Figure 11 Rheology of clays treated by polymer.

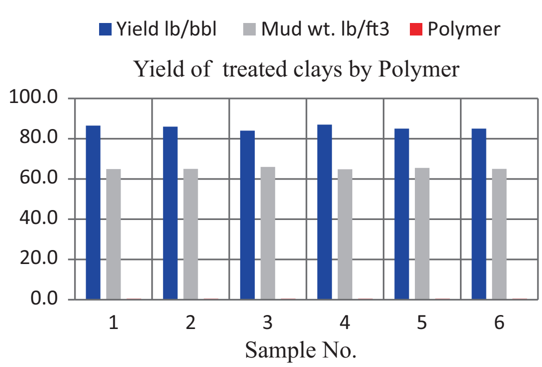

Figure 12 Yield of clays treated by polymer.

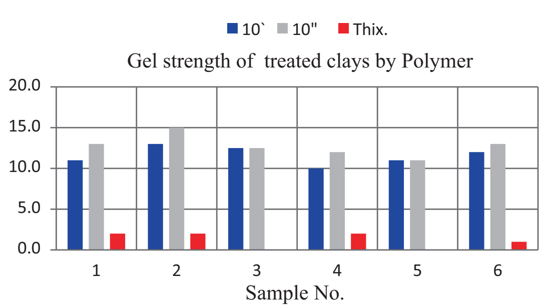

Figure 13 Gel strength of clays treated by polymer.

Table 7 Yield of untreated and treated clays.

Sample no.	Yield of untreated clay lb/bbl	Yield of clay treated by soda ash lb/bbl	Yield of clay treated by CMC lb/bbl	Yield of clay treated by Drispac Polymer lb/bbl
1	29.5	54	68	86.5
2	24.8	52	67	86
3	32.6	51	62	84
4	21.8	50	69	87
5	24	49.5	66	85
6	28.4	53	65	85
Average Yield (%)	26.85	51.58	66.17	85.58

4.3.4. Rheology and gel strength of clay treated by Drispac Polymer

Rheology, gel strength and yield of clay treated by the polymer were measured as shown in Table 6 and Figs. 11–13 and results indicate that apparent and plastic viscosities vary from 15 to 16.5 cp and from 7.5 to 10 cp, respectively while the yield point changes from 10 to 17 lb/100ft^2. Gel strength ranges from 10 to 13 lb/100ft^2 and 11 to 15 lb/100ft^2 after 10 s and 10 min, respectively thixotropy changes from 0 to 2 lb/100ft^2. The above results of clay treated by 0.5% polymer added to 6.4% of the weight percentage of the local clay show an increase in the yield from 84 to 87 lb/bbl.

4.4. Yield of untreated and treated clays

The yield of untreated samples ranges from 21.8% to 32.6% with average yield percentage of about 27% while for the clay treated by soda ash from 49.50% to 54% with average percentage of about 52%. For samples treated by CMC the yield increases in the range of 62–69% with average percentage of about 66%. Also the yield increases from 84% to 87% with average percentage of about 86% when Drispac Polymer was added, which is the highest increase as compared to other additives as shown in Table 7 and Fig. 14.

4.7. Filtration Characteristics for untreated and treated clays

Standard filtrate loss was measured for untreated and treated local clays as shown in Table 8 and Fig. 15, the results indicate that the filter loss ranged between 24.4 and 27 ml with an average of 25.48 ml. For untreated clay the filter loss changed from 23.8 to 25.8 ml, with an average of 24.77 ml. for treated clay by soda ash. For clay treated by CMC the filter loss varies from

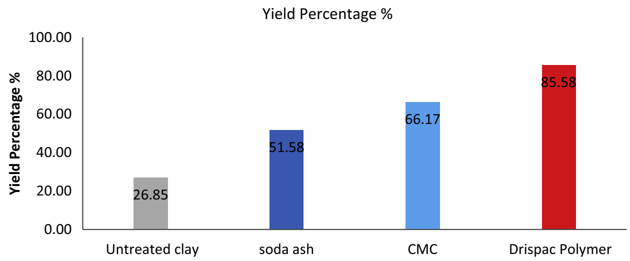

Figure 14 Yield increasing by activation.

Table 8 Filtrate loss of untreated and treated clays.

Sample no.	Untreated F.L. (ml)	Treated F.L. (ml)		
		Soda ash	CMC	Polymer
1	25.5	24.8	19.3	17
2	27	25.6	20.2	18.5
3	26.4	25.8	19.2	18.7
4	25	24.4	20	18.6
5	24.6	24.2	19.3	18
6	24.4	23.8	19	17.2
Average	25.48	24.77	19.50	18.00

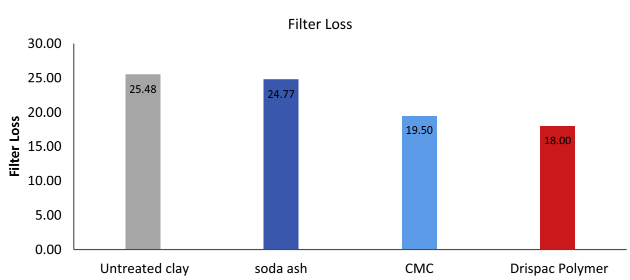

Figure 15 Filtrate loss of untreated and treated clays.

19.0 to 20.2 ml with an average of 19.50 ml and decreases when clay was treated by polymer from 17.0 to 18.7 ml with an average of 18 ml.

5. Conclusion

The activation capabilities for Gabal Um Qumar local clay collected from quarries were explained as drilling mud to minimize the importation cost of the imported bentonite by using local clay. As a result of the present study, it is concluded that:

1. The studied untreated samples show that the 15–17 cp apparent viscosities of height percentage from 16.5 to 23.5 results yield from 21.8 to 32.6 lb/bbl which increase the solids content and accordingly the untreated samples cannot be used as drilling mud in addition to the increase of coast the mud.
2. Activation of 10% from this clay by 1.5% soda ash slightly increases the yield from 49.50 to 54 lb/bbl which also cannot be used as drilling mud due to its high solid content and cost.
3. Activation by 1.0% CMC increases the yield by medium values ranging between 62 and 69 lb/bbl which may be used as drilling mud for shallow depth wells.
4. Activation by 0.5% drispace polymer increases the yield in the range between 84 and 87 lb/bbl that can be used for medium depth wells.
5. Further future work is needed, so as to comply with the international specifications, for example: treatment by other additives to reduce filtrate loss.

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