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Design and evaluation of advanced nanocomposite drilling fluid systems through marl-based lithologies: A study based on outcrop samples from Kurdistan

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Abstract

Swelling is recurring challenges, which can lead to formation damage and compromising the wellbore integrity. Synergizing nanomaterials with their distinctive properties, alongside cost-effective materials, can provide a significant approach in enhancing the treatment of wellbore stability. This study employs a green, simple, and economical approach for the biosynthesis of SiO_2/KCl/Xanthan nanocomposites (NCs), aimed at reducing swelling and improving the rheological and filtration properties of Water-Based Drilling Fluids (WBDFs). The impact of SiO_2/KCl/Xanthan nanocomposite on swelling was assessed, followed by a comprehensive investigation into fluid's filtration and rheological properties, including apparent viscosity, plastic viscosity, yield point, gel strength, and filter cake thickness. The results confirmed that the green-synthesized NCs effectively reduced clay swelling by approximately 22.2%. Furthermore, they significantly improved the mud's rheological characteristics, decreasing filter cake thickness and fluid loss by approximately 91.29% and 91.7%, respectively, under HPHT conditions. The findings strongly suggest that SiO_2/KCl/Xanthan NC is an effective additive for mitigating clay swelling, enhancing rheology, and reducing filtration challenges in marl rich formation.

Keywords: *Nanotechnology; Drilling Engineering; Marl-Rich Formation; Swelling, Rheological and Filtration.*

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1- Introduction

Maintaining a borehole with high stability to marl formations is regarded as one of the primary issues in the oil and gas industry [1-2]. Borehole instability accounts for around 90% of such troubles [3]. In this regard, the adoption of innovative technologies is essential to preserve wellbore stability in marl formations. Technology enhancements lead to minimizing both time and economic losses [21]. Throughout the drilling process in the oil industry, numerous troubles are encountered, for example, the issue of WBM in marl formation often causes wellbore instability due to swelling issues, water absorption, and sloughing. The basic component of marl is clays such as smectite, illite, montmorillonite, calcite, and kaolinite, which are highly reactive when exposed to water, leading to hydration and affects the wellbore stability [4]. Marl formations are highly problematic formations in the Kurdistan region, presenting significant challenges in maintaining wellbore stability [5]. Wellbore instability is a major source of difficulties, resulting in significant costs and delays in drilling operations [6].

While OBMs offer superior stability, lubrication, and temperature resilience [7], environmental regulations often restrict their use, necessitating the development of high performance, environmentally friendly WBMs [4]. Stability in marl is associated with osmotic pressure and pore throat plugging, minimizing filtrate invasion is critical [8]. In this case, wellbore stability of the steadiness is attained by dealing with relevant additives in mud to maintain a suitable osmotic force [9]. In such circumstances, there is a need to gain new technology. According to Pang et al. [10], nanotechnology-based drilling fluid enables the proper design and development of new drilling fluid to keep a sufficient operation with considerably low cost and in an environmentally friendly manner. Nanotechnology, which was first introduced around half a century ago, is now recognized as a leading area of research globally [11, 22]. Currently, nanotechnology is widely relied upon in the oil and gas industry, being considered one of the most operative methods for designing optimal DF systems for oil and gas fields [12, 24].

Nanotechnology offers excellent potential for advancement in industry and particularly in solving the various problems in the field [13, 23]. For instance, the incorporation of nanomaterials helps keep geological formation stability, maintains environmental compatibility, as well as tolerates wellbore pressure, advances thermal stability, and improves filtration and rheological properties [13, 25]. Additionally, Sensoy et al. [14] reveal that the primary causes of wellbore instability are swelling, mud absorption and sloughing of the

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borehole. For this reason, to mitigate filtrate invasion, the most effective strategy is to isolate exposed pore throats of the marl [15]. According to Sensoy et al. [14], employing nanofluids to mitigate water inflow to marl while maintaining appropriate water-based mud can address matters with marl wellbore stability. Some nanoparticles can sustain a great challenge to provide higher stability to the well and improve rheological properties [16]. Therefore, Mao et al. [17] emphasize that incorporating nano silica into water-based mud significantly enhances wellbore stability and rheological properties. Similarly, Ji et al. [18] confirmed that the use of NWBM effectively reduces marl-related issues during drilling. For example, Kang et al. [15] pointed out that the incorporation of Nano-silica at a concentration of % 5% by weight mitigates the fluid invasion by % 42.8% compared to the reference drilling fluid, while a concentration of 10% by weight attains a reduction of 68%. Javeri et al. [19] discovered that the use of silica NPs mitigated filtrate volume by approximately % 35%, when applied at a concentration of 3% by weight, with particle sizes ranging from 40 nm to 130 nm. More recently, WBM has gained traction in drilling operations, as stated by Yu et al. [20].

Recent studies, such as those conducted on Nahr Umr formation tested three different DF systems: WBM, KCL mud, and salt mud; among these, KCl-polymer mud showed the optimum performance, reducing the swelling ratio by approximately 36%. And the salt drilling fluid achieved a % 24% reduction in the swelling ratio, and Gel-polymer DF reduced it by % 22%. These swelling ratios reveal that all three DFs are essential to achieve an improved, stable wellbore. The primary aim of this project is to advance an optimal WBM incorporating nanocomposites to ensure high borehole stability in marl formations. The proposed WBM is to deliver the performance of OBM while being a more cost-effective and environmentally friendly alternative. And the novelty of this research is utilizing SiO_2/KCl/Xanthan Nanocomposite drilling fluids to maintain the borehole of the marl formations. This approach mitigates clay swelling, improves rheological and filtration properties, and enhances stability under high-pressure and high-temperature conditions, effectively minimizing time, and economic losses.

2- Materials and methods

2.1. Materials

Purified chemicals have been sourced from chemical companies, with standard-quality water and bentonite used. Tests and analyses were carried out at Petrochem Drilling Fluid Company and Soran University Scientific Research Centre, as well as the base drilling fluid materials, including bentonite, caustic soda, soda ash, and the chemical additives of the drilling fluids, which were supplied by Petrochem Performance Chemicals Ltd. Sodium silicate was bought from the Sigma-Aldrich Company. For the swelling test, marl plugs were prepared in a compactor cell; the outcrop samples were acquired from an outcrop of the marl clay Formation in the southwest of Harir-Erbil. Then, a linear swell meter was utilized to illustrate the swelling ratio of each designed mud system. The analyzed outcrop sample of marl consists primarily of high amounts of montmorillonite (54%), which represents a dominant clay content, along with zeolite (17%), calcite (17%), lizardite (9%), and a minor amount of quartz (3%).

Fig. 1 shows the schematic representation of the experimental workflow for nanocomposite drilling fluid preparation and evaluation.

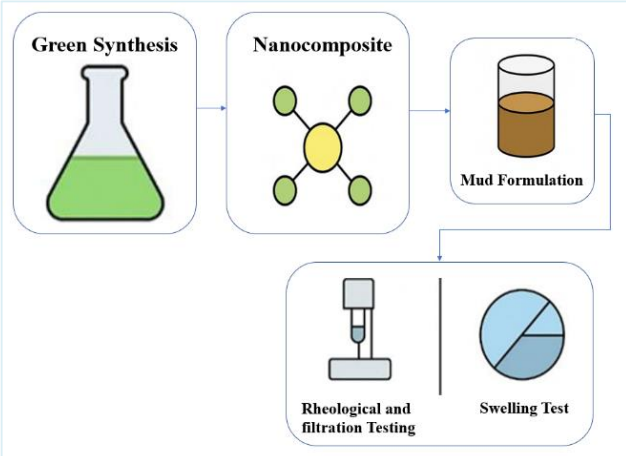

Fig. 1. Schematic illustration of the experimental procedure for preparing and evaluating nanocomposite-based drilling fluids

2.2. Synthesis of SiO_2/KCl/Xanthan nanocomposites

Five grams (5 g) of Na_2SiO_3 were added to the 100 mL Euphorbia condylocarpa plant extract, stirred at 80 ºC for 10 hours, and maintained at pH 10. After thoroughly mixing the components, the resulting precipitate was separated and added to an ethanolic suspension of 10 g of Xanthan substrate under reflux at 80ºC for 5 hours. The final precipitate was then dried and milled. The milled SiO_2/Xanthan NCs were then added to a 100 mL hydroalcoholic solution of KCl (2 M) at 100 ºC and stirred for 4 h. The precipitate was dried and milled again to produce the [SiO_2/Xanthan NCs] KCl compound.

2.3. Preparation of the drilling fluid samples

Drilling fluid samples were prepared according to API standard. The base fluid consisted of water, Bentonite (20 g), Soda Ash (0.5 g of Sodium Carbonate NA_2CO_3 for hardness control), and Caustic Soda (0.3 g for pH control) (Table 1). Nanocomposites were added to this base mud at different concentrations (500,1000,1500, 2000 and 4000 ppm) as shown in Table 2.

2.4. HPHT rheological measurements of drilling mud

The rheological properties were obtained by using an HPHT viscometer with a model modified by the Fann

35SA company in Houston. The HPHT API filter press was used to test the mud cake and fluid loss, and the rheological properties of all the drilling fluid samples yield point, gel strength at 10 sec and 10 minutes, Apparent viscosity and plastic viscosity are measured using the HPHT viscometer, considering the wellbore condition, which reads it in 120°F for water-based drilling fluid. The following equations are used for measuring the yield point, apparent viscosity, and plastic viscosity (PV).

Plastic Viscosity (µp) (cP) = 600 rpm reading – 300 rpm reading

Apparent Viscosity (µa) (cP) = 600 rpm reading/2

Yield Point (τy) (Ib/100 ft^2) = 300 rpm reading – µp

Where µp is plastic viscosity in cP, µa is apparent viscosity in cP, and τy is yield point in Ib/100 ft^2.

Table 1. The composition of the base mud sample

Material	Concentration	Functions
Water	350 ml	Base fluid
Bentonite	20 g	Viscosity and filtration control
Soda Ash NA_2CO_3 (Sodium Carbonate)	0.5 g	to eliminate soluble Ca from mud
Caustic NaOH (Sodium Hydroxide)	0.3g	PH control

Table 2. Formulation of nanocomposite drilling fluid

Sample No.	Nanocomposites fluid (% Wt.)	Concentration (ppm)
S1	WBFs	BFs
S2	WBFs + 0.05	500
S3	WBFs + 0.1	1000
S4	WBFs + 0.15	1500
S5	WBFs + 0.20	2000
S6	WBFs + 0.40	4000

2.5. HPHT and LPLT filtration and filter thickness measurements of drilling mud

API filter press is utilized to evaluate mud cake and measure fluid loss. The filtration properties are studied, including both fluid loss and filter cake, with different concentrations of (SiO_2/KCl/Xanthan) using a high-pressure and temperature filter press. For HPHT conditions, 600 psi as pressure acting on mud, the HPHT filter press measures filter cake thickness after 1.5 hours and the fluid loss measurements are taken at time intervals between 0 and 1.5 hours. But for the LPLT condition, considering room pressure and temperature, the LPLT filter press measures filter cake thickness after 30 min and the fluid loss measurements are taken at time intervals between 0 and 30 min. THE HPHT API filter press was used to test the mud cake and fluid loss with the model of part no. 170-01-1 and serial no. 12-2054 with 230 VAC voltage, which was modified by OFITE Company in Houston, USA.

2.6. Linear swell meter 2100

The marl swelling test is considered a key method to evaluate the performance of each DF system by quantifying marl-fluid interaction. Marl swelling varies depending on the marl type and the fluid used. The theory of marl swelling is necessary to understand the different phases at the surface interface. The linear swell meter, equipped with four vessels, holds the drilling fluid systems and core plugs. Connected to the software Linear Swell Meter 2100 program, it continuously records fluid absorption for 24 hours, showing the absorption rate as a percentage. Furthermore, in the experiments to determine swelling ratios linear swell meter 2100 with 102100513 and SN: 1C70148 model was used, which has been modified by Fann Company, which is used to determine each drilling fluid system interacting with marl core plug samples, indicating the absorption percentage.

3- Results and discussion

3.1. Characterization of SiO_2/KCl/Xanthan nanocomposites

Euphorbia condylocarpa extract was utilised as a green reducing medium. Numerous ecological factors, including light and soil conditions, temperature, humidity, and elevation, have a significant impact on the quantity and type of phytochemicals present in plants as well as their bioactivity strength. These characteristics are among the things used to systematically classify plants, and even the same plants from two different regions may differ as a result of these factors. Fig. 2 illustrates bond systems of existing compounds. Thus, the results from the UV-Vis spectroscopy confirmed the presence of compounds inside the plant extract. Moreover, this caused the appearance of maximum absorbance of nanoparticles and their formation. Therefore, Fig. 2 strongly confirms the presence of compounds inside the plant extract and therefore supports the results obtained by previous reported literature about the plant.

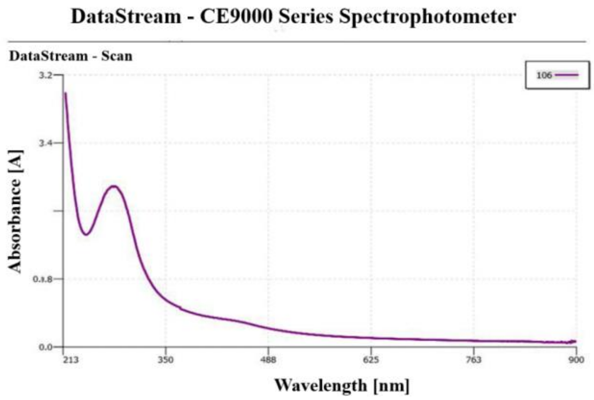

Fig. 2. The Uv-vis spectrum of the Euphorbia condylocarpa plant extract

Fig. 3 illustrates the X-ray diffraction (XRD) pattern of the nanocomposites, showing peaks characteristic of pure SiO_2 nanoparticles on the Xanthan surface. The absence of impurities peaks indicates high phase purity. The X-ray diffraction form of the nanocomposites indicates the peaks of SiO_2 NPs, which in some cases are overlain and composed in the structure of the nanocomposite.

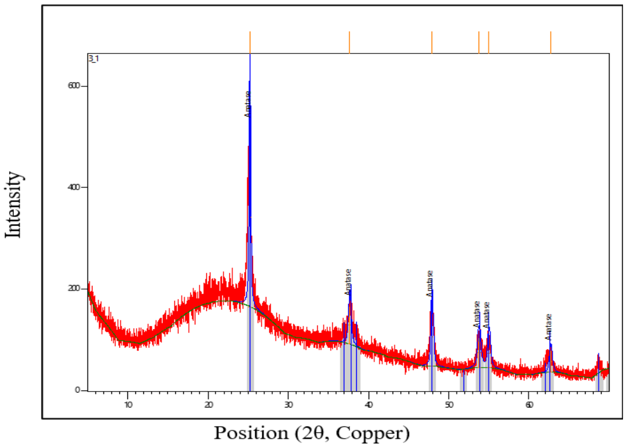

Fig. 3. The XRD pattern of green synthesized SiO_2/KCl/Xanthan NCs

SEM micrographs (Fig. 4) confirm that SiO_2 NPs are consistently disseminated on the surface of the xanthan substrate with particle size in the nanometer range.

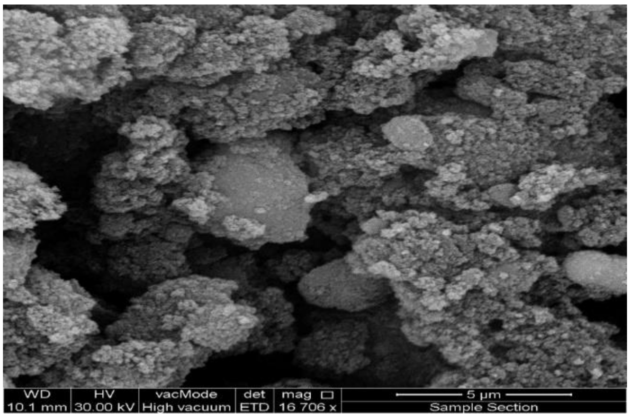

Fig. 4. SEM spectrum of SiO_2/KCl/Xanthan NC

3.2. Rheological properties of drilling nano fluids

The addition of nanocomposites significantly influenced the rheological behavior of the base mud. The base mud's rheological characteristics were measured. The measurements included plastic viscosity, apparent viscosity, yield point, and gel strengths at 10 sec and 10 min. The drilling fluid in the absence of NC offered a minimum value in which the plastic and apparent viscosities and yield point of the base mud were 4, 9 cp and 10.5 lb./100ft2, respectively. The 10 sec and 10 min gel strengths were 10 and 27 lb./100ft2, respectively. The performances increase with increasing concentration of NIDFs added to the base mud. In this study, the NCs with different concentrations (500, 1000, 1500, 2000, and 4000) ppm added into the BM, the influence of the NC and its concentration on the rheological behaviours of the mud was examined. Thus, by adding only 0.19 g (500) ppm of the NC into the base drilling fluid, the plastic viscosity and apparent viscosity of the fluid increased to 10 cP and 21 cP, respectively.

As the concentration of the nanocomposite increases, the viscosity of the mud increases. It is observed that the AP and PV of Sample 6 mud hold the maximum amount of nanocomposite, increased by almost 63.1% and 61.5% respectively, compared to Sample 2 mud, with the minimum concentration of Nanocomposite, from 21 cP and 10 cP to 57 cP and 26 cP. By increasing the concentration of nanocomposites, the rheological characteristics, including the yield point, viscosity, and gel strength of the muds, are affected. Then it detects that the performance of the muds, which is maintained and developed with the addition of nanocomposites by a small percentage. Thus, the mud with a content of solids will decline due to the addition of additives. As a consequence, drilling rate with higher speed, superior and easier to regulate solids to control them, easier re-functioning of the mud, and minimum damage to the formation would be attained. The yield point of mud was increased with the addition. The yield point of S1 drilling mud was measured, which was 10 lb./100 ft2, and it increased to 22 lb./100 ft2 with only 0.19 g of nanocomposite addition. Following that, the yield point was increased significantly to 27 lb./100 ft2 once the concentration of the nanocomposite in the drilling fluid increased to 4000 ppm. In terms of gel strength of the drilling mud, both initial and final values of gel strength were improved when NC contents inside the drilling fluids increased. At the lowest loading level (0.19 g) of NC was added, the measured values of gel strength at 10 sec and 10 min were equal to 19 lb./100 ft2 and 37 lb./100 ft2, respectively. However, the values of gel strength at 10 sec and gel strength at 10 min were prominently increased to 31 lb./100 ft^2 and 54 lb./100 ft^2 after increasing the concentration of NC by 4000ppm. Fig. 5 shows the summary of the rheological properties of nanocomposite (NC) formulations in drilling fluid systems, illustrating the influence of NC concentration and composition on key parameters such as yield point and gel strength across different base fluids.

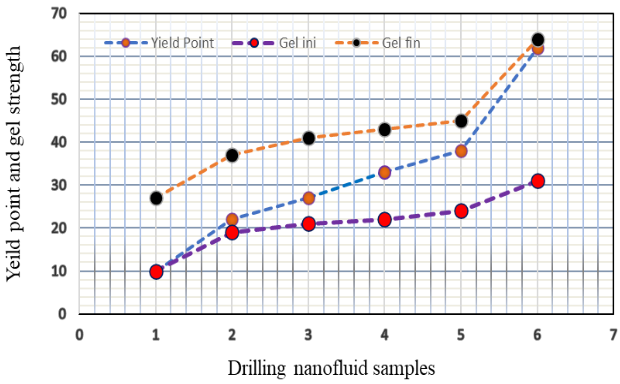

Fig. 5. Summary of the NC rheological properties in all the NCs with different drilling fluids

3.3. Filtration properties of drilling Nanofluid in LPLT and HPHT conditions

The fluid loss and the thickness of the mud cake were measured for all six samples of the drilling fluid at both LPLT and HPHT. A base drilling mud and five samples with different concentrations of NCs. For S1 mud without NC, the fluid loss in the LPLT condition was about 15.2 mL, and 25.84 mL in the HPHT condition. In the LPLT condition, it was reduced in S2, S3, S4, and S5% to 10.2 mL, 8.7 mL, 8.1 mL,7.6 mL and 1.5 mL, while under the HPHT condition it was reduced from 25.84 mL to 17.6 mL, 14.9 mL, 13.86 mL,13.2 mL and 2.4 mL, respectively. Meanwhile, the effect of the NC on the fluid loss was higher than its effect on the filter cake. The thickness of the mud cake for the WB in LPLT condition was measured with a range of 2 mm, but it was reduced in the other samples from S2 to S5 to 1.85 mm, 1.7 mm 1.6 mm,1.5 mm and 0.2 mm, under HPHT condition the thickness of the mud cake for the WB was 3.4 mm, but it was reduced in the other samples from S2 to S6 to 3 mm, 2.85 mm 2.7 mm 2.4 mm and 0.3mm, respectively. Fig. 6 shows that the volume of the fluid loss and the thickness of the mud cake decreased with increasing percentage of NC within the drilling mud. This improvement in filtration properties of the drilling fluid was a result of the effect of silicon dioxide and xanthan NPs existing within the NC, which provides a high surface area. The minimum thickness of the mud cake was found in S4 and S5 muds with the concentrations of 2000-4000ppm.

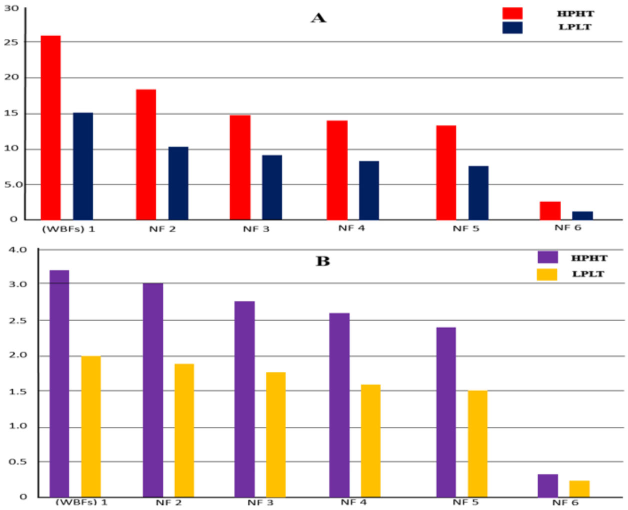

Fig. 6. Filtration properties of Nano fluid in LPLT and HPHT conditions, A) fluid loss ml, and B) filter cake mm

3.4. Swelling behaviour

In this research study, SiO_2/KCl/Xanthan nanocomposite was added as an additive to improve the performance of the water-based mud. The effects of these additives on the swelling clay have been studied and measured. A swelling issue that occurs when water comes into contact with formations containing clay minerals such as montmorillonite, zeolite, and lizardite. And most elements existing in the acquired clay formation sample are MgO elements, which exceed 33% of the sample's element content; it may exist in (montmorillonite, zeolite and lizardite). The silica element would be present in clay minerals, distinctively in zeolite and lizardite. Clay minerals in marl formation tend to water adsorption into the formation, resulting in swelling and wellbore instability.

3.5. Identification of the NCs' effect on swelling

In this section, the effects of (SiO_2/KCl/Xanthan Nanocomposite) are being investigated on mitigating water adsorption into marl formation. Measurements have been done at 22 hours with the swelling linear meter 2100 equipment, collaborating with the software program linear swell meter. From the acquired marl formation, the core plug has been prepared, with an initial length of about 0.60 in. The measurements included water adsorption every single hour for 22 hours. The drilling fluid in the absence of NC offered a minimum value, with a swelling of about 25 % swelling. The performance of water adsorption decreases with increasing concentration (SiO_2/KCl/Xanthan Nanocomposite), added to base mud, except for 500 ppm, which increased to 25.6 about NC, which may be the reason for the non-dispersion of the NC in the WBM. In this study the NC with different concentration (500, 1500, 2000, and 4000) ppm added into the BM, Thus, by adding only 0.19 g (500) ppm of the NC into the base drilling fluid, increased to 25.6 % swelling, Fig. 7 shows NC effect on reduction of Clay Swelling The optimum situation in which investigated is using 4000 ppm NC to the base fluid, the swelling percentage reduced to 19.7 by the mean the swelling reduction reached almost %22.2. Fig. 7 indicates all five conditions related to the NC effect on swelling clay.

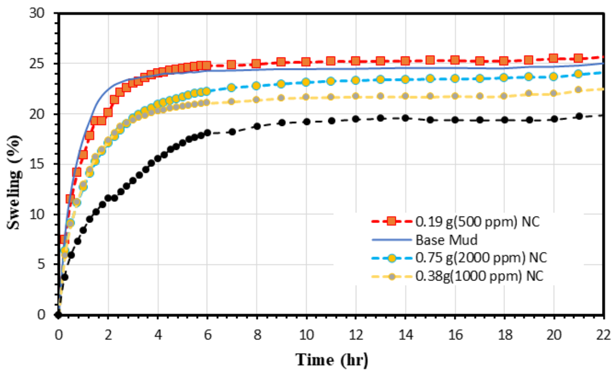

Fig. 7. The nano-composite's effect on the reduction of clay swelling

3.6. Characterizations of the marl-rich rock samples

To identify minerals for the acquired sample of the marl-rich formation in the Kurdistan region, an XRD test has been performed in the SRC (Soran University Research Centre). The mineralogy and chemistry of the outcrop sample are characterised by using X-ray Diffraction (XRD) and fluorescent X-ray (XRF). The Marl-rich formation was characterised using X-ray Diffraction (XRD) for bulk minerals analysis. Fig. 8 points out that the acquired outcrop sample of the Marl-rich formation consists of the minerals shown in Fig. 8.

The most commonly mineral in this sample are (montmorillonite, zeolite, lizardite, quartz and calcite), these three minerals (montmorillonite, zeolite, lizardite) thoroughly considered as problematic in the circumstance water existence, while drilling with WBM the fluid would firmly adsorb through the formation due to reactions with water and occurring hydration, rather than (quartz and calcite) which do not react with water due to the absence of clay in both. Fig. 8 shows the XRD pattern for Marl-rich Formation Minerals. Montmorillonite is the major trouble for hydration, causing smectite and elite existing in it and zeolite, with less possibility for lizardite and zeolite to occur. (Montmorillonite, in the group of mica, which is a clay mineral, could be hydrated with high probability. Lizardite is in the group of Serpentinite, which encompasses a series of hydration reactions. Zeolite is in the group of microporous and aluminosilicate minerals, which are hydrated. The following pick list demonstrates the angle of each mineral with its pick's height, in addition to FWHM, which describes the closeness of picks to each other. Near the Picks to each other, show more crystalline minerals. And then the intensity of minerals matched a standardized reference.

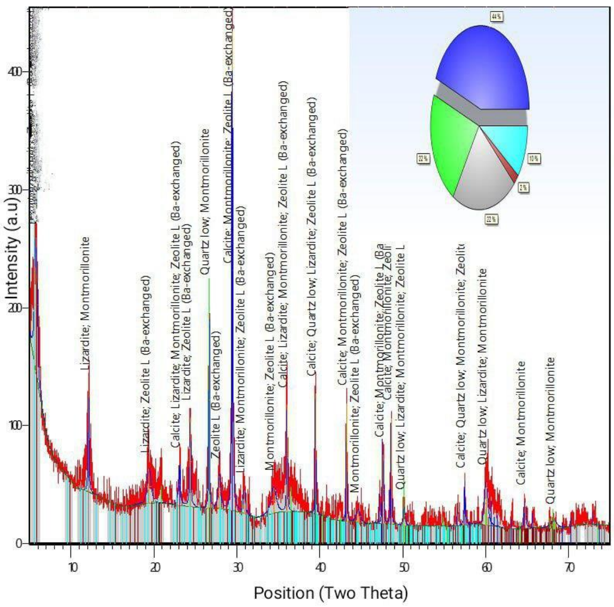

Fig. 8. XRD pattern for Marl-rich Formation Minerals

In addition, XRF is an investigative system which is used for finding out the elemental composition. XRF users conclude the chemistry of a sample by analysing the fluorescent X-ray which is emitted in a sample once it is excited by a primary X-ray source. XRF points out the elements existing in the sample. This demonstrates all the elements and their contents of the Marl-rich formation outcrop sample. According to the results received from XRF on the Marl-rich formation, magnesium is the most abundant element, which exceeds 33% of the sample's element content. Magnesium may exist in (montmorillonite, zeolite and lizardite). It is observed that the high amount of clay minerals in the acquired sample of the Marl-rich formation is associated with the high amount of magnesium. Silica exists in the Marl-rich sample at about 28 per cent as the second-highest amount after magnesium. Silica exists in clay minerals, distinctively in zeolite, lizardite and quartz. Calcium exists in calcite, it stands in clay minerals, and iron exceeds 5 per cent of the element's content of the sample; it may exist in (montmorillonite, zeolite, lizardite) clay minerals. Aluminium is another component of the Marl-rich formation sample; it is the third highest element amount existing in the Marl-rich sample, in which about 8 per cent. Aluminium is another factor; too high an amount of clay in the Marl-rich formation sample may cause clay minerals to be aluminium silicate (Al_2SiO_5). Table 3 shows the XRF Analysis of the Marl-rich Formation Elements Content.

Table 3. XRF Analysis of Marl-rich Formation Elements Content

Element	Content (%)
MgO	33.1372
Al_2O_3	8.4138
SiO_2	28.2911
Phosphorus	0.2924
Potassium	0.072
Calcium	4.3480
Titanium	0.0233
Vanadium	0.0014
Manganese	0.0398
Iron	5.756
Nickel	0.0824
Strontium	0.0086
Yttrium	0.0034
Zirconium	0.0292
Niobium	0.0095
Molybdenum	0.0209
Silver	0.0042
Cadmium	0.0029

4- Conclusion

This study successfully developed a drilling fluid employing SiO_2/KCl/Xanthan nanocomposite, as well as to examine the impact of these materials on swelling, rheological, and filtering properties. During the investigation period, the employed values ranged from 500 to 4000 ppm, implying 0.05–0.4 wt.% of the drilling fluid. Adding NC at varying percentages (0.05–0.4 wt.%) to the base drilling mud had a considerable impact on swelling, rheology, and filtration. By increasing the concentration of NC, the drilling fluids' rheological properties—such as viscosity, yield point, and gel strength—increased. The addition of NC enabled the drilling fluids' performance to be maintained and even improved. Using small amounts of additives would minimise the solid content of the drilling fluids. The NC additive allows for a faster drilling rate, better and easier solid control, easier mud reconditioning, and less formation damage. Among all five different concentrations of NC in the drilling fluid, it is evident that employing NC at 4000 ppm improved rheology and decreased filtration by 91.7%, mud thickness by 91.29%, and swelling by approximately 22.2% compared to the base mud. In this study, it was determined that the best drilling fluid system employed was NC drilling fluid with 4000 ppm, which was highly effective in improving rheological and filtration qualities while also reducing swelling by 22.2%.

5- Recommendations

Based on the experimental findings, the SiO_2/KCl/Xanthan nanocomposite is strongly recommended as a performance-enhancing additive in water-based drilling fluids, particularly when drilling through marl-rich formations such as those in the Kurdistan Region of Iraq. An optimum concentration of 4000 ppm yielded significant improvements, including a 91.7% reduction in filtrate loss, a 91.29% reduction in filter cake thickness, and a 22.2% reduction in clay swelling under HPHT conditions. These results highlight its effectiveness in improving wellbore stability, enhancing rheological properties, and mitigating shale-related challenges. Furthermore, the biosynthetic route using Euphorbia condylocarpa extract demonstrates both environmental compatibility and economic feasibility, aligning with sustainable drilling practices.

For future research, emphasis should be placed on:

- Field-scale verification of the nanocomposite's performance under diverse geological conditions.
- Long-term stability and environmental impact assessment, including biodegradability and toxicity studies.

Conflicts of interest

The author declares no conflict of interest.

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تصميم وتقييم أنظمة سوائل الحفر النانوية المتقدمة من خلال الصخور المعتمدة على المارل: دراسة مبنية على عينات من الصخور البركانية من كردستان

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الخلاصة

يُعدّ الانتفاخ أحد التحديات المتكررة التي تُواجه عمليات الحفر، إذ قد يُؤدي إلى تلف التكوينات ويُعرّض سلامة البئر للخطر. ويُمكن أن يُوفّر تآزر المواد النانوية بخصائصها المميزة، إلى جانب المواد الفعّالة من حيث التكلفة، نهجًا هامًا في تعزيز معالجة استقرار البئر. اعتمدت هذه الدراسة نهجًا صديقًا للبيئة وبسيطًا واقتصاديًا لتخليق مركبات نانوية من ثاني أكسيد السيليكون/كلوريد البوتاسيوم/زانثان (NCs)، بهدف تقليل الانتفاخ وتحسين الخواص الريولوجية والترشيحية لـ WBDFs. بالإضافة إلى ذلك، قُيّم تأثير مركبات نانوية من ثاني أكسيد السيليكون/كلوريد البوتاسيوم/زانثان على الانتفاخ، تبعه بحث شامل في خصائص ترشيح سائل الحفر وريولوجيته، بما في ذلك اللزوجة الظاهرية، واللزوجة اللدنة، ونقطة الخضوع، وقوة الهلام، وكعكة الطين، والسوائل. أكدت النتائج المتحصل عليها أن مركبات الكربون النانوية المُصنّعة الخضراء قللت بفعالية من انتفاخ الطين بنسبة تقارب 22.2%، وحسّنت خصائصه الريولوجية، وخفضت بشكل ملحوظ من كعكة الترشيح وفقدان السوائل بنسبة تقارب 91.29% و 91.7% على التوالي، وذلك عند اختبارها باستخدام مكبس الترشيح HPHT. وتوصي النتائج بشدة باستخدام مركبات الكربون النانوية $SiO_2/KCl/Xanthan$ كمادة مضافة فعالة لتخفيف انتفاخ الطين، وتحسين خصائصه الريولوجية، وتقليل فقدان السوائل وكعكة الترشيح في سائل الحفر. ويمكن التأكيد على أن سوائل الحفر المثبطة للنانو مفيدة للغاية لعمليات الحفر الناجحة نظرًا لقدرتها على تخفيف انتفاخ الطين، وتحسين خصائصه الريولوجية، وتقليل تحديات الترشيح..

الكلمات الدالة: تقنية النانو، هندسة الحفر، التكوين الغني بالمارل، الانتفاخ، الريولوجية والترشيح.