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Improve Rheological Properties of Palygorskite Water-Based Drilling Fluid by Caustic Soda and Soda Ash

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ABSTRACT

In drilling fluid program, selecting the drilling fluid that will reduce the lost time is the first objective, and will be economical regardless of its cost. The amount and type of solids in drilling fluid is the primary control of the rheological and filtration properties. Palygorskite clay (attapulgite) is an active solid that has the ability to reactive with its environment and form a gel structure within a fluid and due to its stability in the presence of brines and electrolytes this type of clay is preferred for use. The aim of this study is to improve properties of Iraqi palygorskite (PAL) by adding different chemical additives such as caustic soda NaOH and soda ash Na_2CO_3 with a different concentration in both fresh and salt water-based drilling fluid to satisfy the API specification and to compete with imported palygorskite. The palygorskite claystone of Late Cretaceous age is present in the Western Desert of Iraq within the Digma Formation. In this study, two areas in Western Desert palygorskite were obtained, Bahr Al-Najaf and Trefawi. The results of rheological properties showed that the performance of Bahr Al-Najaf PAL was more affected by caustic soda than Trefawi PAL. In contrast, Trefawi PAL performance was more affected with low concentrations of soda ash than Bahr Al-Najaf PAL in both fresh and salt water-based drilling fluid. Also, these additives lead to improve the value of pH in both fresh and salt drilling fluid that increases the ability of clay to be more dispersed in drilling fluid. Besides that, enhancement of drilling fluid prepared with Iraqi palygorskite stability to 85 and 80 in fresh and saltwater, respectively, was observed with soda ash additions.

Keywords: clay, palygorskite, caustic soda, soda ash, rheological properties.

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تحسين الخواص الريولوجية لمائع الحفر مائي القاعدة المحضر من البالكورسكايت باضافة الصودا الكاوية و رماد الصودا

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الخلاصة

اختيار مائع الحفر الذي يقلل من الوقت الضائع في عمليات الحفر, هو الهدف الاول في تصميم برنامج مائع الحفر. كمية و نوع المواد الصلبة في مائع الحفر هي السيطرة الاولية للخواص الريولوجية والترشيح. تعتبر أطيان البالكورسكايت من المواد الصلبة الفعالة والتي لها القابلية على التفاعل مع المحيط وتكون تركيب هلامي داخل المائع و نتيجة الى استقطابها بوجود الاملاح يفضل استخدام هذا النوع من الاطيان. الهدف من هذه الدراسة, هو تحسين خواص و ادائية البالكورسكايت العراقي عن طريق اضافة مواد كيميائية مختلفة مثل الصودا الكاوية و بيكربونات الصوديوم بتراكيز مختلفة في الماء العذب والمالح لغرض الوصول الى معيار (API) ومنافسة الاطيان المستوردة التجارية. ثم استخدام البالكورسكايت العراقي المتواجد في بحر النجف و طريفاوي في الصحراء الغربية في العراق. نتائج الخواص الريولوجية بينت تحسن في اداء الاطيان المحضرة من البالكورسكايت/ بحر النجف باضافة الصودا الكاوية (هيدروكسيد الصوديوم) اكثر من الاطيان المحضرة من البالكورسكايت /طريفاوي, بينما اداء الاطيان المحضرة من البالكورسكايت /طريفاوي تحسن باضافة قليلة من رماد الصودا (بيكربونات الصوديوم) اكثر من الاطيان المحضرة من البالكورسكايت/ بحر النجف. كذلك قيم pH تحسنت باضافة كل من الصودا الكاوية و رماد الصودا والذي بدورة يزيد من تشتت اطيان البالكورسكايت. الى جانب هذا, هنالك تحسن باستقرارية موائع الحفرحيث وصل الى 85 و80 في كلا من الماء العذب والمالح على التوالي عند اضافة رماد الصودا.

الكلمات الرئيسية: البالكورسكايت, الصودا الكاوية,بيكربونات الصوديوم, الخواص الريولوجية.

1. INTRODUCTION

Drilling fluid is one of the essential factors to success rotary drilling operation, which consists of liquids and different active solids, inert solids, and chemical additives to enhance its properties. The principal functions of drilling fluid are removing cuttings from beneath the bit and carry out from the borehole, lubricate and cooling the bit, and maintain the stability of borehole by controlling the hydrostatic pressure to prevent blowouts and formation damage **(Caenn, et al., 2017).**

Palygorskite is 2:1 layer silicates, where the tetrahedral sheets are linked infinitely in two dimensions. It is structurally different from other clay minerals in that the octahedral sheets are continuous in only one dimension, and the tetrahedral sheets are divided into ribbons by the periodic inversion of rows of tetrahedrons. In other words, palygorskite consists of double silica tetrahedral chains linked by octahedral oxygen and hydroxyl groups containing aluminum and magnesium ions in a chain-like structure **(Murray, 2007)**, as shown in **Fig. 1 (Aghzzaf, et al., 2017)**. A general formula for palygorskite is $(OH_2)_4(OH2)\ Mg_5Si_8O_{20}$ 4H2O. It is elongate in shape and often occurs as bundles of elongate and lath-like particles, usually, >5A^o. The morphology of this clay mineral, as illustrated in **Fig. 1- a** is the most important physical attribute. This elongate needle shape is in contrast and compares to the flake-shaped kaolinite and montmorillonite, which leads to some unique applications and specifications, as shown in **Table 1 (Haden and Schwint, 1967).**

Table 1. Properties of industrial clays **(Haden and Schwint, 1967).**

Properties	Palygorskite	Bentonite	Kaolin
Principle Mineral	Palygorskite	Montmorillonite	Kaolinite
Crystal Structure	Chain	3-layer sheet	2-layer sheet
Particle Shape	Needle	Flake	Plate
Surface Area	High	Medium	Low
Sorptivity	High	Medium	Low
Binding Power	Medium	High	Low
Color	Gray to pink	Gray to white	White
Brightness	Low	Variable	High
Thickening Power	High	High	Low
Effect of Electrolyte	Little or none	flocculates	flocculates

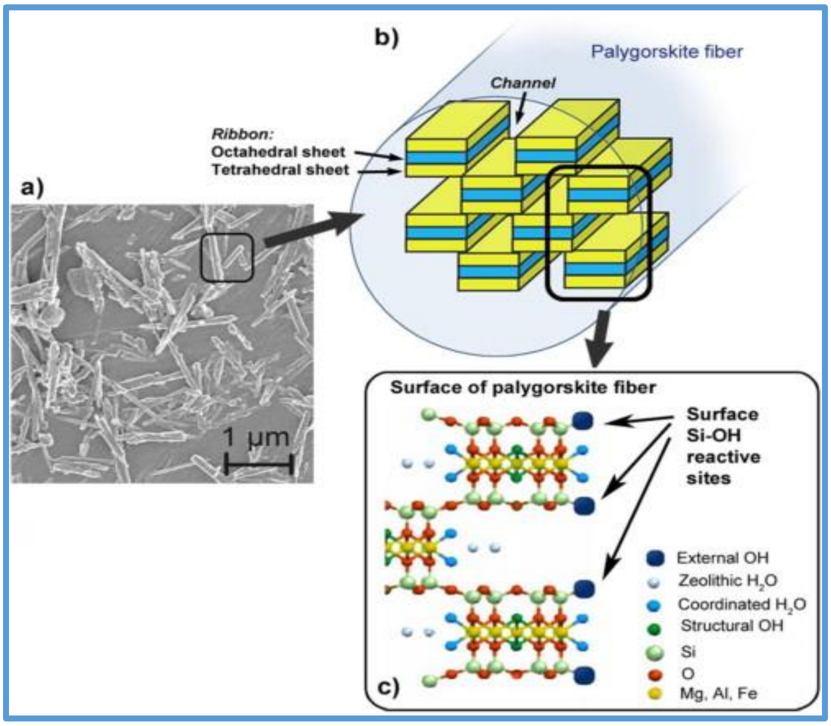

Figure 1. (a) SEM image of palygorskite, (b) the pore distribution of palygorskite, (c) the crystal structure, **(Aghzzaf, et al., 2017).**

The internal arrangement of the tetrahedral and octahedral layers of palygorskite is unique in that there are channels through the structure, as in **Fig.1**. These channels are filled with what is termed zeolitic water. When this water is driven off by heating the surface area, and thus the sorptivity is increased, chemical compounds that are of the size that will fit into these channels are readily absorbed. Absorption and adsorption are properties related to the surface area. Absorption is the penetration of fluid molecules into the bulk of absorbing clay, whereas adsorption is the interaction between the fluid molecules and the clay surface **(Murray, 2007)**.

Palygorskite is one of the most important gel-forming clays where it gives stable suspensions of high viscosity at relatively low concentrations compared to other clays. Palygorskite suspensions are thixotropic and non-Newtonian at all concentrations. During dispersion, the bundles of palygorskite needle-shaped crystals disassociated to form a random lattice that can traps liquid to increase the viscosity of the system **(Haden and Schwint, 1967).** In other words, the particles are cross-linked, and water (liquid) is trapped **(Moore, 1986)**.

Several studies have been conducted to improve the performance of palygorskite. Different additives such as polymers, chemicals, and nanoparticles with various concentrations were added to enhance the properties of palygorskite water-based drilling fluids (fresh and saltwater). **(Al-Baidari, 1997)** studied the effect of aging time, chemicals, and polymers on the rheological properties of drilling fluids prepared with Iraqi claystones from Injana formation/Najaf-Karbala region and showed that when added Iraqi bentonite to palygorskite reached the required viscosity according to API specification. **(Al-Ajeel et al., 2008)** studied the beneficiation of attapulgite – montmorillonite claystone with dispersion sedimentation technique using polyionic salts as dispersant. This study was performed on attapulgite-rich claystone (palygorskite) sample from the Digma Formation exposed in the Western Desert of Iraq. The composition of clay materials mainly consists of attapulgite and montmorillonite minerals, together with quartz, calcite (represents the major impurity), dolomite, and gypsum as impurities. The results showed that tetrasodium pyrophosphate was much better than sodium hexametaphosphate, as a dispersant. Also, the dispersant quantity should be optimized in order to achieve good beneficiation of attapulgite clay from the dilute crude slurry. **(Abdo and Haneef, 2013**) studied the stability and rheological properties of drilling fluid at the HPHT environment by adding palygorskite nanoparticles to montmorillonite.

(Xu, et al., 2013) studied the effect of added different electrolytes such as (KCl, KBr, KI, KH_2PO_4, $KHSO_4$, K_2HPO_4, K_2SO_4, and K_3PO_4) on the electrokinetic, rheological properties, stability of modified series of palygorskite samples. **(Zhou, et al., 2015**) showed the effect of added chemical additives such as magnesium oxide on the rheological behavior of palygorskite suspension. Other studies were conducted on the activation and treatment of palygorskite clay that was used in drilling fluids to enhance its performance**. (Srasra, 2008), (Chen, et al., 2011),** and **(Cruz, et al., 2014)**, investigated the effect of heat activation on the specific surface area of palygorskite. In general, clays are used and applied in several industries such as in water-based mud **(Salam, et al., 2019)** and to remove oil from wastewater **(Alwared and Faraj, 2015).**

This study aims to improve the performance of Iraqi palygorskite in fresh and salt water-based drilling fluid by adding chemical additives such as caustic soda and soda ash with various concentrations.

2. EXPERIMENTAL WORK

2.1 Materials

The materials that have been used in preparing different samples of water-based drilling fluids are:

2.1.1 Palygorskite

Two types of Iraqi palygorskite (PAL) have been supplied by Iraq Geological Survey (GEOSURV- IRAQ) from Bahr Al-Najaf in Al-Najaf governorate and the second from Trefawi in Al-Anbar governorate. These two types were compared with commercial palygorskite, which was supplied from the Basrah Oil Company (BOC).

2.1.2 Chemical Additives

The specifications and the concentration ranges of chemical additives that were used in preparing water-based drilling fluids are shown in **Table 2**

Table 2. Specification of Chemical Additives **(Darley and Gray, 1988),** and **(MI, 1996)**

Name	Formula	Common Name	Solubility g/100g water	Concentr-ation lb/bbl (g/350cc)	Functions
Sodium Chloride	$NaCl$	Rock Salt	36	10-25 or (125) ★	Used as produced or as prepared brine in completion and workover operations to saturate water before drilling rock salt
Sodium Carbonate	Na_2CO_3	Soda Ash	21.5	0.2-4	Principle use is for removal of soluble calcium salts from makeup waters and muds; some use in clay beneficiation
Sodium Hydroxide	$NaOH$	Caustic Soda	119	0.2-4	Used in water muds to raise pH: to solubilize lignite, lignosulfonate and tannin substances; to counteract corrosion, and to neutralize hydrogen sulfide

★To prepare saturated saltwater drilling fluid **(MI,1996)**

2.2 Experiments

The experiments were divided into two parts, as illustrated in **Table 3**. In the first part, an evaluation of Iraqi palygorskite types Bahr Al-Najaf and Trefawi with a concentration of 11 and 9.6 wt. %, respectively, was mixed with different concentrations of caustic soda and soda ash in fresh water-based drilling fluid and compared with the base sample (without chemical additives). In the second part, salt water-based drilling fluid was used.

Drilling fluids (prepared samples) made in the lab from Iraqi palygorskite must be given a preliminary mixing using Hamilton Beach mixer to mix drilling fluid for 20 min, then be aged for 16 hours to allow the colloids time to hydrate. The rheological properties (apparent viscosity (AV), plastic viscosity (PV), and 10 sec/10 min gel strength) of each sample were measured using Fann viscometer model 35. Each experiment was repeated three times to obtain accurate results.

Table 3. Drilling fluid with different additives and concentrations in fresh and salt water.

Type of Based Mud	PAL Type	PAL %	Distilled Water, cc	NaCl, g	NaOH, g	Na_2CO_3, g
Fresh Based Drilling Fluid	Bahr Al-Najaf	11	450	-------	-------	-------
		11	450	-------	0.5,1,2,3	-------
		11	450	-------	-------	1,2,3,4
	Trefawi	9.6	450	-------	-------	-------
		9.6	450	-------	0.5,1,2,3	-------
		9.6	450	-------	-------	0.4,0.6,0.8,1
Salt-Based Drilling Fluid	Bahr Al-Najaf	11	450	80.25	-------	-------
		11	450	80.25	0.5,1,2,3	
		11	450	80.25		1,2,3,4
	Trefawi	9.6	450	80.25	-------	-------
		9.6	450	80.25	0.5,1,2,3	
		9.6	450	80.25		0.6,0.8,1,2,3

3. RESULTS and DISCUSSION

3.1 Rheological properties of Iraqi PAL with caustic soda

The effect of caustic soda on drilling fluid properties is illustrated in **Table 4** to **Table 7** and shown in **Fig.2** to **Fig.7**

Caustic soda is a fresh water-based drilling fluid prepared with Trefawi PAL caused an increase in PV, YP, and AV. While in Bahr Al-Najaf PAL fresh water-based drilling fluids, the effect revealed a considerable difference. Where, due to montmorillonite (MMT) in Bahr Al-Najaf PAL (XRD analysis showed the presence of montmorillonite, palygorskite kaolinite, feldspar, quartz, and calcite) , low concentration of caustic soda caused a decrease in PV, YP, and AV. Poor dispersion (aggregation) of Bahr Al-Najaf PAL caused due to sodium cation. Then with 3 g of caustic soda, an increase in PV, YP, and AV was observed in **Table 4** and **Table 5**, where NaOH addition caused the reinforcing of palygorskite flocculation.

In Bahr Al-Najaf PAL and Trefawi PAL salt water-based drilling fluids, caustic soda with low concentration caused an increase in rheological properties due to flocculation of clay particles. Whilst with 3 g of caustic soda, the PV, YP, and AV decrease due to particle's aggregation, as shown in **Table 6** and **Table 7**.

Drilling fluids prepared with both types are instable with and without caustic soda except Bahr Al-Najaf PAL fresh water-based drilling fluid. Where the stability increased, and there is a 6.25 % enhancement, as shown in **Table4**. This instability also affects gel strength, where the readings are unacceptable.

The ratio of YP/PV is high at all Iraqi PAL drilling fluids with caustic soda according to the rheological requirement where this ratio should be a maximum of 1.5 **(API specification 13A, 2014).**

Adding caustic soda caused an increase in pH value to 10-10.7 with 0.5 and 1.0 g and to 11 with 2 and 3 g in Iraqi PAL fresh water-based drilling fluids, as illustrated in **Table 4** and **Table 5**. While in Iraqi PAL salt water-based drilling fluids, the pH values increased to 10.5 with 0.5 g caustic soda and 11 with 1 g and remained stable with the addition after that, as shown in **Table 6** and **Table 7**.

Table 4. Effect of caustic soda on the properties of Bahr Al-Najaf PAL fresh water-based drilling fluid.

NaOH Weight, g	AV, (cP)	PV, (cP)	YP, (lb/ 100ft²)	YP/PV	pH	ρ, (lb/ gal)	Gel Strength, (lb/100 ft²)		Stability %
							10 sec	10 min	
0	15.17	4.33	21.67	5	7.5	8.5	17.5	18.5	80
0.5	7.5	1.57	11.86	7.55	10.7	8.6	5.5	6	85
1	10	1	18	18	10.7	8.6	16	18.5	85
2	13.75	0.83	25.84	31.13	11	8.6	22	24	85
3	20	2.83	34.34	12.13	11.1	8.6	23	25	85

Table 5. Effect of caustic soda on the properties of Trefawi fresh water-based drilling fluid

NaOH Weight, g	AV, (cP)	PV, (cP)	YP, (lb/ 100ft²)	YP/PV	pH	ρ, (lb/ gal)	Gel Strength, (lb/100 ft²)		Stability %
							10 sec	10 min	
0	15.34	3.34	23.99	7.18	7.4	8.6	11.5	12	75
0.5	20	5.5	29	5.27	10	8.6	8	8.5	75
1	24	8	32	4	10.5	8.6	7	6	75
2	30	10.5	39	3.71	11	8.7	12	12	75
3	35	13	44	3.38	11	8.7	10	9	75

Table 6. Effect of caustic soda on the properties of Bahr Al-Najaf PAL salt water-based drilling fluid.

NaOH Weight, g	AV, (cP)	PV, (cP)	YP, (lb/ 100ft²)	YP/PV	pH	ρ, (lb/ gal)	Gel Strength, (lb/100 ft²)		Stability %
							10 sec	10 min	
0	12.65	5	15.3	3.1	6.6	9.5	9	11	80
0.5	19	5.34	27.14	5.08	10.5	9.5	16	16.5	80
1	21.5	6.2	30.6	4.93	11	9.6	15.5	16	80
2	23	5.8	34.4	5.93	11	9.6	15	15.5	80
3	18.75	5.5	26.5	4.82	11	9.6	14	14.5	80

Table 7. Effect of caustic soda on the properties of Trefawi PAL salt water-based drilling fluid.

NaOH Weight, g	AV, (cP)	PV, (cP)	YP, (lb/100ft²)	YP/PV	pH	ρ, (lb/gal)	Gel Strength, (lb/100 ft²)		Stability %
							10 sec	10 min	
0	12.34	4.34	15.99	3.68	6.5	9.5	7	7.7	80
0.5	15	4.25	21.5	5.05	10.5	9.6	7	7.5	80
1	16	4.5	23	5.11	11	9.6	7.5	8.5	80
2	18.3	3.67	29.26	7.97	11	9.6	8.5	9	80
з	18.5	5	27	5.4	11	9.65	9.5	8.5	80

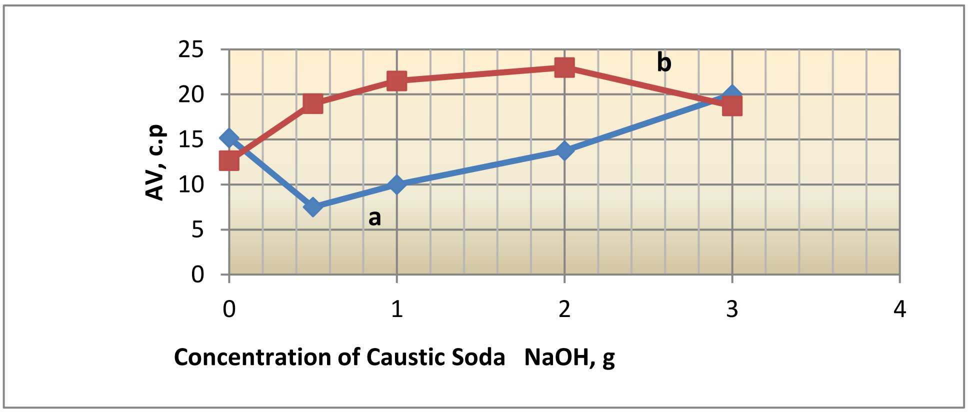

Figure 2. Effect of caustic soda on apparent viscosity for Bahr Al-Najaf PAl a- freshwater b-saltwater.

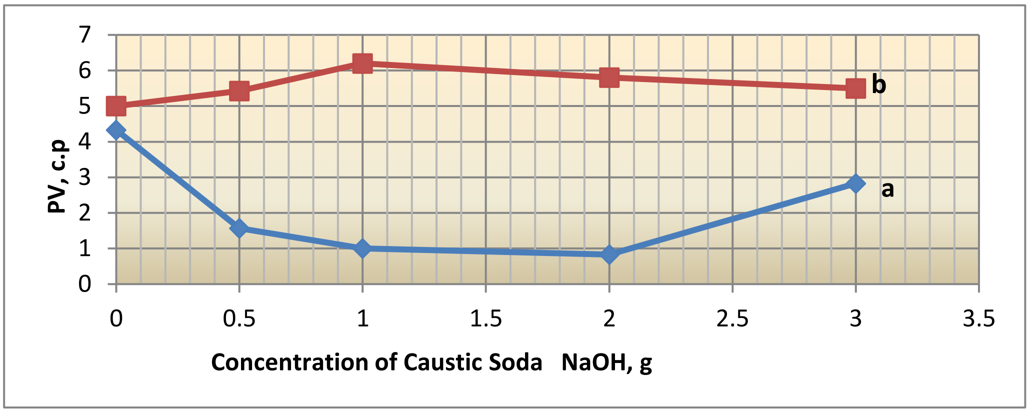

Figure 3. Effect of caustic soda on plastic viscosity for Bahr Al-Najaf PAL in a- freshwater b- saltwater.

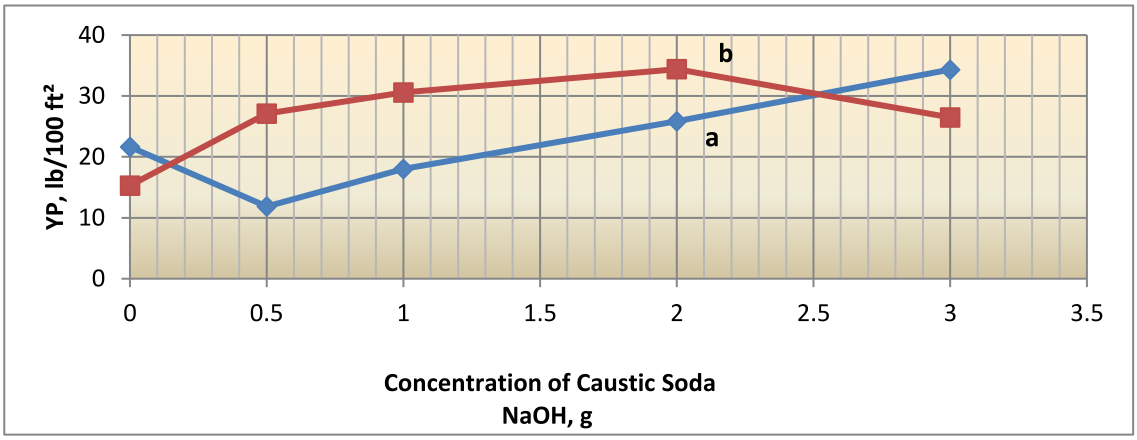

Figure 4. Effect of caustic soda on yield point for Bahr Al-Najaf PAL a- freshwater b- saltwater.

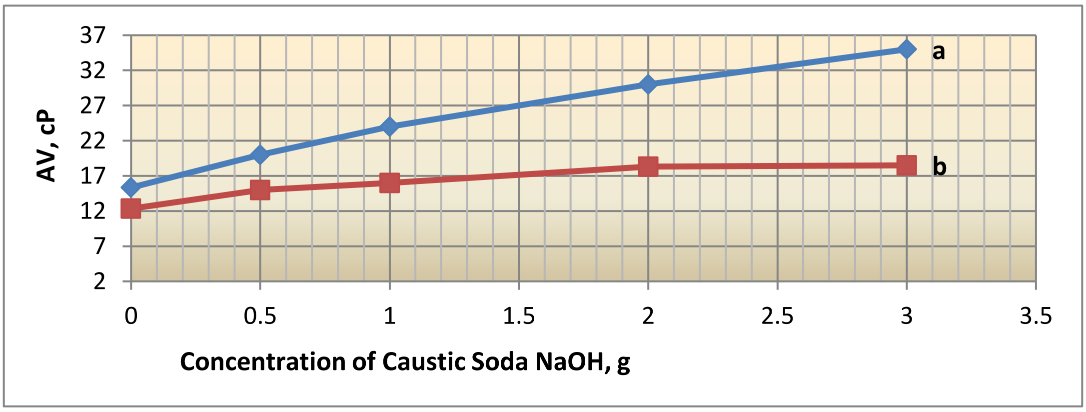

Figure 5. Effect of caustic soda on apparent viscosity for Trefawi PAL a- freshwater b- saltwater.

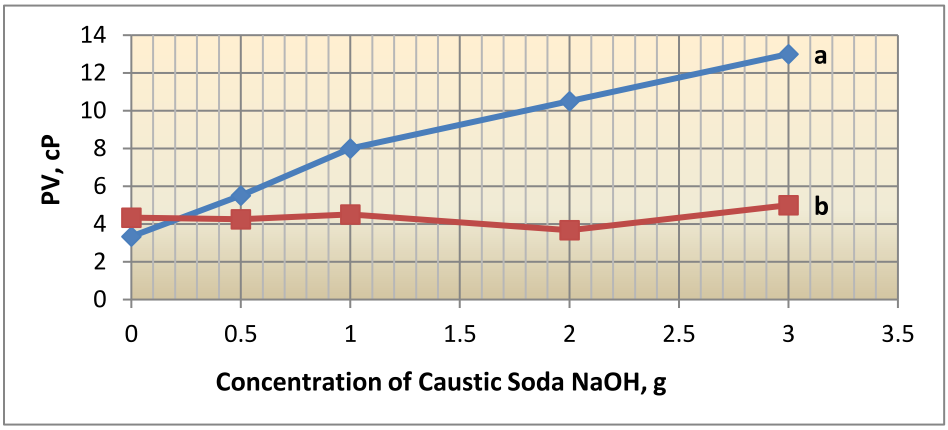

Figure 6. Effect of caustic soda on plastic viscosity for Trefawi PAL a- freshwater b-saltwater.

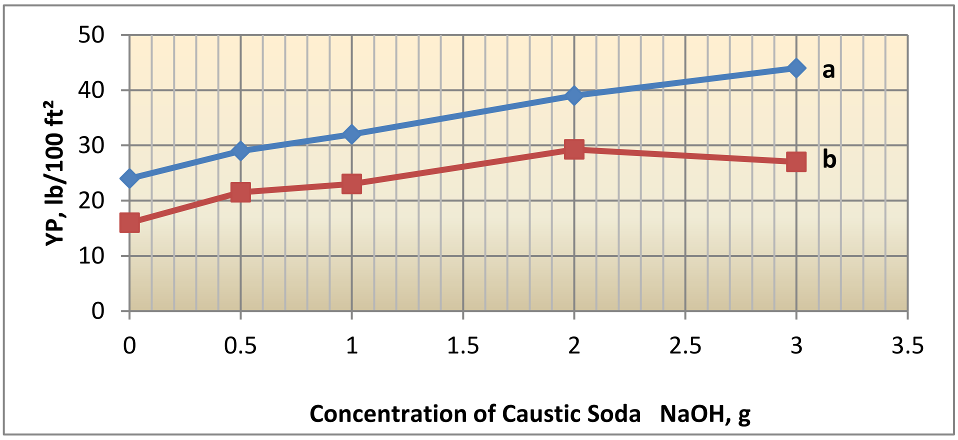

Figure 7. Effect of caustic soda on yield point for Trefawi PAL a-freshwater b-saltwat.

3.2 Rheological properties of Iraqi PAL with soda ash

The effect of soda ash on drilling fluid properties is illustrated in **Table 8** to **Table 11** and shown in **Fig.8** to **Fig. 13**

The rheological parameters, including AP, PV, YP, and gel strength of Bahr AL-Najaf PAL freshwater drilling fluid with different concentrations of soda ash, are illustrated in **Table 8**. These parameters decreased with increasing soda ash concentrations. This effect is due to the montmorillonite (MMT) clay in Bahr AL-Najaf PAL composition. While in Trefawi PAL freshwater drilling fluid, the addition of different concentrations of ash revealed a reverse effect, as shown in **Table 9.** Whereas soda ash concentration increases the rheological properties of Trefawi PAL freshwater drilling fluid that has significant readings with 0.8 and 1.0 g soda ash. An increase in rheological properties is due to the attractive electrostatic interaction between soda ash particles dispersed in the scaffolding structure with positive charges, and the palygorskite rods with negative charges had an impact on the inversion of palygorskite rods configuration (**Zhou, et al., 2015).**

Soda ash in salt water-based drilling fluids prepared with Iraqi PAL salt water-based drilling fluids caused a slight increase in PV, YP, AV, and gel strength, as described in **Table 10** and

Table 11. This is due to the high concentration of sodium cation (from NaCl and Na_2CO_3), which caused an aggregation to palygorskite particles.

In general, all types of drilling fluids with and without soda ash have high values of the YP/PV ratio according to the API specifications.

The stability of Bahr AL-Najaf PAL freshwater drilling fluids did not affect with soda ash concentration. While the stability of Trefawi PAL freshwater drilling fluids increased and there is 6.67 % and 20 % enhancement with 0.4 and 0.8 g soda ash concentration respectively as shown in **Table 8** and **Table 9**. Bahr AL-Najaf PAL salt water drilling fluids stability enhancement is 6.25 % with 1.0 g soda ash and remain the same stability with other concentrations. Also, the stability enhancement of Trefawi saltwater drilling fluids is 6.25 % with 0.6 g soda ash and maintains stability with the rest additions.

There is a significant effect of soda ash on the pH value of all types of drilling fluids prepared with Bahr AL-Najaf PAL. While the slight effect is observed in Trefawi PAL drilling fluids, unlike caustic soda (strong base), weak base soda ash has less effect on pH value.

Table 8. Effect of soda ash on the properties of Bahr Al-Najaf PAL fresh waterbased drilling fluid.

Weight of Na_2CO_3, g	AP, (cP)	PV, (cP)	YP, (lb/ 100ft²)	Yp/PV, (lb/100 ft²/cP)	pH	ρ, (lb/ gal)	Gel Strength (lb/100 ft²)		Stability %
							10 sec	10 min	
0	15.17	4.33	21.67	5.0	7.5	8.5	17.5	18.5	80
1	11.42	2.83	17.17	6.07	9	8.78	17	20	80
2	9.67	2.33	14.67	6.29	9	8.78	12.5	14	80
3	10	2	16	8	9	8.78	14.5	15.8	80
4	10	2.5	15	6	9	8.78	14	15	80

Table 9. Effect of soda ash on the properties of Trefawi PAL fresh waterbased drilling fluid.

Weight of Na_2CO_3, g	AP, (cP)	PV, (cP)	YP, (lb/ 100ft²)	Yp/PV, (lb/100 ft²/cP)	pH	ρ, (lb/ gal)	Gel Strength (lb/100 ft²)		Stability %
							10 sec	10 min	
0	15.34	3.34	23.99	7.18	7.4	8.6	11.5	12	75
0.4	19.33	4.17	30.33	7.27	7.4	8.7	18.5	19.5	80
0.6	22.75	4.83	35.84	7.42	7.5	8.7	20	20.5	80
0.8	70	4	136	68	7.5	8.75	36	43	90
1	80	3.5	155	62	7.7	8.8	90	96	90

Table 10. Effect of soda ash on the properties of Bahr Al-Najaf PAL salt waterbased drilling fluid.

Weight of Na_2CO_3, g	AV, (cP)	PV, (cP)	YP, (lb/ 100ft^2)	YP/PV	pH	ρ, (lb/ gal)	Gel Strength (lb/100 ft^2)		Stability %
							10 sec	10 min	
0	12.65	5	15.33	3.1	6.6	9.5	9	11	80
1	10.67	4	13.33	3.33	8	9.55	8	8.5	85
2	11	2.7	16.66	6.24	8	9.55	8.5	9	85
3	11.5	3.5	16	4.57	8	9.6	8.6	9	85
4	12	4	16	4	8	9.6	9	9.4	85

Table 11. Effect of soda ash on the properties of Trefawi PAL salt waterbased drilling fluid.

Weight of Na_2CO_3, g	AV, (cP)	PV, (cP)	YP, (lb/ 100ft^2)	YP/PV, (lb/100 ft^2/cP)	pH	ρ, (lb/ gal)	Gel Strength (lb/100 ft^2)		Stability %
							10 sec	10 min	
0	12.34	4.34	15.99	3.68	6.5	9.5	7	7.7	80
0.6	11	4	14	3.5	7	9.6	8	8.5	85
0.8	12	4.5	14	2.8	7	9.6	7	7.5	85
2	15.5	5	21	4.2	7.7	9.6	9	9.5	85
3	15.5	5	21	4.2	8	9.6	8.5	9	85

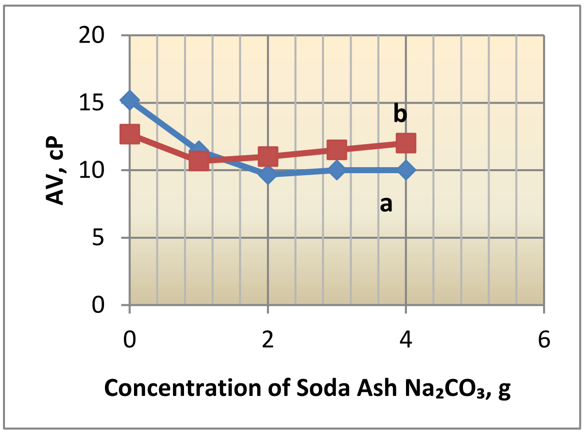

Figure 8. Effect of soda ash on apparent viscosity for Bahr Al-Najaf PAL a-fresh water b-saltwater.

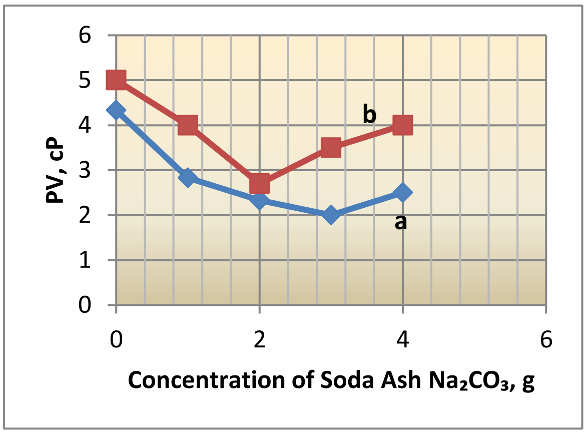

Figure 9. Effect of soda ash on plastic viscosity for Bahr Al-Najaf PAL a-freshwater b- saltwater.

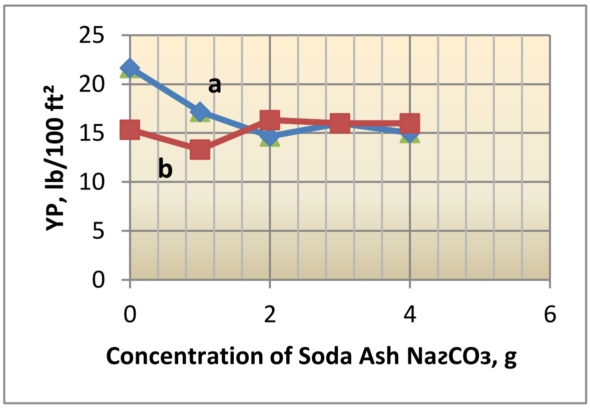

Figure 10. Effect of soda ash on yield point for Bahr Al-Najaf PAL a-freshwater b-saltwater.

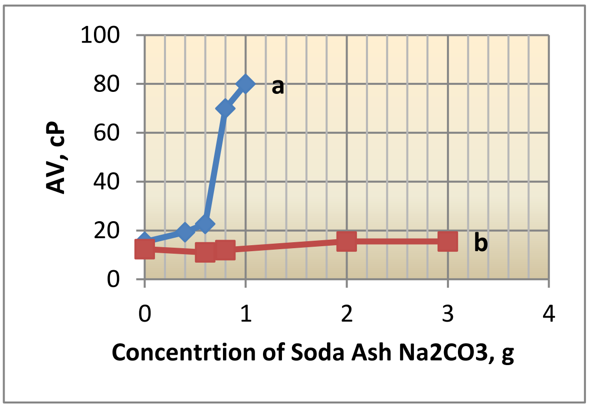

Figure 11. Effect of soda ash on apparent viscosity for Trefawi PAL a-freshwater b-saltwater.

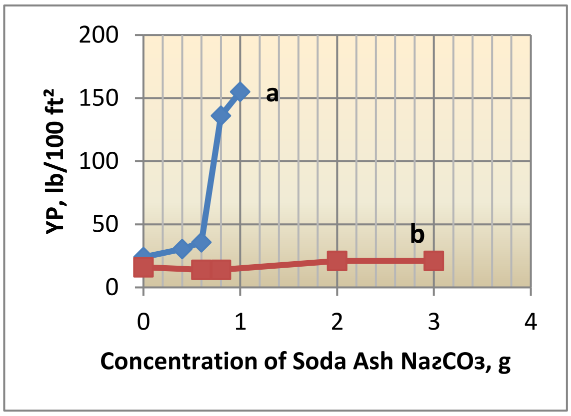

Figure 12. Effect of soda ash on plastic viscosity for Trefawi PAL a-freshwater b-saltwater.

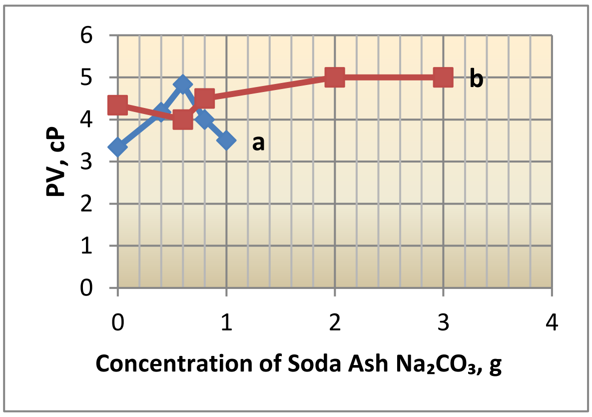

Figure 13. Effect of soda ash on yield point for Trefawi PAL a-fresh water b-saltwater.

4. CONCLUSIONS

- Palygorskite water-based drilling fluids had a low pH value. Adding caustic soda (NaOH) and soda ash (Na_2CO_3), which are strong and weak bases respectively, resulted in an enhancement in pH value and the ability of palygorskite dispersion in drilling fluid.
- Bahr Al-Najaf palygorskite was more affected by caustic soda than Trefawi palygorskite in both fresh and salt water-based drilling fluids while Trefawi palygorskite was more affected with low concentrations of soda ash than Bahr Al-Najaf palygorskite in both fresh and salt water-based drilling fluid.
- The stability of Bahr Al-Najaf PAL fresh water-based drilling fluid was enhanced with caustic soda, while Trefawi PAL fresh water-based drilling fluid stability was enhanced with soda ash. Both of Bahr Al-Najaf PAL and Trefawi PAL salt water-based drilling fluids stability were enhanced with soda ash to 80.

NOMENCLATURE

API= American Petroleum Institute
AV= apparent viscosity, cP
BOC= Basrah Oil Company
Iraqi PAL= Bahr AL-Najaf PAL and Trefawi PAL.
PAL= Palygorskite
PV= plastic viscosity, cP
XRD= X-Ray Diffraction
YP= Yield Point, lb/100ft²
ρ = Density, lb/gal

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