IOP Conference Series: Earth and Environmental Science

Preface

To cite this article: 2024 *IOP Conf. Ser.: Earth Environ. Sci.* **1339** 011001


6TH International Conference of Earth Science, Mineral and Energy
ICEMINE
"Accelerating the Advancements in Lower Carbon Energy for A Sustainable Environment"
2023

Preface

Greetings and a warm welcome to the expansive compilation of research and scholarly contributions presented in the Proceedings of the ICEMINE 2023. In the spirit of intellectual exploration and collaboration, this voluminous collection encapsulates the diverse and profound discussions that unfolded during the conference. As we delve into the following pages, readers will encounter a comprehensive exploration of knowledge, innovation, and interdisciplinary collaboration within the overarching theme of ICEMINE 2023.

ICEMINE 2023 is the 6th International Conference hosted by the Faculty of Mineral Technology, Universitas Pembangunan Nasional "Veteran" Yogyakarta, Indonesia. The conference was held at Grand Keisha Hotel, Yogyakarta, Indonesia, on the 9th of November 2023. The theme of this year's program is *"Accelerating the advancements in lower carbon energy for a sustainable environment"*.

We extend our appreciation to our esteemed partner university, whose unwavering dedication and scholarly contributions have significantly enriched the contents of this conference proceedings. In collaboration with our partner universities, Trisakti University and PEM Akamigas, UPN Veteran Yogyakarta creates an academic platform that fosters diverse perspectives, innovative ideas, and interdisciplinary exchange. Their insightful research and collaborative spirit have undeniably elevated the quality of discourse within our academic community, fostering an environment conducive to intellectual growth and innovation.

Furthermore, we would like to express our profound gratitude to our sponsors, whose generous support has been pivotal in bringing this event to success. Their unwavering commitment to advancing research and cultivating intellectual exchange underscores the importance of their role in shaping the trajectory of our academic disciplines.

Reflecting on Sustainability in Indonesia

In recent years, the imperative to decrease carbon emissions and shift towards energy sources with lower carbon footprints has become exceptionally crucial. Emphasizing the importance of transitioning to cleaner energy sources is paramount for preserving our environment and addressing climate change. The significance of advancing lower carbon energy technologies cannot be overstated, as they play a vital role in mitigating the adverse impacts of climate change and ensuring a sustainable environment for future generations. As scholars and researchers, we carry a distinct responsibility to accelerate the development of these technologies, driving innovation, encouraging critical thinking, and offering the expertise and solutions needed to forge a more sustainable future.

The chosen theme for ICEMINE 2023, *Accelerating the advancements in lower carbon energy for a sustainable environment,* resonates with the evolving landscape of academic inquiry and technological advancement. This theme has served as a catalyst for researchers to delve into various aspects, spanning the theoretical frameworks to practical applications. The rich tapestry of this proceedings volume mirrors the comprehensive exploration undertaken by the conference participants, representing a mosaic of perspectives that collectively contribute to the ongoing narrative of Sustainability.

Within this volume lies a plethora of research, articles, case studies, and theoretical explorations carefully curated from the vast pool of submissions and presentations at the conference. These contributions, emanating from a global community of earth science scholars, reflect the breadth and depth of insights shared during ICEMINE 2023. The contributions cover a wide spectrum of earth sciences, which are:

1. Geological Science and Engineering
2. Geophysics, Geomatics and Geochemistry
3. Earth Resources Project Evaluation and Valuation
4. Petroleum and Geothermal Engineering
5. Mining and Metallurgical Engineering
6. Taxation and Policy
7. Conservation, Geoheritage and Geopark
8. Disaster Management
9. Reclamation and Environmental Issues

Navigating the future: a vision for what lies ahead

As we engage with the contents of this proceedings volume, let us not only celebrate the documented achievements but also contemplate the trajectory of our respective fields. The ideas presented here have the potential to seed new research directions, innovative solutions, and transformative advancements. Readers are encouraged to interact critically with the content, fostering discussions and collaborations that transcend traditional academic silos. The interdisciplinary nature of the contributions invites us to explore the intersections of knowledge, where groundbreaking ideas often emerge from the convergence of diverse perspectives. May the knowledge shared within this volume inspire future generations, spark new avenues of inquiry, and contribute to the advancement of our collective understanding.

Cordially yours,

Dr. Widyawanto Prastistho

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KEYNOTE SPEAKERS

BEST PRESENTERS

Naufal Setiawan	The Prospect of Typhoon Landfall Observation Utilizing L-band InSAR	Geomatics Engineering UPNVY
Andra Y Ginting	The Effectiveness of Soil Washing as a Remediation Method on Oil Spill Contaminated Soil (Case Study: Wonocolo Traditional Oil Mine)	Environmental Engineering UPNVY
Muhammad Irvingia Al Farizzi	Telomoyo Volcano Complex Geotourism: An In-Depth Analysis and Future Development	Geological Engineering UPNVY
David Michael	Optimizing the Impact of Rheological Properties on Bentonite Prehydrated- Based Drilling Mud Through the Utilization of Prehydration	Trisakti University
Muhammad Naufal Hisya Himendra	Comparative Analysis of The Use Emulsion and Watergel Explosive on Fragmentation at PT Dahana Site Kaltim Jaya Bara, East Kalimantan	Mining Engineering, Trisakti University
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PAPER • **OPEN ACCESS**

Peer Review Statement

To cite this article: 2024 *IOP Conf. Ser.: Earth Environ. Sci.* **1339** 011002

IOP Conf. Series: Earth and Environmental Science 1339 (2024) 011002 doi:10.1088/1755-1315/1339/1/011002

Conference Title

"The 6th International Conference on Earth Science, Mineral, and Energy."

Peer review statement

All papers published in this volume have been reviewed through processes administered by the Editors. Reviews were conducted by expert referees to the professional and scientific standards expected of a proceedings journal published by IOP Publishing.

1. Type of peer review: Single anonymous
2. Conference submission management system: Morressier and Icemine Platform
3. Number of submissions received: 79
4. Number of submissions sent for review: 57
5. Number of submissions accepted: 42
6. Acceptance Rate (Submissions Accepted / Submissions Received × 100): 53.16 %
7. Average number of reviews per paper: 2.00
8. Total number of reviewers involved: 22
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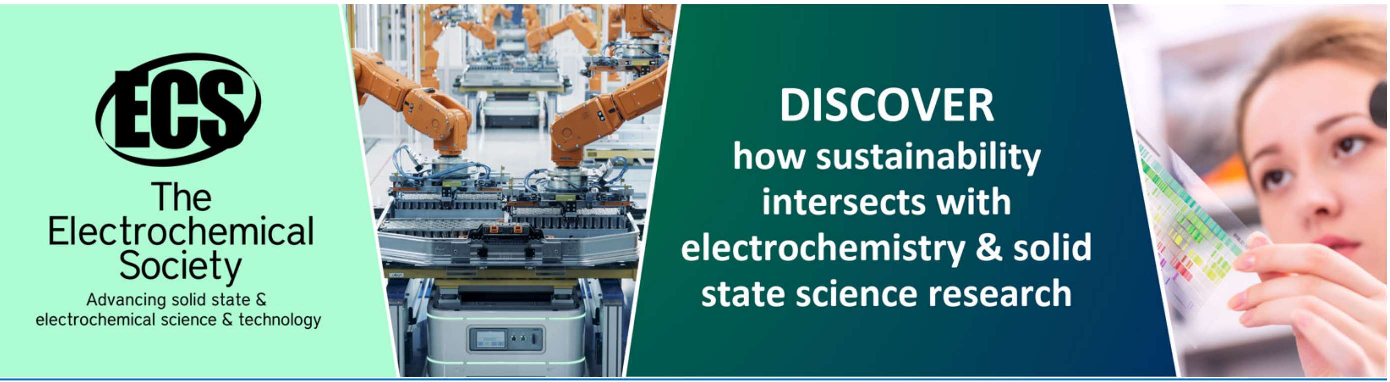
Optimizing the impact of rheological properties on bentonite pre-hydrated based drilling mud through the utilization of pre-hydration

To cite this article: Mustamina Maulani *et al* 2024 *IOP Conf. Ser.: Earth Environ. Sci.* **1339** 012018



Optimizing the impact of rheological properties on bentonite pre-hydrated based drilling mud through the utilization of pre-hydration

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Abstract. In offshore drilling activities, the employment of seawater mud is indispensable, and its adoption is steadily increasing. Traditionally, attapulgite has held a dominant position as the key element in seawater mud composition. However, a shift is underway towards substituting attapulgite with bentonite owing to the manifold advantages that the latter presents. Bentonite boasts favourable viscosity characteristics and efficient control over water loss, outperforming attapulgite particularly in terms of its capacity for clay absorption. Nevertheless, to harness its thickening capabilities for use with seawater, bentonite necessitates a preliminary hydration process. The pre-hydration procedure involves the amalgamation of seawater and bentonite at a low mixing speed for a duration of 10 minutes, succeeded by a resting interval spanning 16 hours. The integration of this pre-hydrated bentonite system necessitated an extensive research undertaking, encompassing a comprehensive review of pertinent literature, the collection of seawater samples, laboratory experiments conducted at three distinct temperatures comparing both fresh water and seawater formulations, the incorporation of diverse additives to augment the assessment of the mud's physical attributes, meticulous measurement of the drilling mud's physical properties, implementing treatments to enhance measurement values under heightened temperatures, meticulous analysis of acquired data, and the comprehensive documentation of research findings in scholarly publications. The crux of this research endeavour lies in attaining the objective of incorporating pre-hydrated bentonite as a pivotal constituent within seawaterbased drilling mud. The realization of this goal hinges on the congruence of the measured physical properties of the drilling mud with predefined specifications. Through a rigorous exploration of these methodologies and a systematic approach to research, the study endeavours to foster advancements in seawater-based drilling mud formulations and their operational effectiveness within offshore drilling contexts.

1. Introduction

Water-based mud, accounting for approximately 98% of drilling mud usage, is commonly the most employed type in drilling operations. Drilling mud viscosity refers to the thickness or resistance to flow of the drilling fluid utilized during drilling processes. One approach to augmenting drilling mud viscosity involves incorporating bentonite, a clay variant frequently employed as a viscosifier in drilling fluids. The composition of the drilling mud necessitates the adaptation of various combinations and quantities of fresh or salt water, clay, and other chemicals to suit the conditions of the subsurface borehole.

Other freshwater is commonly used in water-based mud, particularly in onshore drilling, due to its convenient availability. On the other hand, the use of brine in water-based mud is more common in offshore drilling and less common in onshore drilling. When drilling encounters a hard layer with low absorption, a less dense drilling mud with a higher water content can be used. Conversely, in highpressure layers with higher absorption rates, dense drilling mud is employed to control layer pressures and mitigate the occurrence of kicks, which can pose challenges.

In summary, water-based mud is the predominant type of drilling mud utilized, and its viscosity can be improved by adding bentonite. The precise composition of the drilling mud, including the types and quantities of water, clay, and additives, must be customized to suit the specific underground conditions. Fresh water is frequently utilized in onshore drilling, whereas brine is commonly employed in offshore drilling. The selection of drilling mud density depends on the characteristics of the geological layers encountered, with less dense mud utilized for hard layers and heavier mud employed in high-pressure formations to effectively control pressure differentials and reduce the occurrence of kicks.

2. Literature review

If Water-based mud is a commonly utilized mud type due to its cost-effectiveness, user-friendliness, and ability to create a filtrate layer for borehole protection. However, water-based mud has drawbacks, such as the potential to contaminate formation layers, leading to suboptimal results in logging processes. Additionally, it is unsuitable for active formations that easily expand upon contact with water [1–4].

The utilization of seawater mud has experienced an upsurge in recent times, thanks to the availability of organic polymers that enhance the formulation and treatment of the mud. Initially, seawater mud was prepared and treated with attapulgite and asbestos to enhance its structural strength for cutting and lifting, along with starch for fluid loss control. However, this mud exhibited low viscosity, making cutting and lifting challenging and resulting in a slow penetration rate [5].

In contrast, modern seawater muds predominantly employ polymeric materials like xanthan gum, polyanionic cellulose, or pre-hydrated bentonite to increase viscosity and reduce fluid loss. Compared to the traditional attapulgite-asbestos-starch mud, this composition offers higher efficiency. The incorporation of polymers facilitates better formation stability through a polymer coating process. As a result, the mud's performance is significantly enhanced, enabling improved cutting, lifting, and penetration rates [6].

In the past, prior to the advancement of drilling technology, water alone was utilized to lift drilling cuttings. However, as drilling technology progressed, the introduction of drilling mud became essential. Drilling mud plays a crucial role in ensuring the success of well drilling operations. Effective control over the composition and conditions of the drilling mud is a vital aspect of conducting well drilling operations. To simplify the understanding of this concept, drilling mud can be assessed based on four key physical properties: density, viscosity, gel strength, and water loss. Additionally, there are other notable characteristics of drilling mud, such as mud pH, sand content, and resistivity [7].

Maintaining seawater-prehydrated bentonite mud is comparatively simple and yields a faster penetration rate compared to the attapulgite-starch pre-slurry system. The lower viscosity of the mud makes it easier to separate cuttings using solids separator equipment. However, the utilization of seawater mud with pre-hydrated bentonite necessitates extra tanks to accommodate the bentonite hydration process. This requirement can pose challenges at offshore drilling sites due to spatial limitations [7].

Bentonite serves as a primary component in the composition of drilling mud. Essentially, bentonite is a type of clay consisting of Na-montmorillonite and Ca-montmorillonite. Na-montmorillonite is particularly advantageous as a base material for drilling mud due to its remarkable ability to expand (swell) up to eight times its original volume when immersed in water. This substantial expansion capacity results in a solution with a considerable viscosity, which plays a crucial role in effectively cleaning the bottom of the borehole. Moreover, it enables the formation of an elastic layer on the hole wall known as "mud cake," providing protection against wall collapse. Bentonite is a composite material comprising a collection of minerals and colloidal substances, including illite, kaolinite, siderite, chloride, attapulgite, and predominantly montmorillonite (85%–90%)[8].

It is well established that bentonite undergoes hydration to varying degrees when mixed with water. Hydrated bentonite forms layers of silica and alumina in different arrangements, creating distinct types of clay structures. These clay particles can consist of single layers or be stacked infinitely on top of each other, resembling a deck of cards bound together in a residual manner. When suspended in water, clay exhibits varying levels of swelling [9].

The bentonite molecule comprises three layers: an alumina layer sandwiched between two silica layers. These bentonite plates carry a negative charge and are associated with cations of the opposite charge. If the associated cations are sodium (Na), the clay is referred to as sodium montmorillonite, whereas calcium (Ca) association gives rise to calcium montmorillonite. Remarkably, even a small quantity of 1% hydrated bentonite in fresh water can achieve a similar thickening effect as 19% barite. Consequently, bentonite can be dispersed and utilized in relatively small amounts while still exhibiting physical properties that enable fluids to suspend a significant portion of barite. Achieving optimal viscosity is a crucial aspect of the production of effective drilling mud. To enhance viscosity, the inclusion of bentonite in the mud is pursued due to its advantageous properties [10].

Bentonite is a natural clay mineral composed mainly of montmorillonite (Medhi et al., 2020), which has unique properties that make it effective in enhancing drilling mud viscosity. When bentonite is added to the drilling fluid, it undergoes a process known as hydration, where it absorbs water and forms a gellike structure. This gel formation significantly increases the thickness and consistency of the drilling mud, leading to a higher viscosity [11].

The mechanism behind bentonite's ability to increase viscosity lies in its plate-like structure and the ability of water molecules to interact with its surface. The charged surfaces of the bentonite particles attract water molecules, causing them to surround and interact with the clay particles. As more water is absorbed, the clay particles swell and interlock with each other, creating a three-dimensional network that impedes fluid flow and enhances viscosity [12].

By increasing the viscosity of drilling mud, bentonite offers several advantages in drilling operations. Firstly, it helps to suspend and transport drill cuttings, ensuring efficient removal from the wellbore. This is crucial for maintaining wellbore stability and preventing blockages during drilling. Secondly, the increased viscosity of the drilling mud provides better hole cleaning and helps prevent fluid invasion into the formation being drilled. This can help to minimize formation damage and maintain well integrity [13].

It is important to note that the amount of bentonite added to the drilling mud should be carefully controlled to achieve the desired viscosity [14]. Excessive bentonite addition can lead to excessively high viscosity, which may hinder drilling progress and increase pumping requirements. Therefore, the optimal concentration of bentonite should be determined based on factors such as the specific drilling conditions, desired mud properties, and the characteristics of the formation being drilled [15] and completion [16–18].

Overall, the addition of bentonite to drilling mud effectively increases viscosity, allowing for improved suspension, transport of cuttings, and wellbore stability during drilling operations [19–21].

3. Methodology

The research was carried out at the Drilling and Production Engineering Laboratory of Universitas Trisakti to assess the physical characteristics of drilling mud with a pre-hydrated bentonite system. The experimental procedure began with the preparation of two mud compositions: one with fresh water and the other with sea water, both at room temperature (80°F). In separate mixer cups, 340 ml of fresh water and 345 ml of sea water were combined with 15 grams of bentonite and mixed using a Hamilton mixer for 10 minutes. Subsequently, the resulting mud compositions were transferred into two different beakers for prehydration over a period of 16 hours. The purpose of prehydration was to allow the bentonite to fully blend with the sea water, resulting in improved viscosity and controlled water loss.

Following the 16-hour prehydration period, the pre-hydrated mud samples were first mixed at a low speed for 1 minute to ensure uniform blending. Then, various additives were introduced and mixed at different speeds. The duration and speed of the mixing process were significant factors affecting the mixing rate, which in turn influenced the measurement of the drilling mud's physical properties.

The initial additive introduced was soda ash, which served as a pH controller. A quantity of 1.2 grams was added to fresh water, while 2.2 grams were added to sea water. The mixture was stirred for 1 minute at a low speed. The second additive, XCD, acted as a biopolymer to regulate the rheology of the mud, focusing on plastic viscosity and yield point. For fresh water, 0.5 gram of XCD was added, and for sea water, 1 gram was added. The mixture was stirred for 4 minutes at a low speed.

Next, the third additive, pac-R (also known as Drispac Regular), was included to enhance viscosification and reduce filtration loss. For fresh water, 1 gram of Pac-R was added and mixed for 4 minutes at a low speed. For sea water, 2 grams of Pac-R were added and mixed for 4 minutes at a high speed. The high-speed mixing in sea water was necessary as pac-R proved more challenging to blend in sea water compared to fresh water, leading to an increased presence of pac-R residue when mixed at low speed.

The fourth additive, PHPA, functioned as a biopolymer to regulate mud rheology, particularly gel strength. A quantity of 0.5 gram of PHPA was added to fresh water, while 1 gram was added to sea water. The mixture was stirred for 4 minutes at high speed. The fifth additive, pac-LV, served as both a filtration loss reducer and a viscosifier. For fresh water, 0.5 gram was added, and for sea water, 1 gram was added. The stirring speed was set to low for fresh water and high for sea water.

The sixth additive, lignite, acted as a thinner and was added in a quantity of 1 gram to fresh water. The mixture was stirred for 5 minutes at high speed. Lignite was not added to seawater due to its inability to dissolve effectively in highly concentrated salt solutions. Sea water typically contains a salt concentration of 30,000–35,000 ppm. The mixture was then further stirred for 5 minutes at a high speed to ensure thorough blending of the ingredients. Finally, 2 ml of defoamer was added and stirred for 2 minutes at a low speed to eliminate foaming. Foaming occurred in both compositions as a result of prolonged high-speed mixing.

Once the two mud compositions of the pre-hydrated bentonite system at room temperature have been prepared, the physical properties of the mud will be measured. These properties include mud weight (ppg), funnel viscosity (sec/qt), plastic viscosity (cp), yield point (lbs/100 ft2), 10-second gel strength (lbs/100 ft2), 10-minute gel strength (lbs/100 ft2), water loss (cc), mud cake (mm), and pH. Various tools will be used for these measurements, such as a mud balance for mud weight, a marsh funnel for funnel viscosity, a fann VG meter for mud rheology (PV, YP, and gel strength), an API filter press for water loss and mud cake measurements, and pH stripes with the assistance of an API filter press for pH determination.

The third and fourth compositions of the pre-hydrated bentonite system drilling mud in fresh water and sea water will undergo a temperature increase to 250°F. The pre-hydration solution will be allowed to stand for the usual 16 hours, followed by an additional 1-minute mixing at low speed. The additives added will be the same as the sludge composition at 80°F, with the inclusion of barite as a weighting agent, which will be mixed for 5 minutes at high speed. The mixture will then be placed in a roller tube and baked for 1 hour at a temperature of 250°F. After 1 hour, the two sludge compositions will be placed back in the mixer cup and mixed for 1 minute at low speed. The purpose of this remixing is to prevent material sagging.

Due to the temperature increase, the physical properties of the drilling mud will change, deviating from the mud specifications. Therefore, treatment is necessary. The composition of the freshwater mud will be treated by adding several additives, including 40 grams of barite, 1 gram of lignite, 0.5 gram of pac-LV, 1 gram of pac-R, 0.5 gram of PHPA, and 0.5 gram of XCD. Similarly, the seawater mud composition will be treated with additional additives, including 30 grams of barite, 1 gram of pac-LV, 1.5 grams of pac-R, 1 gram of PHPA, and 1 gram of XCD.

The fifth and sixth compositions of the pre-hydrated bentonite system drilling mud in fresh water and sea water will experience a temperature increase to 300°F. The prehydration solution will undergo the usual 16-hour resting period, followed by an additional 1-minute mixing at low speed. The additives added will be the same as the sludge composition at 250°F, but the volume of water added will change to 330 ml for fresh water and 335 ml for sea water. The mixture will then be placed in a roller tube and baked for 1 hour at a temperature of 300°F. After 1 hour, the two sludge compositions will be placed back in the mixer cup and mixed for 1 minute at low speed.

Again, due to the temperature increase, the physical properties of the drilling mud will change, deviating from the mud specifications. Therefore, treatment is necessary. The composition of the freshwater mud will be treated by adding several additives, including 20 grams of barite, 0.5 grams of lignite, 0.2 grams of pac-LV, 0.5 grams of pac-R, 0.2 grams of PHPA, and 0.2 grams of XCD. Similarly, the seawater mud composition will be treated with additional additives, including 15 grams of barite, 0.3 grams of pac-LV, 0.5 grams of pac-R, 0.3 grams of PHPA, and 0.3 grams of XCD.

After the two sludge compositions have been transferred back into the mixer cup, they will undergo mixing for a duration of 1 minute at a low-speed setting. During this process, the components of the sludge will be thoroughly combined and blended altogether.

The two prepared sludge compositions will be returned to the mixer cup, where they will undergo an additional mixing process for a duration of 1 minute at a low-speed setting. During this mixing step, the components of the sludge will be thoroughly blended altogether to ensure homogeneity and uniformity in the final mixture.

4. Result and discussion

Figure 1 indicates that the rheological properties of the system improved with successive addition of bentonite. This means that the mud weight increased as the temperature increased, making it suitable for drilling in deeper formations. Figure 2 shows that funnel viscosity increases even at higher temperatures. The standard Marsh funnel viscosity of water is approximately 26 seconds, whereas our measurement even reached over 30 seconds at higher temperatures. This makes it ideal for hightemperature targeted drilling formations. Figure 3 shows that plastic can perform in higher temperatures, implying that it could be used not only in shallow formations. Thus, Figure 4 shows that pre-hydrated bentonite could still maintain the rheological property of drilling fluids that represents the level of electro-chemical forces in the fluid or known as the yield point in the higher range of temperature. Figure 5 signifies that bentonite returned desired results in the higher temperature range, indicating that it could be used to avoid problems associated with accumulated drilled cuttings and as the main cause of the sticking of the drill string. Figure 6 shows that when measured in the longer time (10 minutes) of gel strength, the water loss was minimized. Figure 7 shows that the water loss was minimized as it reached the higher temperature, making it suitable for deeper drilling formations. As the temperature reached higher, the mud cake (Figure 8) still performed to filter the deposition of solid particles from the drilling fluid onto the wellbore wall, which helped to prevent the loss of drilling fluid into the formation. Finally, Figure 9 showed that the stability of the pre-hydrated bentonite was still maintained within the range of temperature. This condition is in conformity with other studies that recommend keeping the pH of waterbased drilling fluid based on bentonite in the range of 9 to 10 as it provides the optimum mud rheological and filtration properties. Figure 1 to Figure 9 show the results of laboratory measurement for each property.

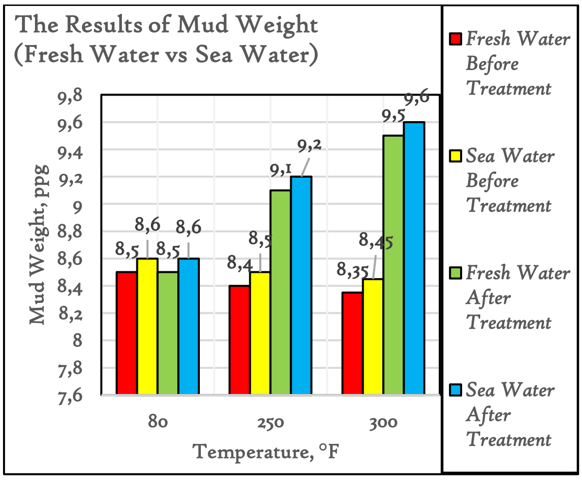

Figure 1. Mud weight measurement Results

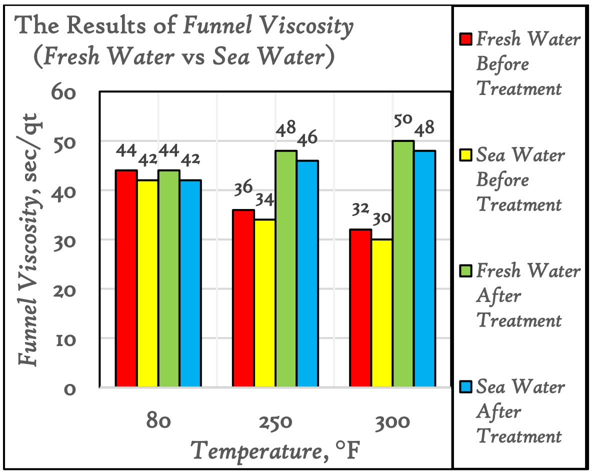

Figure 2. Funnel viscosity measurement results

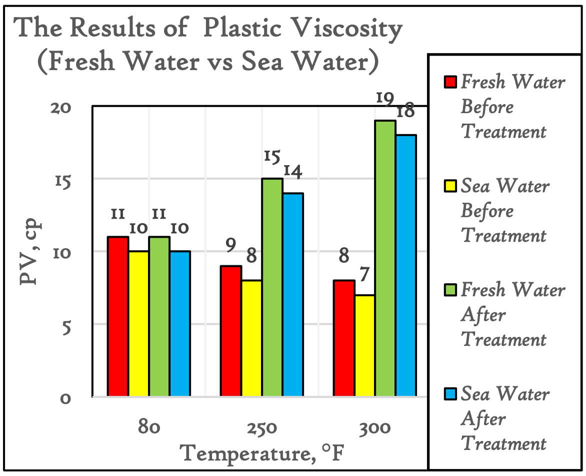

Figure 3. Plastic viscosity measurement results

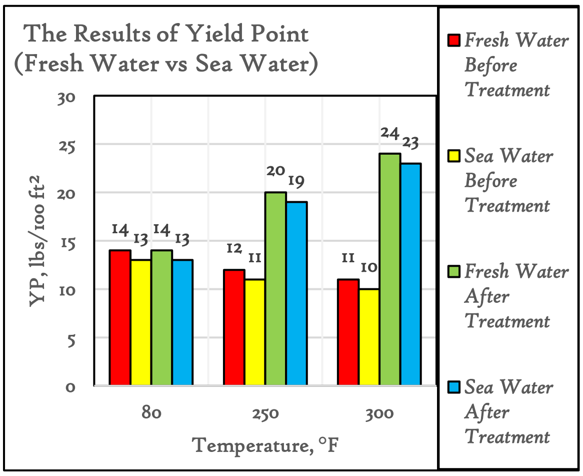

Figure 4. Yield point measurement results

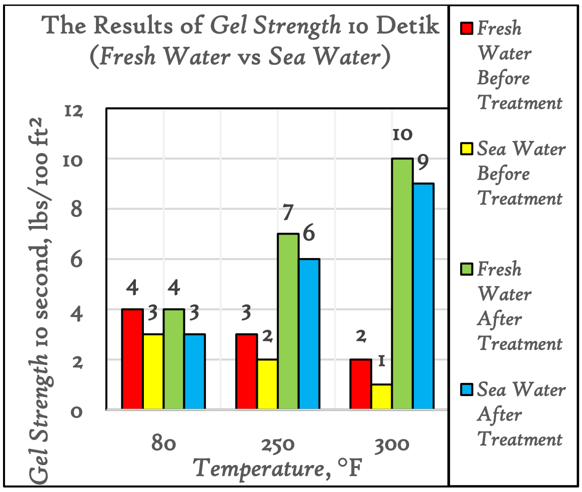

Figure 5. 10 Second gel strength measurement results

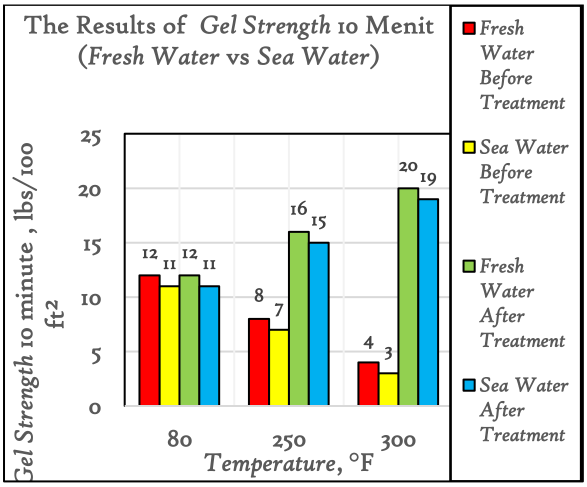

Figure 6. 10 Minute gel strength measurement results

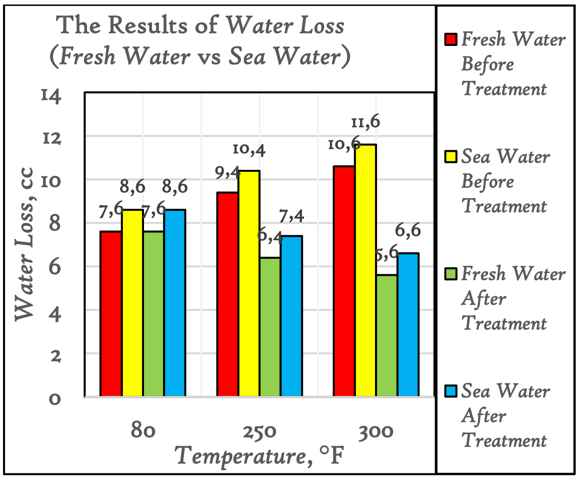

Figure 7. Water loss measurement results

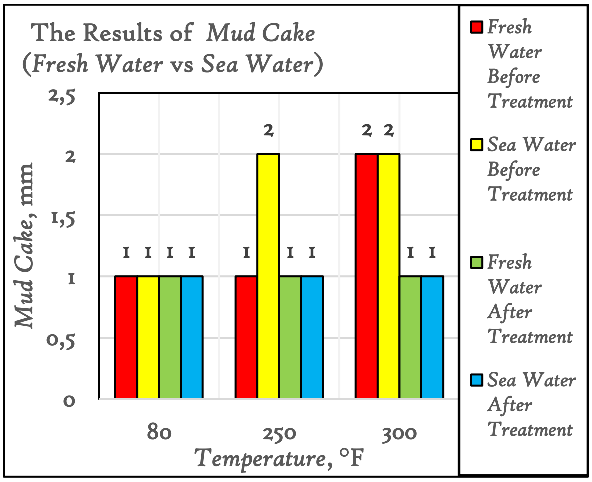

Figure 8. Mud cake measurement results

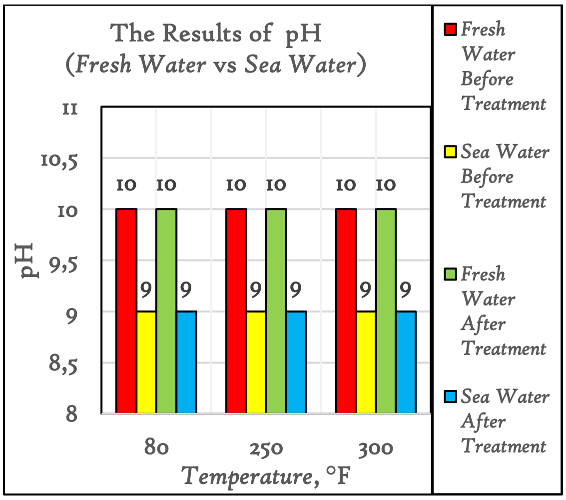

Figure 9. pH measurement results

Table 1. Drilling mud specifications

Properties	Specifications		
	80°F	250°F	300°F
Mud Weight, ppg	8.5 – 9.0	9.0– 9.5	9.5–10.0
Funnel Viscosity, sec/qt	40 – 70	40 – 70	40 – 70
Plastic Viscosity, cp	9.0 – 12.0	12.0 – 16.0	16.0 – 20.0
Yield Point, lbs/100 ft²	9.0 – 15.0	15.0 – 21.0	21.0 – 25.0
10 Second Gel Strength, lbs/100 ft²	2.0 – 5.0	5.0 – 8.0	8.0 – 11.0
10 Minute Gel Strength, lbs/100 ft²	9.0 – 13.0	13.0 – 17.0	17.0 – 21.0
Water Loss, cc	≤10.0	≤10.0	≤10.0
Mud Cake, mm	≤1.0	≤1.0	≤1.0
pH	9.5 – 11.5	9.5 – 11.5	9.5 – 11.5

5. Conclusions

Based on the results of this study, it can be concluded that drilling mud with pre-hydrated bentonite system for sea water is a viable option for optimization in offshore fields. The drilling mud remains in accordance with the specifications that have been given, which is a crucial factor in ensuring that the drilling process is successful. However, to achieve even better results, it is suggested that additives be added to the sea water mud composition. These additives can help to improve the performance of the drilling mud and ensure that it meets the specific requirements of the offshore field. The use of additives in the sea water mud composition can help to enhance the lubricity of the drilling mud, which can reduce the friction between the drill string and the wellbore. This can help to prevent the drill string from getting stuck and improve the overall drilling efficiency. In addition, the use of additives can also help to reduce the amount of fluid loss during drilling, which can minimize the risk of formation damage and improve wellbore stability. By optimizing the composition of the sea water mud, it will be possible to achieve better results in terms of efficiency and effectiveness, which is crucial for successful offshore drilling operations. Therefore, it will be feasible to optimize the drilling process and achieve better results in terms of efficiency and effectiveness.

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PAPER NAME

Maulani_2024_IOP_Conf._Ser.__Earth_Environ._Sci._1339_012018.pdf

AUTHOR

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WORD COUNT

5263 Words

CHARACTER COUNT

27316 Characters

PAGE COUNT

10 Pages

FILE SIZE

706.4KB

SUBMISSION DATE

May 17, 2024 10:47 PM GMT+7

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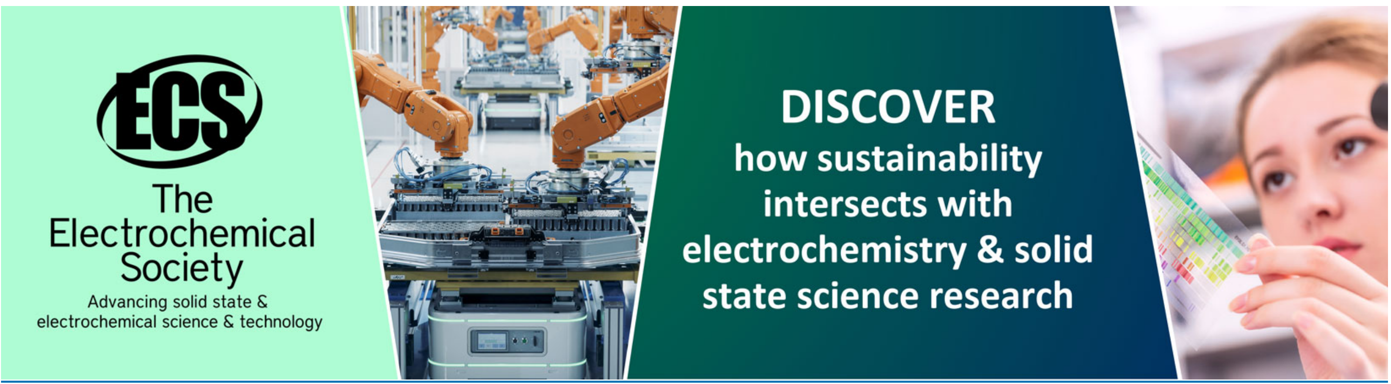

IOP Conf. Series: Earth and Environmental Science 1339 (2024) 012018 doi:10.1088/1755-1315/1339/1/012018

Optimizing the impact of rheological properties on bentonite pre-hydrated based drilling mud through the utilization of pre-hydration

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Abstract. In offshore drilling activities, the employment of seawater mud is indispensable, and its adoption is steadily increasing. Traditionally, attapulgite has held a dominant position as the key element in seawater mud composition. However, a shift is underway towards substituting attapulgite with bentonite owing to the manifold advantages that the latter presents. Bentonite boasts favourable viscosity characteristics and efficient control over water loss, outperforming attapulgite particularly in terms of its capacity for clay absorption. Nevertheless, to harness its thickening capabilities for use with seawater, bentonite necessitates a preliminary hydration process. The pre-hydration procedure involves the amalgamation of seawater and bentonite at a low mixing speed for a duration of 10 minutes, succeeded by a resting interval spanning 16 hours. The integration of this pre-hydrated bentonite system necessitated an extensive research undertaking, encompassing a comprehensive review of pertinent literature, the collection of seawater samples, laboratory experiments conducted at three distinct temperatures comparing both fresh water and seawater formulations, the incorporation of diverse additives to augment the assessment of the mud's physical attributes, meticulous measurement of the drilling mud's physical properties, implementing treatments to enhance measurement values under heightened temperatures, meticulous analysis of acquired data, and the comprehensive documentation of research findings in scholarly publications. The crux of this research endeavour lies in attaining the objective of incorporating pre-hydrated bentonite as a pivotal constituent within seawaterbased drilling mud. The realization of this goal hinges on the congruence of the measured physical properties of the drilling mud with predefined specifications. Through a rigorous exploration of these methodologies and a systematic approach to research, the study endeavours to foster advancements in seawater-based drilling mud formulations and their operational effectiveness within offshore drilling contexts.

1. Introduction

Water-based mud, accounting for approximately 98% of drilling mud usage, is commonly the most employed type in drilling operations. Drilling mud viscosity refers to the thickness or resistance to flow of the drilling fluid utilized during drilling processes. One approach to augmenting drilling mud viscosity involves incorporating bentonite, a clay variant frequently employed as a viscosifier in drilling fluids. The composition of the drilling mud necessitates the adaptation of various combinations and quantities of fresh or salt water, clay, and other chemicals to suit the conditions of the subsurface borehole.

Other freshwater is commonly used in water-based mud, particularly in onshore drilling, due to its convenient availability. On the other hand, the use of brine in water-based mud is more common in offshore drilling and less common in onshore drilling. When drilling encounters a hard layer with low absorption, a less dense drilling mud with a higher water content can be used. Conversely, in highpressure layers with higher absorption rates, dense drilling mud is employed to control layer pressures and mitigate the occurrence of kicks, which can pose challenges.

In summary, water-based mud is the predominant type of drilling mud utilized, and its viscosity can be improved by adding bentonite. The precise composition of the drilling mud, including the types and quantities of water, clay, and additives, must be customized to suit the specific underground conditions. Fresh water is frequently utilized in onshore drilling, whereas brine is commonly employed in offshore drilling. The selection of drilling mud density depends on the characteristics of the geological layers encountered, with less dense mud utilized for hard layers and heavier mud employed in high-pressure formations to effectively control pressure differentials and reduce the occurrence of kicks.

2. Literature review

If Water-based mud is a commonly utilized mud type due to its cost-effectiveness, user-friendliness, and ability to create a filtrate layer for borehole protection. However, water-based mud has drawbacks, such as the potential to contaminate formation layers, leading to suboptimal results in logging processes. Additionally, it is unsuitable for active formations that easily expand upon contact with water [1–4].

The utilization of seawater mud has experienced an upsurge in recent times, thanks to the availability of organic polymers that enhance the formulation and treatment of the mud. Initially, seawater mud was prepared and treated with attapulgite and asbestos to enhance its structural strength for cutting and lifting, along with starch for fluid loss control. However, this mud exhibited low viscosity, making cutting and lifting challenging and resulting in a slow penetration rate [5].

In contrast, modern seawater muds predominantly employ polymeric materials like xanthan gum, polyanionic cellulose, or pre-hydrated bentonite to increase viscosity and reduce fluid loss. Compared to the traditional attapulgite-asbestos-starch mud, this composition offers higher efficiency. The incorporation of polymers facilitates better formation stability through a polymer coating process. As a result, the mud's performance is significantly enhanced, enabling improved cutting, lifting, and penetration rates [6].

In the past, prior to the advancement of drilling technology, water alone was utilized to lift drilling cuttings. However, as drilling technology progressed, the introduction of drilling mud became essential. Drilling mud plays a crucial role in ensuring the success of well drilling operations. Effective control over the composition and conditions of the drilling mud is a vital aspect of conducting well drilling operations. To simplify the understanding of this concept, drilling mud can be assessed based on four key physical properties: density, viscosity, gel strength, and water loss. Additionally, there are other notable characteristics of drilling mud, such as mud pH, sand content, and resistivity [7].

Maintaining seawater-prehydrated bentonite mud is comparatively simple and yields a faster penetration rate compared to the attapulgite-starch pre-slurry system. The lower viscosity of the mud makes it easier to separate cuttings using solids separator equipment. However, the utilization of seawater mud with pre-hydrated bentonite necessitates extra tanks to accommodate the bentonite hydration process. This requirement can pose challenges at offshore drilling sites due to spatial limitations [7].

Bentonite serves as a primary component in the composition of drilling mud. Essentially, bentonite is a type of clay consisting of Na-montmorillonite and Ca-montmorillonite. Na-montmorillonite is particularly advantageous as a base material for drilling mud due to its remarkable ability to expand (swell) up to eight times its original volume when immersed in water. This substantial expansion capacity results in a solution with a considerable viscosity, which plays a crucial role in effectively cleaning the bottom of the borehole. Moreover, it enables the formation of an elastic layer on the hole wall known as "mud cake," providing protection against wall collapse. Bentonite is a composite material comprising a collection of minerals and colloidal substances, including illite, kaolinite, siderite, chloride, attapulgite, and predominantly montmorillonite (85%–90%)[8].

It is well established that bentonite undergoes hydration to varying degrees when mixed with water. Hydrated bentonite forms layers of silica and alumina in different arrangements, creating distinct types of clay structures. These clay particles can consist of single layers or be stacked infinitely on top of each other, resembling a deck of cards bound together in a residual manner. When suspended in water, clay exhibits varying levels of swelling [9].

The bentonite molecule comprises three layers: an alumina layer sandwiched between two silica layers. These bentonite plates carry a negative charge and are associated with cations of the opposite charge. If the associated cations are sodium (Na), the clay is referred to as sodium montmorillonite, whereas calcium (Ca) association gives rise to calcium montmorillonite. Remarkably, even a small quantity of 1% hydrated bentonite in fresh water can achieve a similar thickening effect as 19% barite. Consequently, bentonite can be dispersed and utilized in relatively small amounts while still exhibiting physical properties that enable fluids to suspend a significant portion of barite. Achieving optimal viscosity is a crucial aspect of the production of effective drilling mud. To enhance viscosity, the inclusion of bentonite in the mud is pursued due to its advantageous properties [10].

Bentonite is a natural clay mineral composed mainly of montmorillonite (Medhi et al., 2020), which has unique properties that make it effective in enhancing drilling mud viscosity. When bentonite is added to the drilling fluid, it undergoes a process known as hydration, where it absorbs water and forms a gellike structure. This gel formation significantly increases the thickness and consistency of the drilling mud, leading to a higher viscosity [11].

The mechanism behind bentonite's ability to increase viscosity lies in its plate-like structure and the ability of water molecules to interact with its surface. The charged surfaces of the bentonite particles attract water molecules, causing them to surround and interact with the clay particles. As more water is absorbed, the clay particles swell and interlock with each other, creating a three-dimensional network that impedes fluid flow and enhances viscosity [12].

By increasing the viscosity of drilling mud, bentonite offers several advantages in drilling operations. Firstly, it helps to suspend and transport drill cuttings, ensuring efficient removal from the wellbore. This is crucial for maintaining wellbore stability and preventing blockages during drilling. Secondly, the increased viscosity of the drilling mud provides better hole cleaning and helps prevent fluid invasion into the formation being drilled. This can help to minimize formation damage and maintain well integrity [13].

It is important to note that the amount of bentonite added to the drilling mud should be carefully controlled to achieve the desired viscosity [14]. Excessive bentonite addition can lead to excessively high viscosity, which may hinder drilling progress and increase pumping requirements. Therefore, the optimal concentration of bentonite should be determined based on factors such as the specific drilling conditions, desired mud properties, and the characteristics of the formation being drilled [15] and completion [16–18].

Overall, the addition of bentonite to drilling mud effectively increases viscosity, allowing for improved suspension, transport of cuttings, and wellbore stability during drilling operations [19–21].

3. Methodology

The research was carried out at the Drilling and Production Engineering Laboratory of Universitas Trisakti to assess the physical characteristics of drilling mud with a pre-hydrated bentonite system. The experimental procedure began with the preparation of two mud compositions: one with fresh water and the other with sea water, both at room temperature (80°F). In separate mixer cups, 340 ml of fresh water and 345 ml of sea water were combined with 15 grams of bentonite and mixed using a Hamilton mixer for 10 minutes. Subsequently, the resulting mud compositions were transferred into two different beakers for prehydration over a period of 16 hours. The purpose of prehydration was to allow the bentonite to fully blend with the sea water, resulting in improved viscosity and controlled water loss.

Following the 16-hour prehydration period, the pre-hydrated mud samples were first mixed at a low speed for 1 minute to ensure uniform blending. Then, various additives were introduced and mixed at different speeds. The duration and speed of the mixing process were significant factors affecting the mixing rate, which in turn influenced the measurement of the drilling mud's physical properties.

The initial additive introduced was soda ash, which served as a pH controller. A quantity of 1.2 grams was added to fresh water, while 2.2 grams were added to sea water. The mixture was stirred for 1 minute at a low speed. The second additive, XCD, acted as a biopolymer to regulate the rheology of the mud, focusing on plastic viscosity and yield point. For fresh water, 0.5 gram of XCD was added, and for sea water, 1 gram was added. The mixture was stirred for 4 minutes at a low speed.

Next, the third additive, pac-R (also known as Drispac Regular), was included to enhance viscosification and reduce filtration loss. For fresh water, 1 gram of Pac-R was added and mixed for 4 minutes at a low speed. For sea water, 2 grams of Pac-R were added and mixed for 4 minutes at a high speed. The high-speed mixing in sea water was necessary as pac-R proved more challenging to blend in sea water compared to fresh water, leading to an increased presence of pac-R residue when mixed at low speed.

The fourth additive, PHPA, functioned as a biopolymer to regulate mud rheology, particularly gel strength. A quantity of 0.5 gram of PHPA was added to fresh water, while 1 gram was added to sea water. The mixture was stirred for 4 minutes at high speed. The fifth additive, pac-LV, served as both a filtration loss reducer and a viscosifier. For fresh water, 0.5 gram was added, and for sea water, 1 gram was added. The stirring speed was set to low for fresh water and high for sea water.

The sixth additive, lignite, acted as a thinner and was added in a quantity of 1 gram to fresh water. The mixture was stirred for 5 minutes at high speed. Lignite was not added to seawater due to its inability to dissolve effectively in highly concentrated salt solutions. Sea water typically contains a salt concentration of 30,000–35,000 ppm. The mixture was then further stirred for 5 minutes at a high speed to ensure thorough blending of the ingredients. Finally, 2 ml of defoamer was added and stirred for 2 minutes at a low speed to eliminate foaming. Foaming occurred in both compositions as a result of prolonged high-speed mixing.

Once the two mud compositions of the pre-hydrated bentonite system at room temperature have been prepared, the physical properties of the mud will be measured. These properties include mud weight (ppg), funnel viscosity (sec/qt), plastic viscosity (cp), yield point (lbs/100 ft2), 10-second gel strength (lbs/100 ft2), 10-minute gel strength (lbs/100 ft2), water loss (cc), mud cake (mm), and pH. Various tools will be used for these measurements, such as a mud balance for mud weight, a marsh funnel for funnel viscosity, a fann VG meter for mud rheology (PV, YP, and gel strength), an API filter press for water loss and mud cake measurements, and pH stripes with the assistance of an API filter press for pH determination.

The third and fourth compositions of the pre-hydrated bentonite system drilling mud in fresh water and sea water will undergo a temperature increase to 250°F. The pre-hydration solution will be allowed to stand for the usual 16 hours, followed by an additional 1-minute mixing at low speed. The additives added will be the same as the sludge composition at 80°F, with the inclusion of barite as a weighting agent, which will be mixed for 5 minutes at high speed. The mixture will then be placed in a roller tube and baked for 1 hour at a temperature of 250°F. After 1 hour, the two sludge compositions will be placed back in the mixer cup and mixed for 1 minute at low speed. The purpose of this remixing is to prevent material sagging.

Due to the temperature increase, the physical properties of the drilling mud will change, deviating from the mud specifications. Therefore, treatment is necessary. The composition of the freshwater mud will be treated by adding several additives, including 40 grams of barite, 1 gram of lignite, 0.5 gram of pac-LV, 1 gram of pac-R, 0.5 gram of PHPA, and 0.5 gram of XCD. Similarly, the seawater mud composition will be treated with additional additives, including 30 grams of barite, 1 gram of pac-LV, 1.5 grams of pac-R, 1 gram of PHPA, and 1 gram of XCD.

The fifth and sixth compositions of the pre-hydrated bentonite system drilling mud in fresh water and sea water will experience a temperature increase to 300°F. The prehydration solution will undergo the usual 16-hour resting period, followed by an additional 1-minute mixing at low speed. The additives added will be the same as the sludge composition at 250°F, but the volume of water added will change to 330 ml for fresh water and 335 ml for sea water. The mixture will then be placed in a roller tube and baked for 1 hour at a temperature of 300°F. After 1 hour, the two sludge compositions will be placed back in the mixer cup and mixed for 1 minute at low speed.

Again, due to the temperature increase, the physical properties of the drilling mud will change, deviating from the mud specifications. Therefore, treatment is necessary. The composition of the freshwater mud will be treated by adding several additives, including 20 grams of barite, 0.5 grams of lignite, 0.2 grams of pac-LV, 0.5 grams of pac-R, 0.2 grams of PHPA, and 0.2 grams of XCD. Similarly, the seawater mud composition will be treated with additional additives, including 15 grams of barite, 0.3 grams of pac-LV, 0.5 grams of pac-R, 0.3 grams of PHPA, and 0.3 grams of XCD.

After the two sludge compositions have been transferred back into the mixer cup, they will undergo mixing for a duration of 1 minute at a low-speed setting. During this process, the components of the sludge will be thoroughly combined and blended altogether.

The two prepared sludge compositions will be returned to the mixer cup, where they will undergo an additional mixing process for a duration of 1 minute at a low-speed setting. During this mixing step, the components of the sludge will be thoroughly blended altogether to ensure homogeneity and uniformity in the final mixture.

4. Result and discussion

Figure 1 indicates that the rheological properties of the system improved with successive addition of bentonite. This means that the mud weight increased as the temperature increased, making it suitable for drilling in deeper formations. Figure 2 shows that funnel viscosity increases even at higher temperatures. The standard Marsh funnel viscosity of water is approximately 26 seconds, whereas our measurement even reached over 30 seconds at higher temperatures. This makes it ideal for hightemperature targeted drilling formations. Figure 3 shows that plastic can perform in higher temperatures, implying that it could be used not only in shallow formations. Thus, Figure 4 shows that pre-hydrated bentonite could still maintain the rheological property of drilling fluids that represents the level of electro-chemical forces in the fluid or known as the yield point in the higher range of temperature. Figure 5 signifies that bentonite returned desired results in the higher temperature range, indicating that it could be used to avoid problems associated with accumulated drilled cuttings and as the main cause of the sticking of the drill string. Figure 6 shows that when measured in the longer time (10 minutes) of gel strength, the water loss was minimized. Figure 7 shows that the water loss was minimized as it reached the higher temperature, making it suitable for deeper drilling formations. As the temperature reached higher, the mud cake (Figure 8) still performed to filter the deposition of solid particles from the drilling fluid onto the wellbore wall, which helped to prevent the loss of drilling fluid into the formation. Finally, Figure 9 showed that the stability of the pre-hydrated bentonite was still maintained within the range of temperature. This condition is in conformity with other studies that recommend keeping the pH of waterbased drilling fluid based on bentonite in the range of 9 to 10 as it provides the optimum mud rheological and filtration properties. Figure 1 to Figure 9 show the results of laboratory measurement for each property.

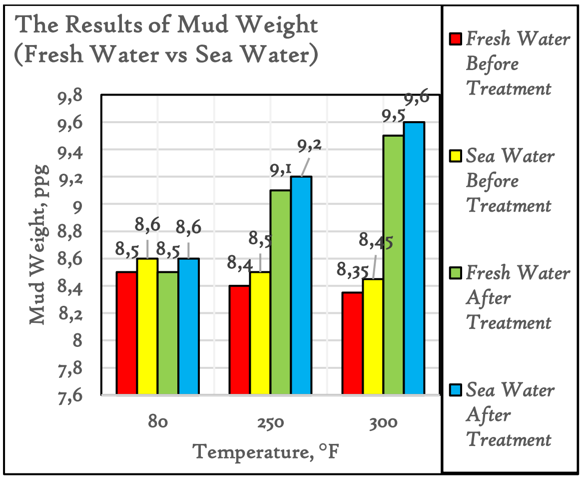

Figure 1. Mud weight measurement Results

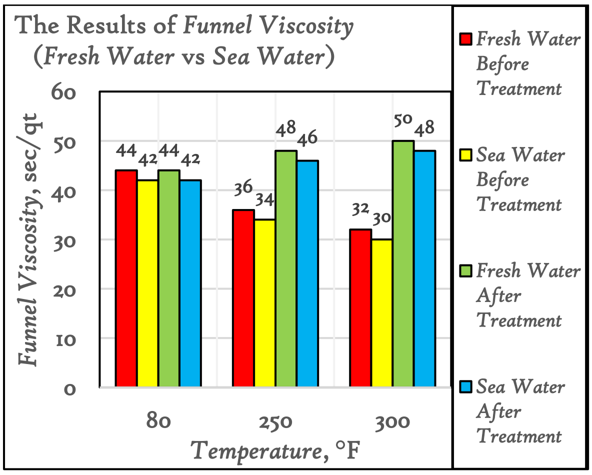

Figure 2. Funnel viscosity measurement results

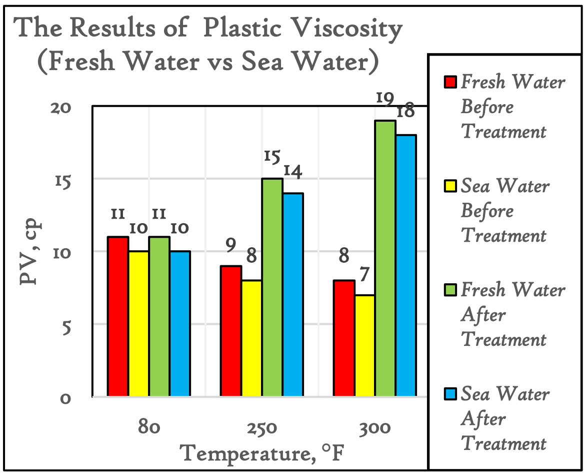

Figure 3. Plastic viscosity measurement results

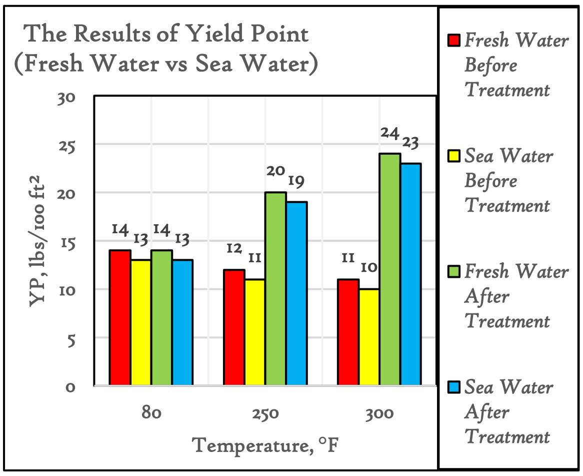

Figure 4. Yield point measurement results

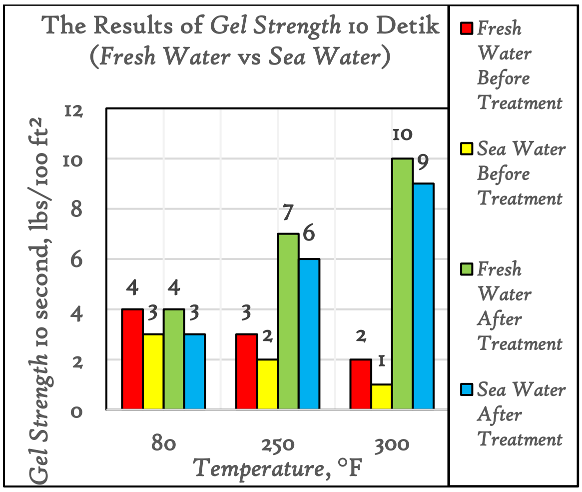

Figure 5. 10 Second gel strength measurement results

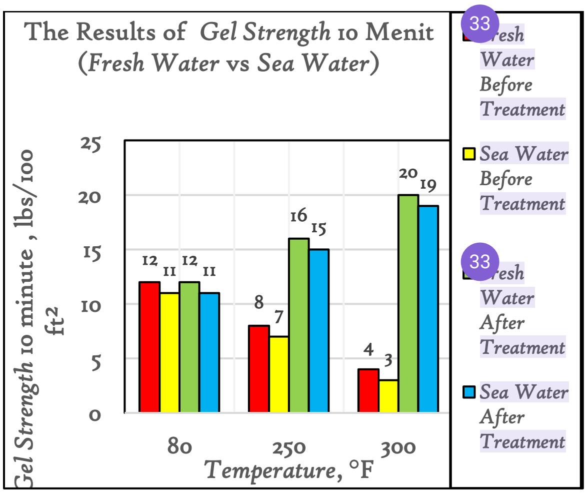

Figure 6. 10 Minute gel strength measurement results

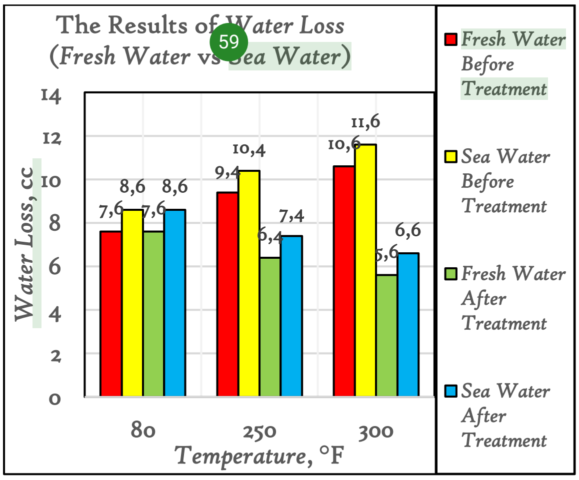

Figure 7. Water loss measurement results

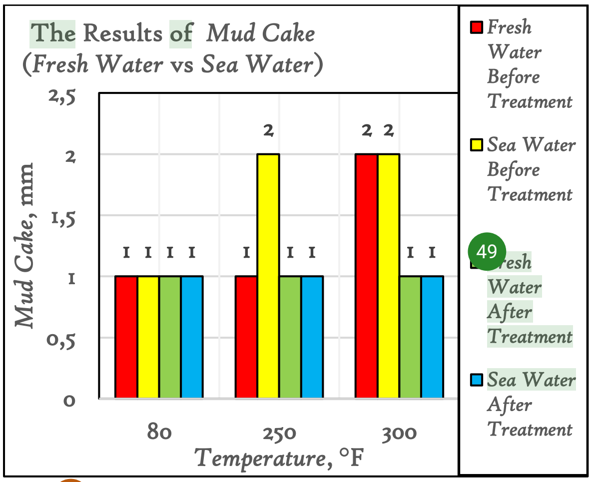

Figure 8. Mud cake measurement results

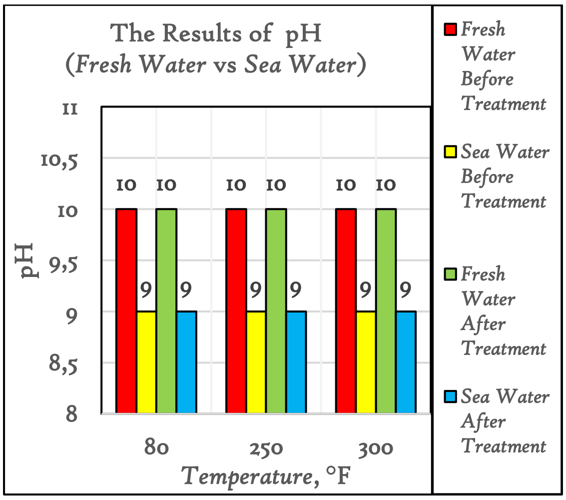

Figure 9. pH measurement results

Table 1. Drilling mud specifications

Properties	Specifications		
	80°F	250°F	300°F
Mud Weight, ppg	8.5 – 9.0	9.0– 9.5	9.5–10.0
Funnel Viscosity, sec/qt	40 – 70	40 – 70	40 – 70
Plastic Viscosity, cp	9.0 – 12.0	12.0 – 16.0	16.0 – 20.0
Yield Point, lbs/100 ft²	9.0 – 15.0	15.0 – 21.0	21.0 – 25.0
10 Second Gel Strength, lbs/100 ft²	2.0 – 5.0	5.0 – 8.0	8.0 – 11.0
10 Minute Gel Strength, lbs/100 ft²	9.0 – 13.0	13.0 – 17.0	17.0 – 21.0
Water Loss, cc	≤10.0	≤10.0	≤10.0
Mud Cake, mm	≤1.0	≤1.0	≤1.0
pH	9.5 – 11.5	9.5 – 11.5	9.5 – 11.5

5. Conclusions

Based on the results of this study, it can be concluded that drilling mud with pre-hydrated bentonite system for sea water is a viable option for optimization in offshore fields. The drilling mud remains in accordance with the specifications that have been given, which is a crucial factor in ensuring that the drilling process is successful. However, to achieve even better results, it is suggested that additives be added to the sea water mud composition. These additives can help to improve the performance of the drilling mud and ensure that it meets the specific requirements of the offshore field. The use of additives in the sea water mud composition can help to enhance the lubricity of the drilling mud, which can reduce the friction between the drill string and the wellbore. This can help to prevent the drill string from getting stuck and improve the overall drilling efficiency. In addition, the use of additives can also help to reduce the amount of fluid loss during drilling, which can minimize the risk of formation damage and improve wellbore stability. By optimizing the composition of the sea water mud, it will be possible to achieve better results in terms of efficiency and effectiveness, which is crucial for successful offshore drilling operations. Therefore, it will be feasible to optimize the drilling process and achieve better results in terms of efficiency and effectiveness.

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