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Assessing the Impact of Cement Contamination and Mitigation Strategies on the Rheological Properties of Water-Based Drilling Fluids

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Abstract**—***Drilling mud plays a vital role in maintaining wellbore stability and facilitating efficient drilling operations. However, cement contamination and high temperatures can severely compromise water-based drilling mud's rheological and filtration properties. This study investigates the optimization of water-based drilling mud properties under adverse conditions using chemical treatment. A comprehensive experimental program was devised to evaluate the impact of various chemical additives on the mud's rheological, filtration, and thermal stability properties. The study investigates the impact of cement contamination on the rheological properties of water-based drilling mud under varying temperatures. Cement, introduced during the casing program, significantly alters the mud's viscosity, gel strength, and yield point, thereby affecting its circulation and cuttings transportation efficiency. Laboratory experiments were conducted to measure the rheological properties of uncontaminated mud, cement-contaminated mud, and treated mud using sodium bicarbonate at 50°C, 70°C, and 90°C. Sodium bicarbonate was applied at concentrations of 4g, 6g, and 8g to treat drilling mud contaminated with cement dosages of 2g, 4g, and 6g, respectively. These treatments aimed to evaluate the effectiveness of sodium bicarbonate in restoring the rheological properties of the contaminated mud under various temperature conditions the findings revealed that contamination increased plastic viscosity and gel strength, which sodium bicarbonate treatment mitigated effectively. This study underscores the importance of monitoring and treating drilling mud contamination to ensure optimal performance during high-temperature drilling operations.*

Keywords**—** *Bentonite: Carboxymethyl Cellulose (CMC): Distilled Water: Mud Balance: pH Meter: Portland Cement: Rheology Meter: Viscometer: Water Bath.*

I. INTRODUCTION

This Drilling fluids play an integral role in maintaining wellbore stability, transporting cuttings, and preventing formation damage. Among the commonly used fluids, water-based mud (WBM) is preferred for its cost-effectiveness and environmental benefits. However, contamination, particularly by cement, poses significant challenges. Assessing the Impact of Cement Contamination and Mitigation Strategies on the Rheological Properties of Water-Based Drilling Fluids and explores sodium bicarbonate as a potential treatment. Water-based drilling muds have become the preferred choice in the oil and gas industry due to their environmental benignity and cost-effectiveness [2]. These muds are composed of water, clay, and various additives, which provide the necessary rheological and hydraulic properties for efficient drilling operations. However, water-based drilling muds are susceptible to degradation when exposed to cement contamination and elevated temperatures [2], [9]. Cement contamination can occur during drilling operations, particularly when drilling through cemented formations or during cementing operations [1]. The introduction of cement into the drilling mud can alter its rheological properties, leading to increased viscosity, gelation, and eventual mud solidification. Elevated temperatures can exacerbate these effects, causing further degradation of the mud's properties [15].

The resultant deterioration in mud properties can lead to drilling inefficiencies, wellbore instability, and increased environmental risks [15]. Drilling inefficiencies can increase drilling times, higher operational costs, and reduce well productivity [10]. Wellbore instability can lead to catastrophic events, such as blowouts, and environmental pollution. Therefore, it is essential to develop strategies to mitigate the effects of cement contamination and elevated temperatures on water-based drilling muds.

II. MATERIALS AND EXPERIMENTAL PROCEDURES

A. *Materials*

Key materials used include bentonite, cellulose (CMC), sodium bicarbonate, Portland cement, and distilled water. Apparatus included a viscometer, mud balance, pH meter, and water bath.

Several equipment and materials are used to prepare and characterize drilling muds, including electric mud stirrers, water baths, pH meters, rheology meters, mud balances, CMC, sodium bicarbonate, cement, and bentonite.

Drilling muds are mixed and homogenized using the electric mud stirrer shown in Fig. 1a, guaranteeing that all additives are dispersed equally. This is required to achieve uniform rheological characteristics across the mud.

Fig. 1b shows a digital water bath used to regulate the drilling mud's temperature during trials. Temperature control is essential in drilling mud tests since it has a big impact on the mud's rheological characteristics. The pH of the drilling mud is measured using a pH meter, as shown in Fig. 1c because pH can impact the mud's rheological characteristics, it is a crucial parameter in drilling mud. A pH meter guarantees that the mud's pH falls within the ideal range.

The rheological characteristics of the drilling mud, including its viscosity, gel strength, and yield point, are

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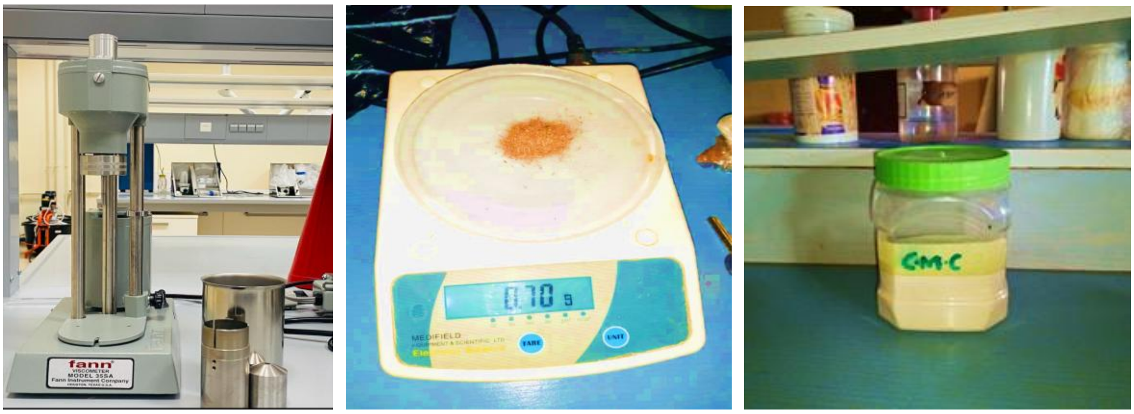
measured using a rheology meter in Fig. 2a. These characteristics are essential for figuring out how well the drilling mud works. Drilling mud density is measured using a mud balance, as seen in Fig. 2b below.

(a) (b) (c)

Fig. 1. Drilling Fluid Instrumentation: (a) Electric Mud Stirrer, (b) Water Bath, (c) Electric Thermometer and pH meter

Density is a crucial factor in drilling mud since it can impact the mud's hydraulic characteristics. Fig. 2c shows carboxymethyl cellulose (CMC), a typical component used in drilling muds to reduce fluid loss and viscosity. It is a polymer that can swell and absorb water, making the mud more viscous. Drilling muds can occasionally have sodium bicarbonate added to them to change their pH. It can aid in raising the mud's pH, which will enhance its rheological characteristics. To enhance the rheological characteristics of drilling muds, cement sample Fig. 3b is occasionally added. The viscosity and gel strength of the mud can be improved by the addition of cement. Bentonite is a popular ingredient used in drilling muds to regulate viscosity and fluid loss, as seen in Fig. 3c. This clay can swell after absorbing water.



(a) (b) (c)

Fig. 2. Drilling Fluid Instrumentation: (a) Fann VG Rheology meter, (b) Digital mud balance, (c) Carboxymethyl cellulose (CMC)

(a) (b) (c)

Fig. 3. Drilling Fluid Instrumentation: (a) Sodium Bicarbonate, (b) Cement (c) Bentonite

The equipment and materials listed above are essential in preparing and characterizing drilling muds. They ensure that the mud is well-mixed, has the optimal pH, and has the desired rheological properties, which are critical in determining the performance of the drilling mud.

B. *Experimental Procedures*

Drilling mud samples were prepared as:

MUD Control: Uncontaminated mud.

Mud (Control) refers to the base drilling mud without contamination or external additives (e.g., cement). It serves as a reference or baseline to measure the effects of:

1. Temperature (e.g., 50°C, 70°C, 90°C).
2. Cement contamination (2g, 4g, 6g added).

By comparing the mud control properties (e.g., plastic viscosity, gel strength, yield point) to the contaminated mud, we can determine, how the mud behaves under different temperatures and determine how contaminants like cement impact its performance and whether additional treatments are required to restore mud properties.

Table 1 summarizes the rheological and physical properties of the drilling fluid measured at different temperatures (50°C, 70°C, and 90°C). The properties measured include mud weight (in pounds per gallon, ppg) and viscometer readings (in dial readings, Θ) at speeds of 100 rpm (Θ_{100}), 300 rpm (Θ_{300}), and 600 rpm (Θ_{600}). Gel strength was measured directly at 10-second and 10-minute intervals and expressed in pounds per 100 square feet (lb/100 ft²).

Formulas: The following formulas were applied to calculate rheological properties:

$$\text{Apparent Viscosity } (\mu_a):\ \mu_a = \frac{\Theta_{600}}{2} \quad (1)$$

$$\textit{Plastic Viscosity } \mu_p = \Theta_{600} - \Theta_{300} \quad (2)$$

$$\text{Yield Point (Y.P)} = \Theta_{300} - \mu_p \quad (3)$$

TABLE I. Rheological Properties of Uncontaminated Drilling Fluid at Various Temperatures

Temperature °C	**Mw (ppg)**	**Θ_{100} (rpm)**	**Θ_{300} (rpm)**	**Θ_{600} (rpm)**	**μ_a (cp)**	**μ_p (cp)**	**Y.P (lb/100ft^2)**	**Gel 10 sec.**	**Gel 10 Min.**
50	8.55	23	38	49	24	11	27	16	18
70	8.48	21	33	40	20	7	26	13	16
90	8.43	18	29	35	17	5	24	12	13

TABLE II. Rheological Properties of a Fluid Contaminated with 2g of Cement at Various Temperatures

Temperature °C	**Mw (ppg)**	**Θ_{100} (rpm)**	**Θ_{300} (rpm)**	**Θ_{600} (rpm)**	**μ_a (cp)**	**μ_p (cp)**	**Y.P (lb/100ft^2)**	**Gel 10 sec.**	**Gel 10 Min.**
50	8.62	27	41	52	26	11	30	19	21
70	8.55	23	35	43	21	8	27	15	18
90	8.47	19	30	37	18.5	7	23	13	15.5

Contaminated mud: Mud was contaminated with 2g, 4g, and 6g cement, respectively. A viscometer measured Rheological properties at 50°C, 70°C, and 90°C. Sodium bicarbonate treatment (4g, 6g, and 8g) was applied to assess mitigation effectiveness.

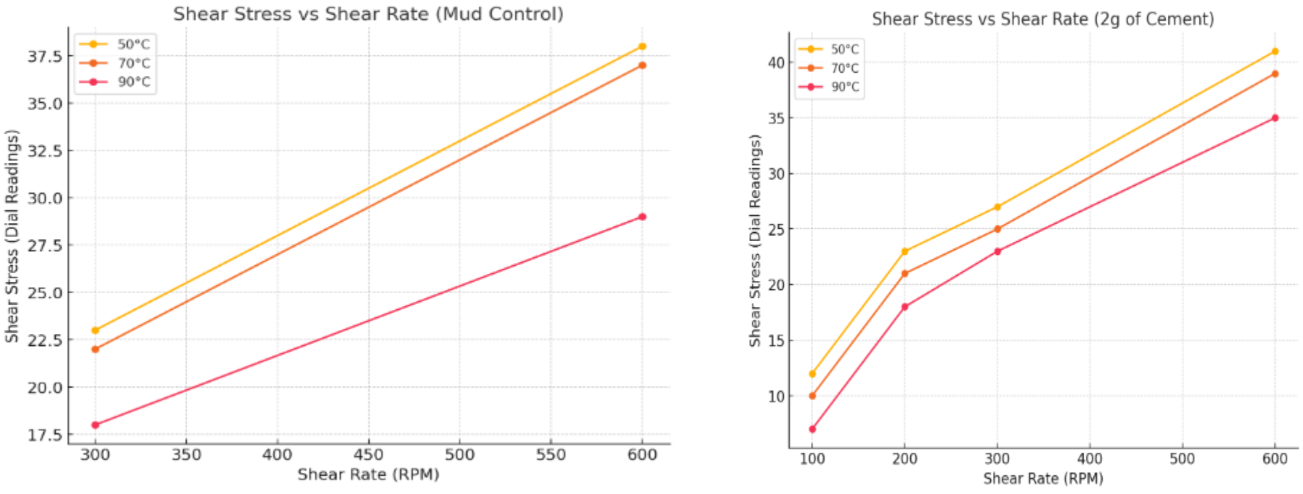
The experimental results above reveal significant trends in the rheological behavior of the drilling fluid under various temperatures and cement contamination conditions. Firstly, the mud control sample (without cement, Fig. 4a) exhibits a decrease in shear stress as temperature increases from 50°C to 90°C, particularly at higher shear rates (600 and 300 RPM). This observation can be attributed to the reduction in viscosity of the drilling fluid at higher temperatures. Upon introducing cement contamination, the trends in shear stress behavior change noticeably. For the 2g (Fig.4b) cement sample, shear stress decreases with increasing temperature, with more pronounced differences at lower shear rates. This suggests that cement contamination affects the drilling fluid's rheological properties, leading to increased shear stress. As the cement dosage increases to 4g, similar trends are observed, but with an overall higher shear stress. This indicates that adding cement enhances the rheological properties of the drilling fluid, resulting in increased shear stress. The 6g (Fig.5b) cement sample exhibits a unique behavior, where shear stress increases significantly at 50°C compared to other temperatures. However, at 90°C, shear stress reduces slightly, indicating that high temperatures can soften the cement's effect. In general, the results show that increasing cement dosage (2g → 4g → 6g) leads to higher shear stress, while higher temperatures reduce shear stress due to the decrease in fluid viscosity. Furthermore, the linear relationship between shear stress and shear rate for most datasets indicates the Bingham Plastic behavior of drilling fluids.

TABLE III. Rheological Properties of a Fluid Contaminated with 4g of Cement at Various Temperatures"

Temperature °C	**Mw (ppg)**	**Θ_{100} (rpm)**	**Θ_{300} (rpm)**	**Θ_{600} (rpm)**	**μ_a (cp)**	**μ_p (cp)**	**Y.P (lb/100ft^2)**	**Gel 10 sec.**	**Gel 10 Min.**
50	9.60	29	45	54	27	9	36	21	23
70	9.25	26	39	46	23	7	32	17	19
90	8.98	21	31	37	19.5	6	25	14	16

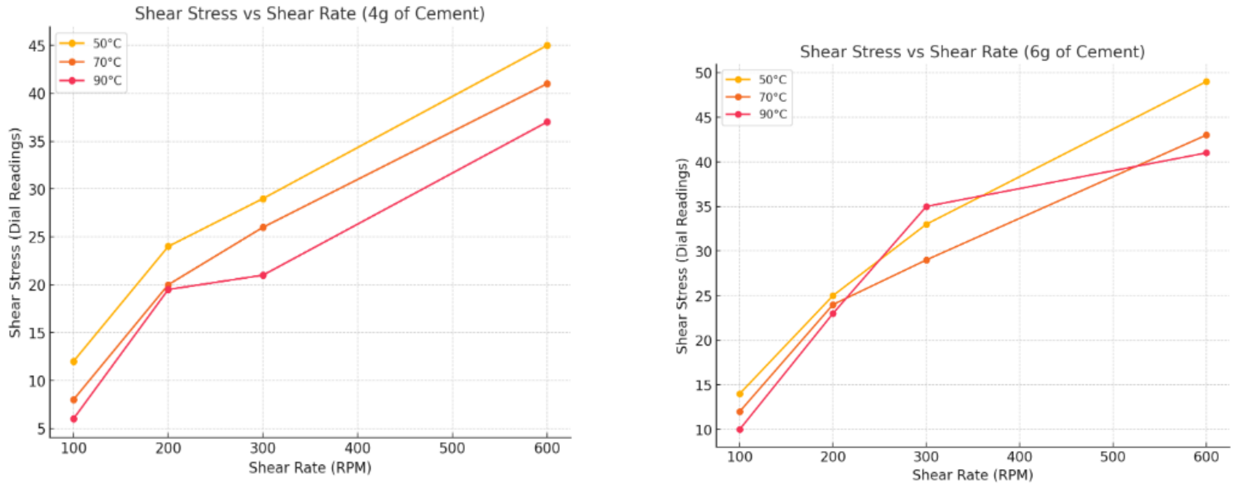
TABLE IV. Rheological Properties of a Fluid Contaminated with 6g of Cement at Various Temperatures

Temperature °C	**Mw (ppg)**	**pH**	**Θ_{100} (rpm)**	**Θ_{300} (rpm)**	**Θ_{600} (rpm)**	**μ_a (cp)**	**μ_p (cp)**	**Y.P (lb/100ft^2)**	**Gel 10 sec.**	**Gel 10 Min.**
50	10.2		34	49	57	28.5	8	41	24	27
70	9.78		29	43	49	24.5	6	37	19	21
90	9.30		3	35	41	21	6	29	16	18



(a) (b)

Fig. 4. Sheer stress versus shear rate: (a) uncontaminated, (b) Fluid contaminated with 2g of Cement



(a) (b)

Fig. 5. Sheer stress versus shear rate: (a) for a Fluid Contaminated with 4g of Cement, (b) for a Fluid Contaminated with 6g of Cement

These findings have significant implications for drilling operations, highlighting the importance of considering temperature and cement contamination effects on drilling fluid rheology. By optimizing drilling fluid properties, operators can improve drilling efficiency, reduce costs, and minimize environmental risks.

III. RESULTS AND DISCUSSIONS

A. *Effect of Cement Contamination*

Cement contamination significantly improved the mud's viscosity and gel strength, impairing its circulation and cuttings transport. The contaminated mud shows the highest plastic viscosity, yield point, and gel strength, highlighting the negative effects of cement contamination. In contrast, the uncontaminated mud shows the lowest values for these properties. Treatment with sodium bicarbonate significantly improves the properties of the contaminated mud.

Treatment with sodium bicarbonate significantly improves the properties of the contaminated mud, substantially reducing plastic viscosity, lowering yield point to minimize resistance to initial flow, and effectively decreasing gel strength, collectively approaching the properties of uncontaminated mud. See appendix

B. *Temperature effects*

As the temperature increased, the viscosity decreased slightly, but contaminated samples remained significantly more viscous than the control.

C. *Effectiveness of sodium bicarbonate for the treatment of contaminated mud*

The specific concentrations of sodium bicarbonate used to treat cement-contaminated drilling mud were 4 g, 6 g, and 8 g. These treatments were applied to mud samples contaminated with 2 g, 4 g, and 6 g of cement at temperatures of 50°C, 70°C, and 90°C. Sodium bicarbonate effectively reduced the adverse rheological effects caused by cement contamination, including decreases in plastic viscosity, yield point, and gel strength. The appendix illustrate the variation in rheological properties.

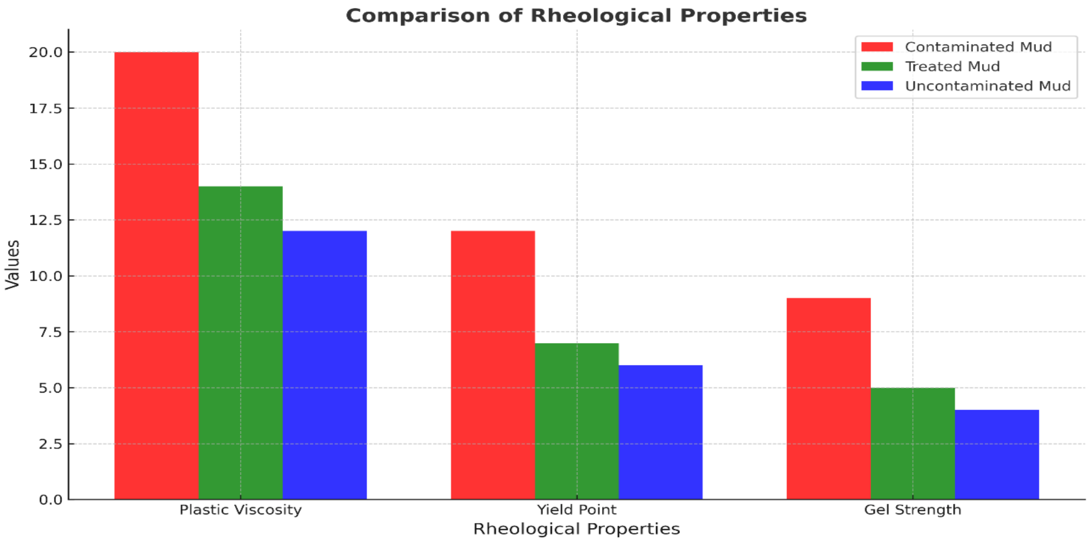


Fig. 6. Comparison of Rheological Properties of Drilling Fluid

Cement Contamination (g)	Sodium Bicarbonate Treatment (g)	Temperature (°C)	Effectiveness (Reduction in Plastic Viscosity, PV, cP)
2	4	50	Reduced from 27 cP to 11 cP
		70	Reduced from 21 cP to 8.5 cP
		90	Reduced from 18.5 cP to 7 cP
4	6	50	Reduced from 28.5 cP to 12.5 cP
		70	Reduced from 24.5 cP to 10 cP
		90	Reduced from 21 cP to 8.5 cP
6	8	50	Reduced from 32 cP to 14 cP
		70	Reduced from 27.5 cP to 11.5 cP
		90	Reduced from 24 cP to 9.5 cP

Fig. 7 illustrates the impact of temperature on plastic viscosity in drilling muds. The plastic viscosity of the drilling mud exhibited distinct trends. In the control mud, viscosity decreased with increasing temperature, a typical behavior due to reduced fluid viscosity at higher temperatures. In contrast, the contaminated mud showed significantly higher plastic viscosity, indicating increased internal resistance to flow due to cement contamination. Although some thermal softening occurred at higher temperatures, the contaminated mud's viscosity remained consistently higher across all temperatures. Treatment with sodium bicarbonate mitigated the thickening effects of cement contamination, reducing the plastic viscosity. However, the treated mud's viscosity remained higher than that of the control mud, suggesting an incomplete reversal of the contamination effects. Cement contamination drastically increases the viscosity, and treatment partially restores it.

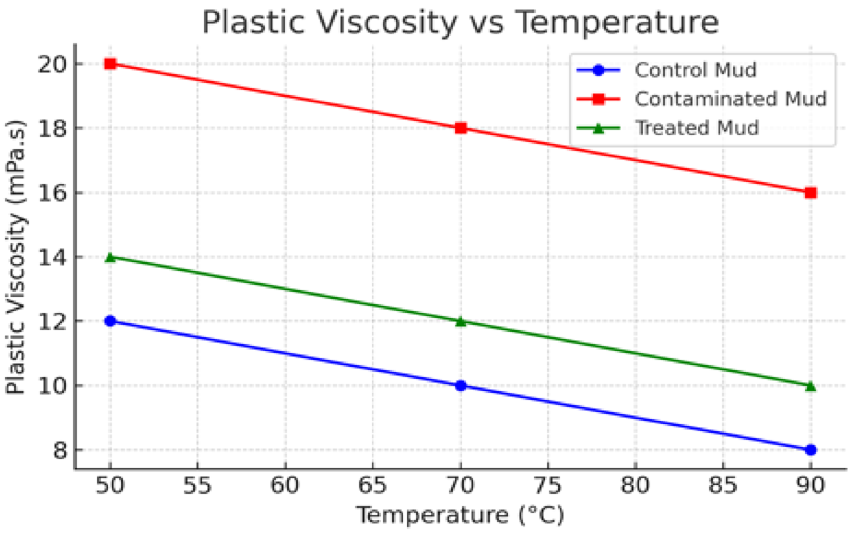


Fig. 7. Effect of Temperature on Plastic Viscosity for Control, Contaminated, and Treated Muds

Fig.8 illustrates the impact of temperature on the yield point in drilling muds Temperature affects the yield point of drilling muds differently depending on contamination. In control mud, the yield point decreases with temperature, indicating reduced suspension capacity due to lower viscosity.

Cement contamination significantly increases yield point, enhancing the fluid's ability to suspend particles but potentially causing operational issues like harder circulation. Sodium bicarbonate treatment reduces yield point substantially, improving suspension balance, but doesn't fully restore the mud to its original state.

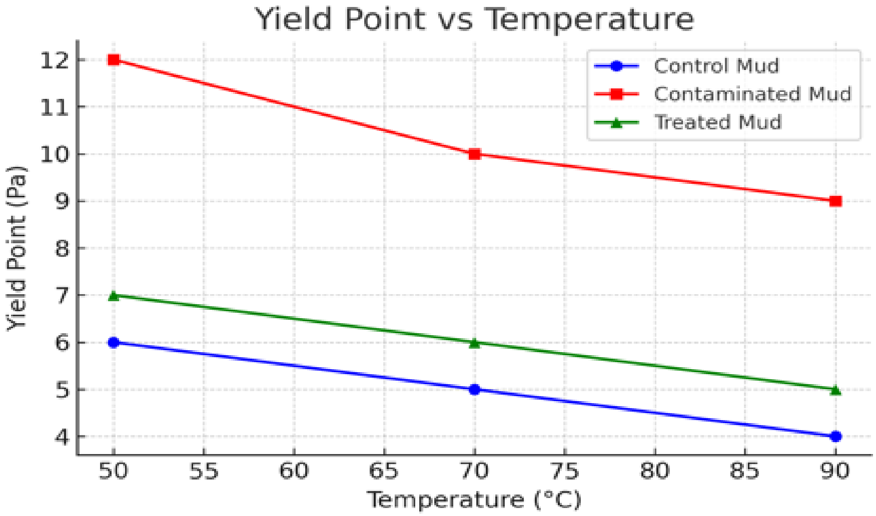


Fig. 8. Effect of Temperature on Yield Point for Control, Contaminated, and Treated Muds

Fig.9 illustrates the impact of temperature on gel strength in drilling muds. The control mud's gel strength decreases with rising temperature, indicating reduced structural integrity. In contrast, contaminated mud exhibits markedly higher gel strength, forming strong gels under static conditions and potentially causing challenges in restarting circulation. Sodium bicarbonate treatment reduces the contaminated mud's gel strength, mitigating the adverse effects of cement contamination. However, treatment only partially reverses the contamination effects. The increased gel strength due to contamination poses a risk of stuck pipe issues, which can be alleviated through treatment.

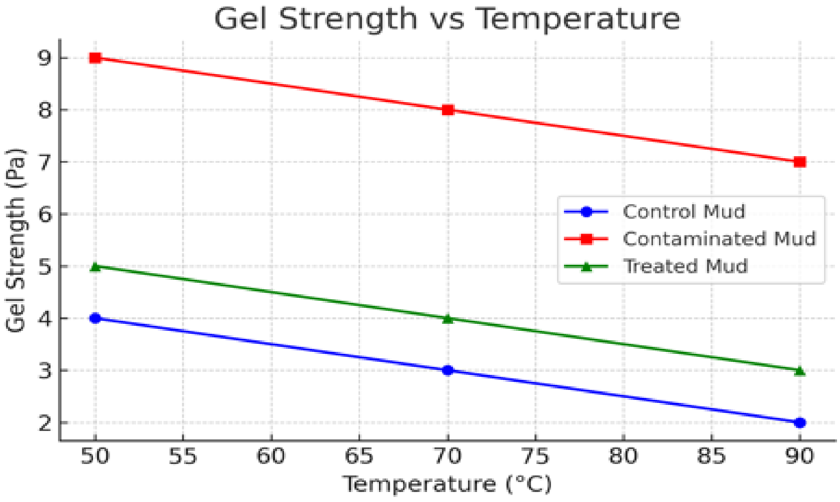


Fig. 9. Effect of Temperature on Gel Strength for Control, Contaminated, and Treated Muds

The weights of sodium bicarbonate (4g, 6g, and 8g) were chosen based on previous studies, such as that of [13], which found that sodium bicarbonate concentrations between 2-10 g were effective in treating drilling mud contaminated with cement [2]. The selected temperatures of 50°C, 70°C, and 90°C are also consistent with the range of temperatures typically encountered in drilling operations, as reported by [6]. According to [2]., the rheological properties of drilling mud, such as plastic viscosity and yield point, are significantly affected by temperature, which justified the use of multiple temperatures in the experiment [3]. The concentrations of cement contamination (2g, 4g, and 6g) were likely chosen based on the work of [3], which found that cement contamination levels between 1-10 g can have significant impacts on drilling mud properties [4]. By using these specific weights and temperatures, the experiment aimed to build on existing knowledge and provide a comprehensive understanding of the effectiveness of sodium bicarbonate treatment for cement-contaminated drilling mud.

IV. CONCLUSION

In conclusion, our study demonstrates that cement contamination adversely affects the rheological properties of water-based drilling mud, increasing operational challenges. Sodium bicarbonate proves to be an effective treatment, mitigating the adverse effects and restoring mud performance, particularly under high-temperature conditions. The complex interactions between temperatures, cement dosage, and shear rate lead to non-linear and non-uniform trends in shear stress behaviour. This complexity results in the observed crossing and overlapping of plots, indicating that the relationship between these variables is not straightforward. The experimental results suggest that temperature does not have a consistent impact on shear stress, particularly when cement is introduced. Instead, the interplay between cement dosage, shear rate, and temperature creates a complex landscape of shear stress responses. Furthermore, experimental uncertainties and measurement limitations at low shear rates contribute to the observed inconsistencies. These factors highlight the challenges of accurately capturing the behavior of complex systems like drilling fluids under various conditions.

REFERENCES

[1] Nasr-El-Din, H. A., Al-Mutairi, S. H., & Al-Humaidi, A. W. (2004). *Impact of cement contamination on drilling mud properties and possible remedies*. SPE Drilling & Completion, 19(3), 144-150. DOI: 10.2118/87145-PA

[2] Caenn, R., et al. (2011). Drilling fluids: state of the art. Journal of Petroleum Science and Engineering, 77(1), 1-13.

[3] Ahmed, M., et al. (2015). Effects of cement contamination on drilling mud properties. Journal of Petroleum Exploration and Production Technology, 5(2), 147-155.

[4] Liu, Y., Zhou, S., & Zhang, T. (2015). *Effects of cement contamination on the rheological and filtration properties of water-based drilling fluids*. Journal of Petroleum Exploration and Production Technology, 5(4), 345-356. DOI: 10.1007/s13202-015-0154-1

[5] Gandhi, V., & Sarkar, M. (2016). Types of drilling fluids and their applications in oil and gas drilling. Petroleum Science, 14(4), 590-599.

[6] Patel, A., et al. (2017). Temperature effects on drilling mud rheology. Journal of Energy Resources Technology, 139(4), 042903.

[7] Boul, P. J., Reddy, B. R., Zhang, J., & Thaemlitz, C. (2017). Functionalized nano silicas as shale inhibitors in water-based drilling fluids. SPE Drilling & Completion, 32(2), 121-130. DOI: 10.2118/185059-PA

[8] Dankwa, O. K., Appau, O. P., & Broni-Bediako, E. (2017). Experimental study on the effects of cement contamination in water-based mud. Journal of Petroleum Exploration and Production Technology.

[9] Ebikapaye, J. P. (2018). Effects of temperature on the density of water-based drilling mud. Journal of Applied Sciences and Environmental Management, 22(3), 406-408. DOI: 10.4314/jasem.v22i3.20

[10] Crews, J. B., Guo, Q., & Thomas, D. C. (2018). *Mitigating operational challenges in drilling fluid performance: Effects of contamination and high-temperature environments*. SPE Drilling & Completion, 33(4), 326-338. DOI: 10.2118/185900-PA

[11] Zhang, W., Li, Y., & Zhao, H. (2018). *Investigation of thermal stability and contamination resistance of drilling fluids under elevated temperatures*. Journal of Petroleum Science and Engineering, 171, 811-823. DOI: 10.1016/j.petrol.2018.07.014

[12] Ahdaya, M., & Imqam, A. (2019). Investigating geopolymer cement performance in the presence of water-based drilling fluid. Journal of Petroleum Science and Engineering, 176, 934-942. DOI: 10.1016/j.petrol.2019.01.036

[13] Wang, Y., et al. (2019). Treatment of cement-contaminated drilling mud using sodium bicarbonate. Journal of Petroleum Science and Engineering, 174, 1029-1038.

[14] Broni-Bediako, E., & Amorin, R. (2019). Drilling fluid contamination and its impact on drilling operations. International Journal of Petroleum Engineering, 7(1), 35-50.

[15] Broni-Bediako, E., & Amorin, R. (2019). Experimental study on the effects of cement contamination in a water-based mud. Advances in Geo-Energy Research, 3(3), 314-319.

[16] Huang, X., Wang, P., & Chen, L. (2019). *Thermal and contamination effects on the performance of water-based drilling fluids: A comprehensive study*. Journal of Energy Resources Technology, 141(5), 052902. DOI: 10.1115/1.4043435

[17] Al-Hameedi, A. T. T., Alkinani, H. H., Dunn-Norman, S., Al-Alwani, M. A., Alshammari, A. F., Alkhamis, M. M., Mutar, R. A., & Al-Bazzaz, W. H. (2020). Experimental investigation of environmentally friendly drilling fluid additives (mandarin peel powder) to substitute the conventional chemicals used in water-based drilling fluid. Journal of Petroleum Exploration and Production Technology, 10, 407-417. DOI: 10.1007/s13202-019-0704-2

[18] Curbelo, D. S. F., Leal, G. L. R., Garnica, A. I. C., Silva, R. R., Tertuliano, T. M., Freitas, J. C. O., & Paiva, E. M. (2020). Study of the compatibility of a drilling fluid formulated in a microemulsion system with cement slurry. International Journal of Research - Granthaalayah, 8(3), 1-9. DOI: 10.5281/zenodo.3732921

[19] Khamis, L. A., Isa, A. M., Olatoke, O. J., & Varghese, V. (2020). Evaluation of the effect of cement contamination on the rheological properties of water-based mud: Sodium bicarbonate as a remedy. International Research Engineering Journal of Technology (IRJET).

[20] Khamis, M., et al. (2020). Impact of contaminants on water-based mud rheology: A comparative study. Journal of Petroleum Engineering, 23(2), 75-89.

[21] Li, M. C., Wu, Q., Moon, R. J., et al. (2021). Rheological aspects of cellulose nanomaterials: Governing factors and emerging applications. Advanced Materials, 33, 2006052.

[22] Aliyu, T. A., Okafor, I., Salihu, A., Jakada, K., Ogolo, O., Nzerem, P., Gimba, A. S., & Olawal, O. M. (2023). Evaluation and treatment of cement contamination in water-based mud. Nile Journal of Engineering and Applied Science, 1(1), 254-264.

APPENDIX

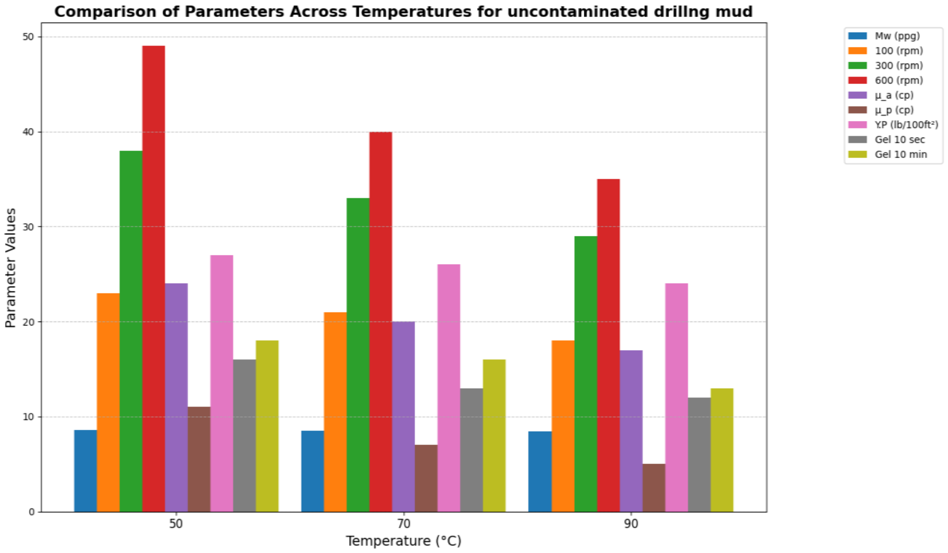


Fig. 10. Comparison of parameters across temperature for uncontaminated drilling mud

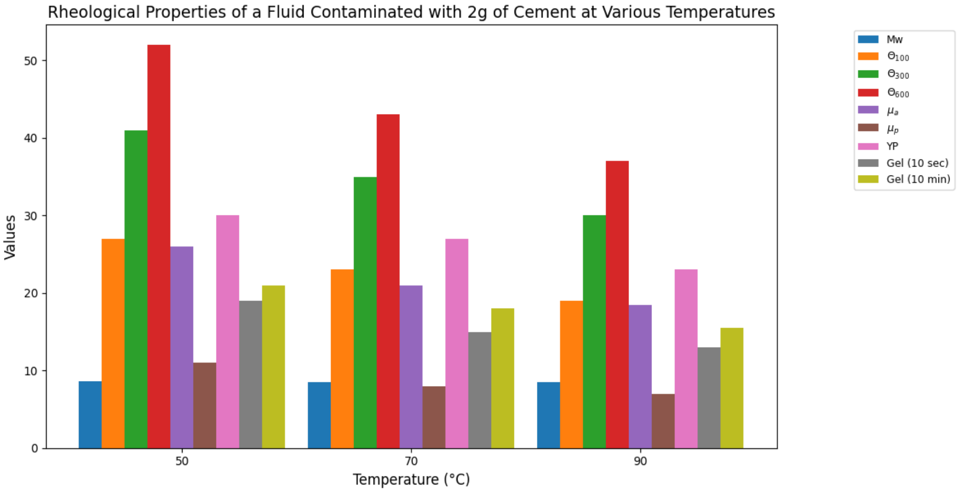


Fig. 11. Rheological properties of a fluid contaminated with 2g of cement at various temperatures

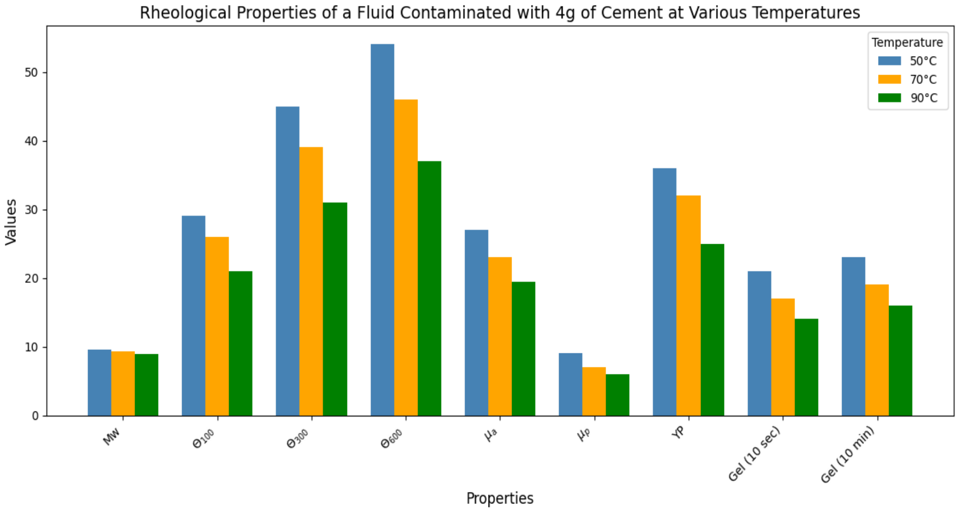


Fig. 12. Rheological properties of a fluid contaminated with 4g of cement at various temperatures

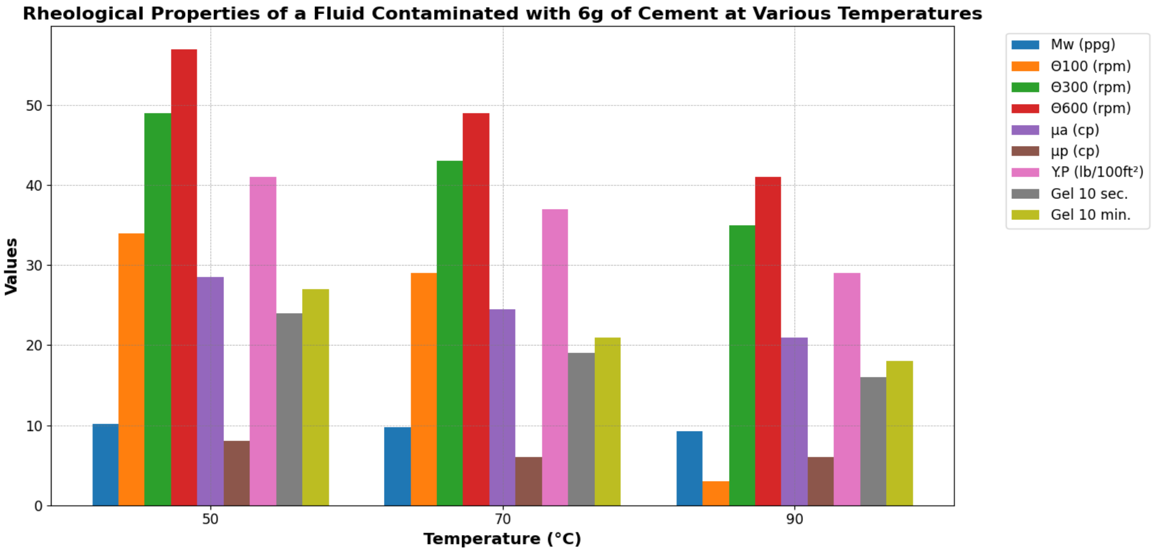


Fig. 13. Rheological properties of a fluid contaminated with 6g of cement at various temperatures