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Effect of Ferric Oxide and Magnesium Oxide Nanoparticles on Iraqi Bentonite Performance in Water Based Drilling Fluid

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Abstract. In oil and gas industry, the nanotechnology has been applied in different fields. Reservoir, exploration, drilling, completion, production, processing, and refinery are nanotechnology applications fields. Nanoparticles materials are one of the areas that are utilized in preparing drilling fluids. These nanomaterials are used to formulate high performance drilling fluids. In other words, these nano particles materials can be used to design smart drilling fluids. The properties of these drilling fluids can be met the well conditions requirements. The aim of this study is to enhance the performance of Iraqi bentonite in drilling fluids using nanomaterials. Iraqi calcium montmorillonite clay (Ca- bentonite) from Wadi Bashera in Iraqi Western Desert was obtained and studied in order to use it as an alternative active solid to the imported commercial bentonite. Water based drilling fluids were prepared with 3, 6, and 12 wt. % of Iraqi bentonite. Mgnesium oxide nanoparticles (MgO NPs) and ferric oxide nanoparticles (Fe_2O_3 NPs) with different concentrations were used. The experimental work showed that, MgO NPs resulted in a significant increase in the rheological properties of drilling fluids prepared with 3 and 6 wt. % of Iraqi bentonite. In contrast, moderate effect on the rheological properties of drilling fluid prepared with 12 wt. % of Iraqi bentonite were obtained with low concentrations of Fe_2O_3 NPs. Basically drilling fluids prepared with Iraqi bentonite had extreme filtrate volume compared with API specifications and poor controlling to filtration properties were obtained with MgO NPs and Fe_2O_3 NPs additions. The impact of these two nanomaterials was revealed on the stability of drilling fluids prepared with Iraqi bentonite, where an enhancement from 65 % to 100% was observed.

Keywords— Calcium montmorillonite, Iraqi bentonite, Magnesium Oxide Nanoparticles, Ferric Oxide Nanoparticles, Rheological and Filtration properties.

1. Introduction

Nanotechnology is defined as any technology that is applied at the nano scale dimension (1-100 nm). As the particle size shrinks, the larger portion of it is exposed. Therfore the surface area increases and available to interact with other surfaces. Nanoparticles materials have unique characteristic, physical and chemical properties. Thus the drilling fluid properties can be improved. Rheological and filtration properties can be improved by nanomaterials. Besides, wellbore and shale stabilization, wellbore strengthening, cuttings suspension and thermal properties can be enhanced. Nanomaterials are environmentally friendly compared to conventional materials. Nano particles materials are eco-friendly due to their small amount additions in drilling fluid. Due to their small size (1-100 nm) the attractive forces between the particles increases. Thus the viscosity or thickening of drilling fluid increases. Also, due to high interaction between particles causes strong bonds. Therefore, the drilling fluid can be withstood high pressure and high temperature conditions [10],[3]. The applications of nanotechnology in drilling fluid are; fluid loss control and wellbore stability, bit balling, torque and drag, removal of toxic gases, high temperature and high pressure challenges, and increase downhole tools [2].

Several studies and investigations on the performance of commercial Ca-bentonite in drilling fluid or upgrading it with different nanomaterials addition were published. Water based drilling fluid was developed using nanographite and nano-silicon wires. An enhancement was observed on both rheological and filtration properties when nanomaterials were added to the water based drilling fluid which can be applied in deep wells where elevated temperatures and pressures were quite common [7]. Multi-walled carbon nanotubes (MWCNTs) with different concentrations were used and a slight effect was observed in the rheological properties of water based and ester based drilling fluids at various temperatures [4]. Nanoclay with different concentrations in water based drilling fluids at different temperature was used to enhance the rheological and filtration properties [1]. An enhancement on the rheological and filtration properties at low pressure and low temperature was observed with silica dioxide nanoparticles addition [9]. Magnesium oxide MgO NP, titanium dioxide TiO_2 NP and graphene NP were added to study their effect on the rheological and filtration properties. Results showed that, MgO NP resulted in best enhancement in the rheological and filtration properties compared with TiO2 NP and Graphene NP [6]. Significant improvements in the rheological and hydraulics properties of the flocculated water-based drilling fluid treated by nanosilica, nanotitanium, and nanoaluminum were obtained. The ability of nanosilica and nanotitanium to reduce the filtration volume was observed but no filtration reduction based on nanoaluminum [8].

In this study Iraqi bentonite was used to prepare water based drilling fluid. The effect of Mgnesium oxide nanoparticles (MgO NPs) and ferric oxide nanoparticles (Fe_2O_3 NPs) with different concentrations on the performance of Iraqi bentonite was studied.

2. Experimental Work

2.1 *Materials*

2.1.1 *Iraqi bentonite*

Iraqi raw bentonite was supplied as rock from Wadi Bashera in Iraqi Western Desert by Iraq Geological Survey (GEOSURV- IRAQ). It needs to be grinded and the impurities, minerals, and compounds that adversely effect on the bentonite grade to be decanted. Processing raw bentonite included, drying, grinding and sieving (using 200 mesh screen). The receiving from 200 mesh screen was used to prepare drilling fluids in this study.

2.1.2 *Nanomaterials additives*

Two types of nanomaterials additives, magnesium oxide nanoparticles (MgO NPs , which is white powder, very slightly soluble in water, and 50nm size) and ferric oxide nanoparticles (Fe2O3 NPs , which is nutty to red powder, insoluble, and 50nm size) were used to study their impact on the performance of Iraqi bentonite in water based drilling fluid.

2.2 *Preparing drilling fluids*

Drilling fluid preparation comprises of two steps as described below:

Preparing reference drilling fluid as follows:

1. Add the required quantity of Iraqi bentonite to tap water as required and mix for 10 minutes. Then add 0.2 g NaOH and mix for 20 minutes.

2. The mixture is aged for 24 hours to allow the colloids time to hydrate. After that the fresh water based drilling fluid is ready to be tested.

Preparing drilling fluid with nanomaterials, the following procedure has been followed:

1. First add the required quantity of nanomaterial to tap water as required and mix for 2 minutes. Second, add the required quantity of Iraqi bentonite and mix for 10 minutes. Then add 0.2 g NaOH and mix for 20 minutes. Then, use ultrasonic device for 10 minutes to ensure good dispersion of nanomaterial.

2. The mixture is aged for 24 hours to allow the colloids time to hydrate. Then the fresh water based drilling fluid is ready to be tested.

3. Results and Discussion

3.1 *Effect of MgO NPs*

Magnesium oxide nanoparticles with different concentrations were added to fresh water based drilling fluid prepared with 3 wt. % of Iraqi bentonite and 0.2 g NaOH. The drilling fluid properties are illustrated in Table 1 and shown in Fig. 1.

Instable rheological parameters were obtained with MgO NPs concentrations less than 0.5 g. While with concentrations more than 0.5 g, a stable increase in rheological parameters were observed. MgO NPs with 0.9 g resulted in a significant increase in viscosity. The values of AV, PV, and YP were increased by 347.82, 354.22, and 345.32 % respectively compared with the reference formula (3 wt. % and 0.2 g NaOH fresh water based drilling fluid). MgO NP in drilling fluid causes an increase in viscosity due to the clay platelets can come closer to one another and tendency to flocculate will be greater with nanoparticles addition [5].Also, the effect of MgO NPs on the properties of 6 wt. % Iraqi fresh water based drilling fluid was studied as illustrated in Table 2 and shown Fig.2. The apparent viscosity and yield point were enhanced with 0.6 g MgO NPs unlike 10 sec / 10 min gel strength have less values and YP/PV ratio have unconvincing values. Slight increase in the properties with 0.9 g MgO NPs was observed, therefore it is better to add 0.6 g MgO NPs. Nano additives with high surface to volume ratio such as MgO NPs provide significant control of drilling fluid rheological properties.

Low concentration of MgO NPs resulted in an enhancement in the stability of the reference drilling fluid (with 3 wt. %Iraqi bentonite) from 65 to 100% as shown in Table 1. The referenc drilling fluid with 6 wt. % Iraqi basically has high stability of 98 % as shown in Table 2.

As mentioned earlier, nano additives with high surface to volume ratio such as MgO NPs provide significant control of drilling fluid rheological properties. This statement can be specified by the range of addition concentrations, where the impact of this material started with 0.2 g up to 0.9 g (Table 2). In contrast MgO NPs effect on the filtration properties of 6 wt. % Iraqi bentonite and 0.2 g NaOH fresh water based drilling fluid was inconspicuous as shown in Table 3. Adding 0.2 MgO NPs resulted in 30.77 % reduction in filtrate volume, while this addition caused a decrease in the rheological properties (Table 2 and Table 3). In contrast 0.5 g MgO NPs addition has opposite effect, where it resulted in an increase in the filtration properties. Adding 0.5, 0.6, and 1.5 g MgO NPs to 3 wt. % Iraqi bentonite and 0.2 g NaOH fresh water based drilling fluid caused debatable results as illustrated in Table 4. Fairly stable filtrate volumes were observed with 0.5 and 0.6 g MgO NPs except 1.5 g MgO NPs resulted in significant increase in filtrate volume.

3.2 *Effect of Fe_2O_3 NPs*

The effect of adding Fe2O3 NPs on the reference drilling fluid (12 wt. % fresh water based drilling fluid) properties was studied and the results are illustrated in Table 5 and shown in Fig. 3. Adding Fe_2O_3 NPs with 0.03 g concentration caused an increase in the apparent viscosity and yield point by 26.66% and 45.20% respectively. Increasing Fe_2O_3 NPs concentration showed instable rheological parameters. So, the addition of Fe_2O_3 NPs at low concentration leads to an effective linking with the bentonite particles and greater tendency to flocculate occurred. Also, the stability of the base fluid improved from 65% to 100% with low concentration of Fe_2O_3 NPs.

Formulate reference drilling fluid with less weight percent Iraqi bentonite weight percent (6 wt. %) and study the effect of Fe_2O_3 NPs with different concentrations on the properties of reference fluid are shown Table 6 and Fig. 4. Slight increase in the rheological parameters was observed with all Fe_2O_3 NPs concentrations. Basically reference drilling fluid has low rheological parameters. In contrast a significant impact of Fe_2O_3 NPs on the reference fluid stability which was improved to 100 % with low concentration of 0.01 g/350 cc fresh water.

API fluid loss tests were performed to12 wt. % Iraqi bentonite fresh water based drilling fluid only, because this type of nano material did not affect on 6 wt. % Iraqi fresh water drilling fluids. Fe_2O_3 NPs impact on the filtration properties of 12 wt. % reference drilling fluid is illustrated in Table 7. An enhancement in the rheological properties was observed up to 0.03 g Fe_2O_3 NPs addition (Table 5) therefor Fe_2O_3 NPs additions with 0.03, 0.4, and 0.7 g were selected to implement filtration test. As shown in Table 7, adding Fe_2O_3 NPs resulted in an increase in filtrate volume, while mud cake thickness remained within the range of 2-4 mm.

Table 1: Effect of MgO NPs on 3 wt. % Iraqi bentonite and 0.2g NaOH fresh water based drilling fluid

MgO NP Weight g/350cc Fresh Water	Rheological Properties						pH	Density ppg	Stability %
	AV cp	PV cp	YP $lb_f/100\ ft^2$	YP/PV	Gel Strength $lb_f/100ft^2$ 10 sec	Gel Strength $lb_f/100ft^2$ 10 min			
0	12.17	3.67	16.99	4.63	15.5	27	12	8.41	65
0.01	8.17	3	10.33	3.44	7	10	9.5	8.50	100
0.05	4.67	2	5.33	2.66	4	5	9.5	8.50	100
0.08	8.83	3	11.66	3.88	9	10	9.5	8.50	100
0.1	9.33	3.33	12	3.60	10	10.5	9.5	8.50	100
0.2	12	3	18	6	17	19	9.5	8.40	100
0.5	15	2	26	13	16	13	9.5	8.41	100
0.6	20	2	36	18	9	9.5	9.5	8.35	100

0.9	54.5	16.67	75.66	4.538	16	18	9.5	8.40	100
1	43.42	13.33	60.17	4.51	13	14	9.5	8.50	100
1.5	33	8.67	48.66	5.61	11	11.5	9.5	8.50	100

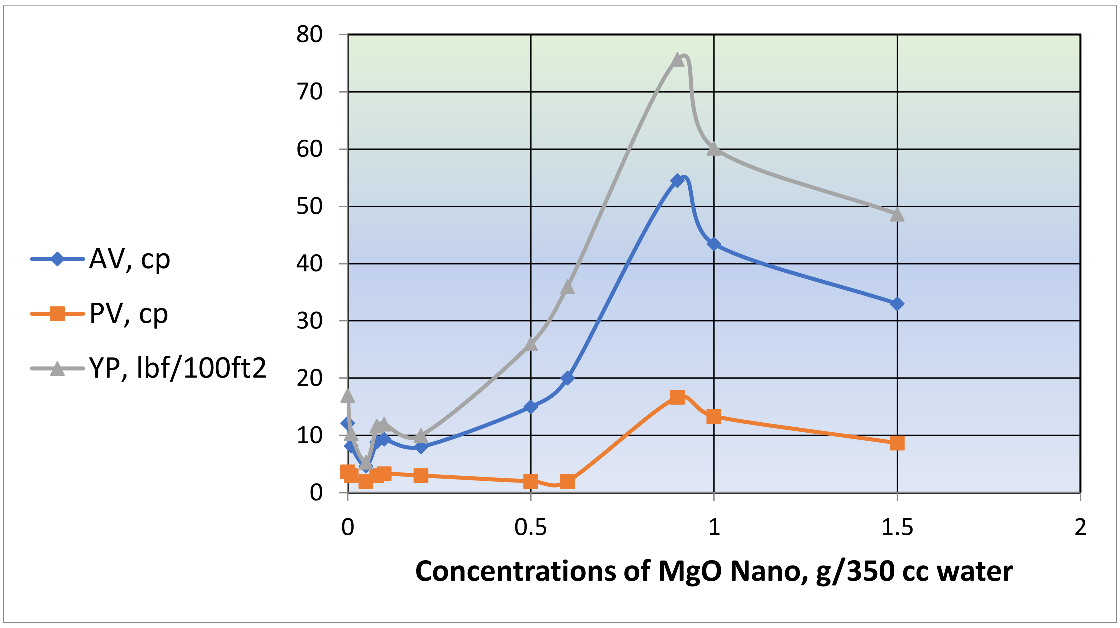

Figure 1 : Effect of MgO NPs on the apparent viscosity, the plastic viscosity, and yield point on 3 wt. % Iraqi bentonite and 0.2 g NaOH water based drilling fluid

Table 2: Effect of MgO NPs on 6 wt. % Iraqi bentonite and 0.2 g NaOH fresh water based drilling fluid

MgO NP Weight g/350cc Fresh Water	Rheological Properties						pH	Density ppg	Stability %
	AV cp	PV cp	YP $lb_f/100ft^2$	YP/PV	Gel Strength $lb_f/100ft^2$ 10 sec	Gel Strength $lb_f/100ft^2$ 10 min			
0.0	42	2	80	40	73	76	12	8.50	98
0.2	23.25	2	42.5	21.25	31.5	32.5	10	8.55	98
0.5	38.25	4	68.5	17.125	40.5	41	10.8	8.55	98
0.6	50.12	3	94.25	31.41	49.5	50	10.8	8.55	98
0.9	52.75	5	95.5	19.1	50.5	51	10.8	8.55	98

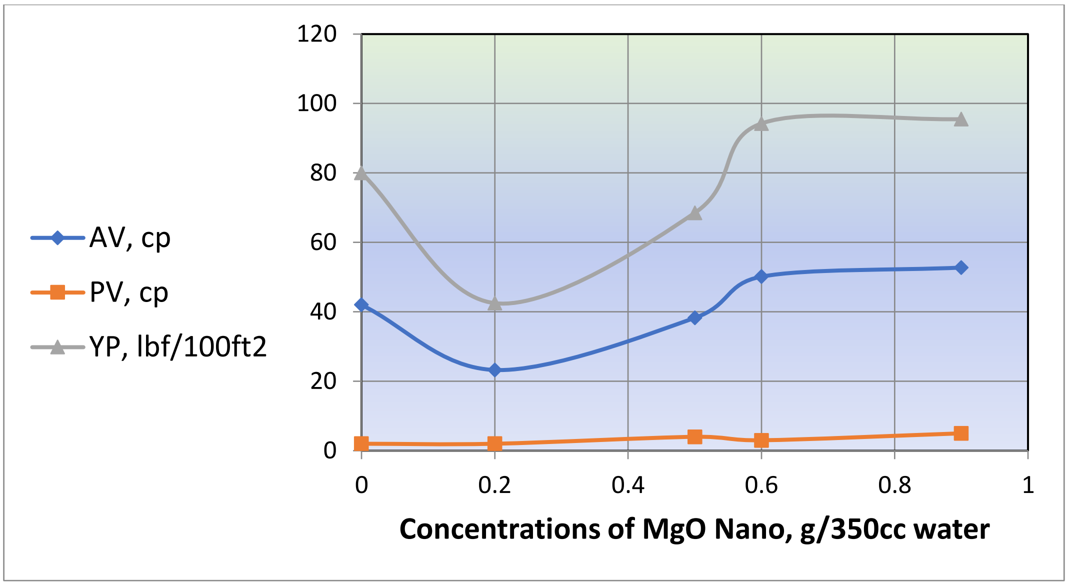

Figure 2: Effect of MgO NPs on the apparent viscosity, the plastic viscosity, and yield point on 6 wt. % Iraqi bentonite and 0.2 g NaOH water based drilling fluid

Table 3: Filtration properties of 6 wt. % Iraqi bentonite and 0.2 g NaOH fresh water based drilling fluid with MgO NPs

Addition States	, ml$V_{7.5}$	, mlV_{30}	, mmt_{mc}
Reference(6 wt.% Iraqi Bentonite + 0.2 g NaOH+Fresh water)	13	26	2
Reference +0.2 g MgO NPs	9	18	2
Reference +0.5 g MgO NPs	18	36	3

Table 4: Filtration properties of 3 wt. % Iraqi bentonite and 0.2 g NaOH fresh water based drilling fluid with MgO NPs

Addition States	, ml$V_{7.5}$	, mlV_{30}	, mmt_{mc}
Reference (3 wt.% Iraqi Bentonite + 0.2 g NaOH+fresh water)	18	36	2
Reference+0.5 g MgO NPs	16	32	2
Reference+0.6 g MgO NPs	19	38	1
Reference+1.5 g MgO NPs	39	78	4

Table 5: Effect of Fe_2O_3 NPs on 12 wt. % Iraqi bentonite fresh water based drilling fluid

Fe_2O_3 NPs Weight g/350cc Fresh Water	Rheological Properties						pH	Density ppg	Stability %
	AV cp	PV cp	YP $lb_f/100\ ft^2$	YP/PV	Gel Strength $lb_f/100ft^2$				
					10 sec	10 min			
0.0	15	4.67	20.66	4.42	16.67	29	8	8.70	65
0.01	17.5	4	27	6.75	24	25	8	8.89	100
0.02	18.17	3.33	29.67	8.90	25	26	8	8.89	100
0.03	19	4	30	7.5	26	26.5	8	8.80	100
0.04	18.17	4	28.33	7.08	24.5	25	8	8.89	100
0.05	17	4	26	6.5	22	24	8	8.81	100
0.1	17.17	4	26.33	6.58	23.5	24	8	8.87	100
0.2	17.58	4.83	25.5	5.27	23.5	26	8	8.88	100
0.3	17.58	5.17	24.83	4.80	23.5	29	8	8.88	100
0.4	18	4	28	7	24.5	29.5	8	8.85	100
0.5	17.5	5	25	5	23	25	8	8.88	100
0.55	18.5	4	29	7.25	24.5	25	8	8.89	100
0.6	18.16	4	28.33	7.08	24	26	8	8.90	100
0.7	18.5	4	29	7.25	23.5	24	8	8.90	100

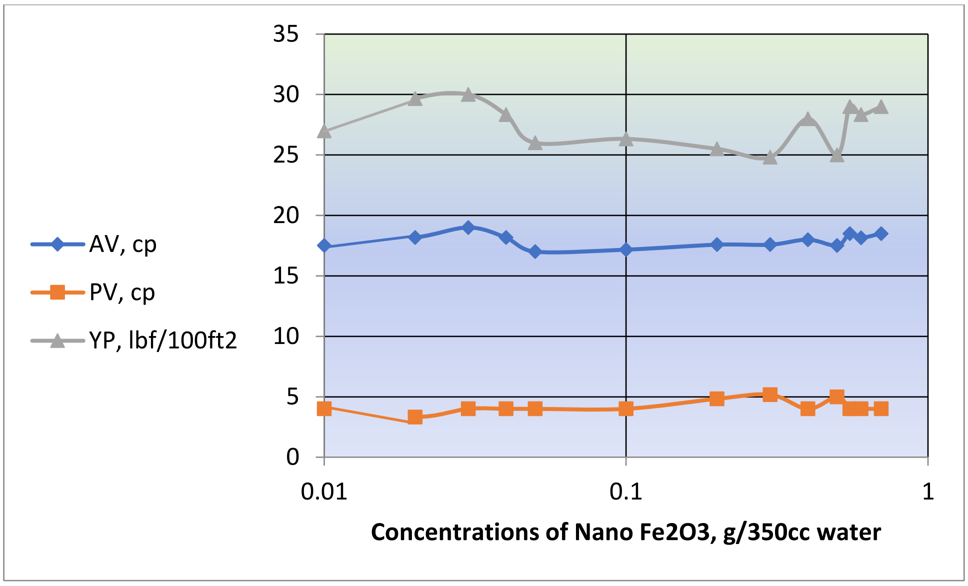

Figure 3: Effect of Fe2O3 NPs on the apparent viscosity, the plastic viscosity, and yield point on 12 wt. % Iraqi bentonite fresh water based drilling fluid

Table 6: Effect of Fe_2O_3NP on 6 wt. % Iraqi bentonite fresh water based drilling fluid.

Nano Fe2O3 Weight g/350cc Fresh Water	Rheological Properties						pH	Density ppg	Stability %
	AV cp	PV cp	YP $lb_f/100\ ft^2$	YP/PV	Gel Strength $lb_f/100ft^2$ 10 sec	Gel Strength $lb_f/100ft^2$ 10 min			
0.0	3	1	4	4	2	2.5	8	8.60	65
0.01	4.5	1.5	6	4	4.5	7	8	8.60	100
0.04	4.75	2	5.5	2.75	4.5	8	8	8.61	100
0.05	5	2	6	3	4.5	8.5	8	8.62	100
0.7	5	2	6	3	4.5	9	8	8.62	100

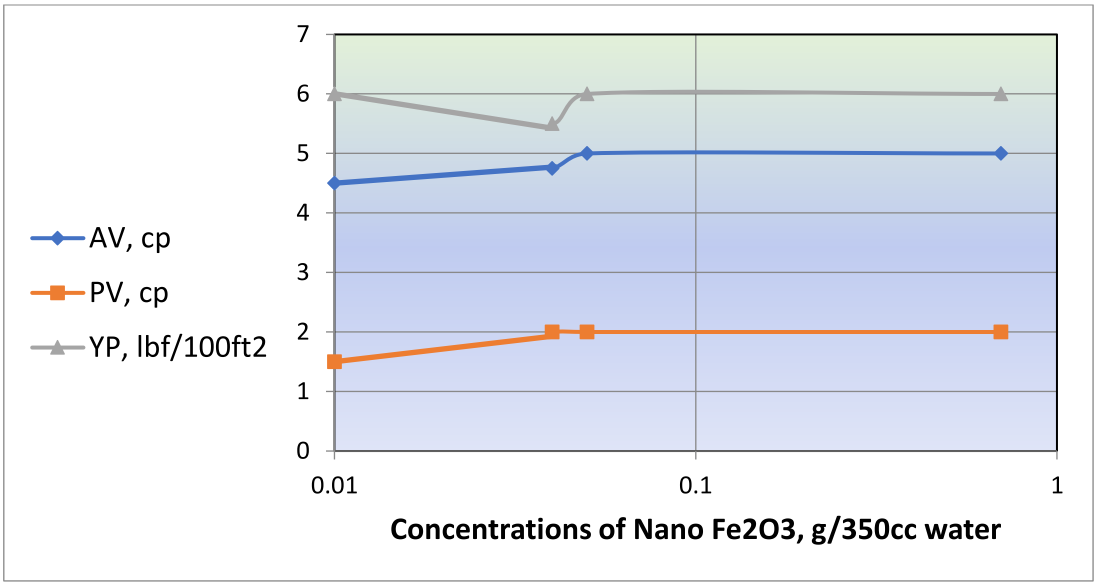

Figure 4: Effect of Fe_2O_3 NPs on the apparent viscosity, the plastic viscosity, and yield point on 6 wt. % Iraqi bentonite fresh water based drilling fluid

Table 7: Filtration properties of 12 wt. % Iraqi bentonite fresh water based drilling fluid with Fe_2O_3 NPs

Addition States	, ml$\boldsymbol{V_{7.5}}$	, ml$\boldsymbol{V_{30}}$	, mm$\boldsymbol{t_{mc}}$
Reference (12 wt.% Iraqi Bentonite +0.2 g NaOH + Fresh water)	20	40	4
Reference + 0.03 g Fe_2O_3 NPs	22	44	2
Reference + 0.4 g Fe_2O_3 NPs	22	44	3
Reference + 0.7 g Fe_2O_3 NPs	23	46	4

4. Conclusions

Based on the experimental work and results, the following conclusions are recapitulated:

1. MgO NPs resulted in significant increase in the rheological properties of fresh water based drilling fluid prepared with 6 wt. % Iraqi bentonite. The concentration of MgO NPs that impacts these properties depends on the weight percent of Iraqi bentonite in drilling fluid.
2. Low concentrations of Fe_2O_3 NPs resulted in moderate effect on the rheological properties of 12 wt. % Iraqi bentonite fresh water based drilling fluid. While with high Fe_2O_3 NPs concentrations, instable values of rheological parameters were resulted.

3. The stability of all drilling fluids prepared with Iraqi bentonite was enhanced to 100% with MgO NPs and Fe_2O_3 NPs.
4. Adding MgO NPs and Fe_2O_3 NPs resulted in poor controlling to the filtration properties (high filtrate volume), therefore it is recommended to add fluid loss control additives with them.

Acknowledgement

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Nomenclature

API	American Petroleum Institute
AV	Apparent viscosity (cp)
PV	Plastic viscosity (cp)
t_{mc}	Thickness of mud cake (mm)
$V_{7.5}$	Filtrate volume after 7.5 minute (ml)
V_{30}	Filtrate volume after 30 minute (ml)
YP	Yield Point ($Ib_f/100ft^2$)

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تأثير اوكسيد الحديديك النانوي واوكسيد المغنيسيوم النانوي على اداء البنتونايت العراقي في موائع الحفر مائية القاعدة

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الخلاصة – تطبق تقنية النانو في مجالات مختلف في الصناعة النفطية, حيث يتم تطبيقها في المكامن, الاستكشاف, الحفر, الاكمال, الانتاج, و التصفية. تستخدم المواد النانوية لتحسين اداء موائع الحفر, بتعبير اخر تستخدم المواد النانوية في تصميم ما يطلق عليه Smart drilling fluids والتي تحقق ما تتطلبه ظروف البئر. الهدف من هذه الدراسة هو تحسين ادائية البنتونايت العراقي في موائع الحفر باستخدام المواد النانوية. حيث تم استخدام الصلصال العراقي نوع المونتموريلونايت الكالسيومي (البنتونايت الكالسيومي) المستخرج من وادي بشيرة في الصحراء الغربية-العراق لغرض دراسته واستخدامه كبديل للصلصال المستورد التجاري. تم تحضير موائع حفر مائية القاعدة بتراكيز مختلفة من البنتونايت العراقي (3, 6, و 12 نسبة مئوية وزنية) واضيف لها بتراكيز مختلفة من اوكسيد المغنيسيوم النانوي MgO NPs و اوكسيد الحديديك النانوي Fe_2O_3 NPs . النتائج المختبرية بينت ان اوكسيد المغنيسيوم النانوي له تأثير كبير على الخواص الريولوجية المحضرة من 3 و 6 نسبة مئوية وزنية من البنتونايت العراقي. بينما لوحظ التأثير المتوسط لأوكسيد الحديديك النانوي على الخواص الريولوجية للموائع المحضرة فقط من 12 نسبة مئوية وزنية من البنتونايت العراقي. ان الموائع المحضرة من البنتونايت العراقي هي اصلا لها خواص ترشيح ضعيفة (حجم راشح عالي) مقارنة بالمواصفات المطلوبة من قبل معهد البترول الامريكي API و اضافة المواد النانوية اعلاه لم تتمكن من السيطرة على الترشيح العالي لهذه الموائع. ان تأثير اضافة هذه المواد النانوية وبتراكيز قليلة على استقرارية جميع الموائع المحضرة من البنتونايت العراقي كان واضحا جدا و مؤثرا , حيث رفعت الاستقراية من 65 % الى 100%.

الكلمات الرئيسية –" المونتموريلونايت الكالسيومي،البنتونايت العراقي،اوكسيد المغنيسيوم النانوي،اوكسيد الحديديك النانوي،الخواص الريولوجية و خواص الترشيح ".