International Journal of Innovative Scientific & Engineering Technologies Research 14(3):200-205, July-Sept, 2026

© SEAHI PUBLICATIONS, 2026 www.seahipublications.org **ISSN: 2360-896X**

DOI:10.5281/zenodo.22877920

Evaluation of the Drilling Fluid Properties of Suspected Montmorillonite Mud from River Ethiope, Abraka, Delta State, Nigeria

Igoru Ufuoma Alex

Department of Petroleum Engineering,
Faculty of Engineering,
Delta State University, Abraka, Nigeria
Corresponding Author: ufuomaigoru@delsu.edu.ng

ABSTRACT

This study examines the rheological properties of a locally sourced suspected montmorillonite clay located along the River Ethiope in Abraka, Delta State, Nigeria, to evaluate its suitability for use in water-based drilling fluid formulations. Clay samples were collected from a depth of 2.5 ft. The samples were air-dried, crushed, and sieved to 75 μm to ensure uniform particle size. Various mud formulations were prepared by dispersing clay concentrations of 20.0 g, 25.0 g, 30.0 g, and 35.0 g in 400 mL of fresh water, then mixed and aged at room temperature for 24 hours. Rheological and physical properties, including plastic viscosity, apparent viscosity, yield point, mud weight, sand content, and pH, were analyzed using the Fann V-G meter, Baroid mud balance, sand content kit, and pH paper.Initial results showed that unmodified clay samples had viscosities below API standards (30 cp at 600 rpm). However, after beneficiation with 1.0 g of hydroxyl ethyl cellulose (HEC) and ageing for five days, the formulation containing 35.0 g of clay achieved optimal rheological values of 62 cp (600 rpm), 35.0 cp (plastic viscosity), 31.0 cp (apparent viscosity), and 8.0 lb/100 ft² (yield point). The native mud pH increased from 7 to 12 following treatment with 0.1 g of KOH, aligning with the API-recommended range of 9.5–12.5. Mud weight also increased to 10.2 ppg with the addition of 0.5 g of barite, while sand content remained low at 0.2%, well within API limits.These findings indicate that with proper beneficiation and ageing, this locally available clay holds potential as an effective substitute for imported bentonite in drilling fluid applications.

Keywords: Montmorillonite clay; Drilling Fluid; Rheology; Apparent Viscosity; Plastic Viscosity; Yield Point; Mud Weight; Sand Content.

1. INTRODUCTION

Drilling fluids, commonly known as drilling muds, are essential in oil and gas exploration, serving multiple functions, including lubricating and cooling drill bits, stabilizing borehole walls, and transporting cuttings to the surface. The effectiveness of drilling fluids significantly impacts the efficiency and safety of drilling operations (Amani & Al-Jubouri, 2021). Among various types of drilling fluids, water-based muds (WBMs) are particularly favoured for their environmental friendliness and cost-efficiency Ahmed *et al*. (2022). Montmorillonite, a major constituent of bentonite clay, is widely utilized in drilling fluid formulations due to its exceptional swelling capacity, thixotropic behaviour, and superior rheological

properties Chen *et al.* (2023). As a layered silicate mineral with a high cation exchange capacity (CEC), montmorillonite's hydration and swelling characteristics enhance its ability to stabilize wellbores and facilitate efficient cuttings transport (Liu *et al.* 2022; Huang *et al.*2023). Its established role in maintaining viscosity and ensuring wellbore stability under challenging downhole conditions is well-documented Singh *et al.* (2021).

In Nigeria, the presence of extensive local clay deposits offers a promising alternative to imported bentonite, providing a cost-effective solution for drilling operations. Recent studies suggest that suspected montmorillonite-rich clays in Nigeria have the potential to be used as drilling fluid additives Adepoju *et al*. (2023). This study aims to investigate the drilling fluid properties of suspected montmorillonite mud sourced from River Ethiope in Abraka, Delta State, Nigeria. By evaluating key parameters such as viscosity, density, filtration loss, and pH, the study seeks to determine its suitability for application in oilfield operations. Previous research by Alade *et al.* (2024) revealed that indigenous montmorillonite-containing clays exhibit comparable rheological performance to commercial bentonite. Likewise, Adepoju *et al.* (2023) emphasized the effectiveness of local clays in drilling fluid applications when adequately processed and activated. The utilization of locally sourced clay not only reduces operational expenses but also mitigates the environmental impact associated with the transportation of imported drilling additives. Recent technological advancements in beneficiation have further improved the quality and applicability of indigenous clay-based drilling fluids, promoting their adoption within the Nigerian oil and gas sector (Ahmed *et al*.2022; Chen *et al*. (2023). While previous studies primarily explored the characterization and application of bentonite and other clays, there remains a gap in research regarding the suspected montmorillonite deposits along the River Ethiope. This study aims to address this knowledge gap by providing empirical data on the drilling fluid properties of these local clay deposits, contributing to sustainable and cost-efficient drilling practices in Nigeria.

2. MATERIALS AND METHODS

The material used in this study was a suspected Montmorillonite mud extracted from a depth of 2.5 feet beside the River Ethiope in Abraka, Delta State, Nigeria. The collected sample was subsequently air-dried, crushed, and sieved to 75µm to ensure uniform particle size distribution. This process was consistent with the preparation methods described by Adewumi and Ismail (2023) for evaluating clay materials in drilling applications.Following sieving, specific amounts of the sample were accurately weighed using a triple-beam balance to obtain 20.0g, 25.0 g, 30.0g and 35.0g of the clay. Each portion was mixed with 400 mL of fresh water in separate containers. The mixtures were then agitated to achieve homogeneity and allowed to age for 24 hours at room temperature to simulate field conditions, asrecommended by Alade *et al.* (2024).After the ageing period, the following parameters were determined using industry-standard equipment:Fann V-G Meter was used to measure Apparent Viscosity (AV), Plastic Viscosity (PV), and Yield Point (YP).Baroid Mud Balance to determine the mud density.The Triple Beam Balance was used for precise sample measurement.The Sand Content Kit was used for assessing the sand content in the mud.pH Paper was used for determining the pH level of the mud, while the Retort Stand was used for holding the apparatus securely during measurements.

The following standard formulas were applied to compute the required rheological parameters (API, 2023):

$$Apparent\ Viscosity(AV) = \frac{\theta_{600}}{2}(centipoise) \quad (1)$$

$$Plastic\ Viscosity\ (PV) = \theta_{600} - \theta_{300}(centipoise) \quad (2)$$

$$Yield\ Point\ (YP) = \theta_{300} - PV\ \left({}^{lb}/_{100ft^2}\right) \quad (3)$$

$$Power\ law\ Index\ (n) = 3.32 \log\left(\frac{\theta_{600}}{\theta_{300}}\right) - - - - - - - - - - - - - - - - (4)$$

$$Consistency\ Index\ (K) = 5.1 \times \frac{\theta_{600}}{y^n} - - - - - - - - - - - - - - - - - (5)$$

Where y=511 and 1022, and n is the power law index.

This approach ensures accurate determination of the drilling fluid properties, which is essential for evaluating the suitability of suspected montmorillonite clay in drilling operations (Jayaraman *et al.*2021; API, 2023).

3. RESULTS

Table 1:Initial Characterization of the Clay Sample

Clay conc. (g)	Viscosity reading (Cp)	Mud gel strength	Consistency Index(k) (Dyne sec/cm3)	Mud power law index (n)	Mud (PV) Cp	Mud(AV) Cp	Mud (YP)lb/100 ft^2	Mud Weight ppg	Mud pH	Sand Content (%)
	600rpm 300rpm	10sec 10min	@511 @1022							
	1.5	0.3	0.0004							
20.0	0.5	0.2	0.0001	1.58	1.0	0.75	-0.5	8.9	7.0	0.2
	1.7	0.5	0.0097							
25.0	0.8	0.3	0.0045	1.09	0.9	0.85	-0.1	8.9	7.0	0.2
	2.2	0.7	0.0234							
30.0	1.1	0.3	0.0118	0.99	1.1	1.1	0.0	8.9	7.0	0.2
	2.5	0. 9	0.1263							
35.0	1.5	0.4	0.0756	0.74	1.0	1.25	0.5	8.9	7.3	0.2

Table 2:Experimental datacollected after a 24-hour fresh water ageing period of the beneficiated clay.

Clay conc. (g)	Viscosity reading (Cp)	Mud gel strength	Consistency Index(k) (Dyne sec/cm3)	Mud power law index (n)	Mud (PV) Cp.	Mud (AV) Cp.	Mud Yield Point (Y.P)lb/100 ft^2	Mud Weight (MW) ppg	Mud pH	Sand Content (SC).(%)
	600rpm 300rpm	10sec 10min	@511 @1022							
	1.7	0.2	0.0097							
20.0	0.8	0.3	0.0045	1.09	0.9	0.85	-0.1	8.9	7.0	0.2
	1.9	0.5	0.0012							
25.0	0.7	0.6	0.0004	1.44	1.2	0.95	-0.5	8.9	7.0	0.2
	2.1	1.0	0.0053							
30.0	0.9	0.9	0.0023	1.22	1.2	1.05	-0.3	8.9	7.0	0.2
	2.3	1.2	0.0158							
35.0	1.1	1.1	0.0076	1.06	1.2	1.15	-0.1	8.9	7.0	0.2

Table 3: API standard values

Mud Parameters	API Numerical Requirement	Reference
Mud Density (lb/gal)	8.65 – 9.60 (min – max)	API RP 13B-1 (2019); Rabia (2002)
Viscosity at 600 rpm (dial reading)	≥ 30 cp	API RP 13 B-1 (2019)
Plastic Viscosity (PV) (cp)	8 – 10 cp	API RP 13B-1 (2019); Darley & Gray (1988)
Yield Point (YP) (lb/100 ft²)	YP = 3 × PV	Rabia (2002); Gray & Darley (1988)
Fluid Loss (API Filtration Test)	≤ 15.0 mL	API RP 13 B-1 (2019)
pH Level	9.5 – 12.5	API RP 13 B-1 (2019)
Sand Content (%)	≤ 1.0 – 2.0%	API RP 13 B-1 (2019)
YP/PV (Marsh Ratio)	≤ 3.0	Rabia (2002); API Tech Manual
Power Law Index "n"-factor	≤ 1.0	API RP 13D (2009); Caenn et al. (2017)

Table 4: showing the result of the sample after ageing for five days

Clay conc. (g)	No of Days	V.R (Cp) 600rpm 300rpm	GS. 10sec 10min	K. Dyne sec/cm3 @511 @1022	N	PV Cp.	AV Cp.	Y.P lb/100ft^2	MW ppg	Mud pH	SC %
		8	0.5	0.59							
20.0	2	5	0.8	0.37	0.68	2.0	4.0	3.0	8.9	12	0.2
		9	1.2	0.003							
	3	7	0.9	0.001	1.54	2.0	4.5	5.0	8.9	12	0.2
		10	1.4	20.01							
	4	9	1.2	18.04	0.15	1.0	5.0	8.0	8.9	12	0.2
		15	0.9	4.62							
	5	11	0.6	3.38	0.45	4.0	7.5	7.0	8.9	12	0.2
		23	1.5	0.33							
25.0	2	12	1.1	0.17	0.94	11.0	11.5	1.0	8.9	12	0.2
		24	1.9	0.006							
	3	8	0.7	0.002	1.58	16.0	12.0	-8.0	8.9	12	0.2
		26	1.9	0.02							
	4	10	0.7	0.004	1.38	16.0	13.0	-6.0	9.3	12	0.2
		33	1.9	0.26							
	5	16	0.7	0.125	1.04	17.0	16.5	-1.0	9.3	12	0.2
		36	2.3	0.07							
30.0	2	15	1.7	0.03	1.26	21.0	18.0	-6.0	9.6	12	0.2
		40	2.4	1.48							
	3	23	1.4	0.86	0.79	17.0	20.0	6.0	10.2	12	0.2
		40	1.9	2.02							
	4	24	0.7	1.21	0.74	16.0	20.0	8.0	10.2	12	0.2
		50	3.0	6.44							
	5	33	2.7	4.28	0.59	17.0	25.0	16.0	10.2	12	0.2

		49	3.5	1.17							
35.0	2	27	1.8	0.65	0.86	22.0	24.5	5.0	10.2	12	0.2
		58	2.9	0.42							
	3	28	1.7	0.20	1.05	30.0	29.0	-2.0	10.2	12	0.2
		60	2.8	1.05							
	4	32	2.7	0.56	0.91	28.0	30.0	4.0	10.2	12	0.2
		62	3.6	0.19							
	5	27	2.0	0.08	1.19	35.0	31.0	8.0	10.2	12	0.2

5. DISCUSSION

The rheological properties and physicochemical characteristics of the montmorillonite clay-based mud samples are presented in Table 4. The results indicate notable trends consistent with prior research on drilling fluids formulated from bentonite and similar clays. As clay concentration increased from 20.0 g to 35.0 g, both the plastic viscosity (PV) and apparent viscosity (AV) showed a corresponding increase, with peak values observed on the fifth day of ageing (PV = 35.0 cp and AV = 31.0 cp at 35.0 g). This behaviour aligns with findings by Jayaraman et al. (2021), who reported that higher clay concentrations improve the suspension stability and viscosity of drilling muds, enhancing hole cleaning efficiency and suspension of cuttings. The yield point (YP), an indicator of the mud's ability to carry solids, also increased with clay content and ageing time, reaching 8.0 lb/100 ft² at 35.0 g. This is within the typical range recommended for water-based muds by the API (2023) to maintain sufficient carrying capacity without excessive pump pressure. Alade et al. (2024) similarly observed that ageing improves the interaction between clay particles, thus increasing YP and overall mud stability.
The mud weight increased progressively with clay concentration, peaking at 10.2 ppg at 35.0 g, which is within the typical range for water-based drilling fluids used in shallow to medium depth wells (API, 2023). The pH of the mud was consistently maintained at 12, which is optimal for montmorillonite clays to prevent flocculation and ensure colloidal stability (Adewumi & Ismail, 2023). Maintaining an alkaline pH also improves the chemical stability of additives such as potassium hydroxide used for beneficiation, as supported by results from Singh et al. (2022). Sand content remained low (0.2%) across all samples, significantly below the API maximum limit of 2%, indicating effective beneficiation and preparation methods. Low sand content is critical to prevent abrasion and wear in drilling equipment and to maintain mud viscosity and filtration properties (Chukwu et al., 2021). These results are consistent with Adewumi and Ismail (2023), who demonstrated that beneficiated Nigerian montmorillonite clays could meet or exceed API standards when properly prepared and aged. Similarly, Jayaraman et al. (2021) showed that ageing and appropriate additive use substantially improve rheological properties, corroborating the upward trends observed in Table 3. Recent advances by Liao et al. (2023) emphasize the importance of optimizing power law rheological parameters for effective drilling fluid performance, and the data from this study suggest that the local clay behaves as a pseudoplastic fluid, ideal for drilling operations.

6. CONCLUSION

This study has effectively evaluated the drilling fluid properties of a suspected montmorillonite clay sourced from the River Ethiope in Abraka, Delta State, Nigeria. The findings reveal that the raw clay possesses favourable baseline characteristics, including a low sand content (0.2%) and neutral ph. Following chemical beneficiation with potassium hydroxide (KOH), the pH increased to 12, aligning well with the API recommended range for drilling fluids (9.5–12.5). Although the initial rheological properties fell below API specifications, treatment with hydroxyl ethyl cellulose (HEC) and an ageing period of five days significantly enhanced the clay's performance. The optimised formulation (35.0 g/400 mL) met critical rheological benchmarks, achieving 62 cp at 600 rpm, 35.0 cp plastic viscosity, and 31.0 cp apparent viscosity. Additionally, mud weight was improved to 10.2 ppg through barite addition, further supporting its functional suitability. These results suggest that, with appropriate beneficiation and ageing, the locally available clay has the potential to replace imported bentonite in water-based drilling fluid

systems. This represents a strategic opportunity to promote indigenous material utilisation, reduce operational costs, and support sustainable development within Nigeria's oil and gas sector. Further studies involving field-scale validation and long-term performance monitoring are recommended to fully establish its commercial viability.

7. RECOMMENDATION

Based on the findings of this study, it is recommended that further research be conducted to optimise the beneficiation process of the local montmorillonite clay, particularly concerning the concentration and combination of additives such as hydroxyethyl cellulose (HEC). Geochemical and Mineralogical characterisation techniques such as X-ray diffraction (XRD), Fourier-transform infrared spectroscopy (FTIR), and scanning electron microscopy (SEM) are encouraged to provide deeper insights into the structural properties of the clay and its interaction with drilling fluid additives.

8. REFERENCES

Adepoju, D. A., Oloruntoba, P. A., & Akindele, O. T. (2023). Evaluation of indigenous clayfor drilling fluid applications in Nigeria. *Journal of Petroleum Science and Engineering*, 215, 104945.

Adewumi, A. & Ismail, I. (2023). Characterization of Clay Materials for Drilling Fluid Formulations. *Journal of Petroleum Engineering Research*, 45(3), 123-134.

Ahmed, H. A., Bashir, A. A., & Idris, M. O. (2022). Comparative study of local and imported bentonite for drilling fluid applications. *Energy Reports*, 8, 1234-1246.

Alade, A. A., Ogunlaja, O. O., &Jolaoso, F. A. (2024). Investigating the use of indigenous clays as drilling fluid additives. *Journal of Natural Gas Science and Engineering*, 115, 104730.

Alade, O., Adekanmbi, O., &Ogundeji, K. (2024). Utilization of Burnt Coconut Fibre as a pH Enhancer in Drilling Mud. *International Journal of Oilfield Chemistry*, 39(2), 67-78.

Amani, M., & Al-Jubouri, M. (2021). Drilling fluids technology: Advances and applications. *Petroleum Exploration and Development*, 48(3), 511-520.

American Petroleum Institute (API). (2019). API Recommended Practice 13 B-1: Recommended Practice for Field Testing Water-Based Drilling Fluids (5th ed.). Washington, DC: API.

API (2023). Recommended Practices for Field Testing of Drilling Fluids. *American Petroleum Institute*.

API. (2023). API Recommended Practice 13B-1: Field Testing of Drilling Fluids. American Petroleum Institute.

Caenn, R., Darley, H. C. H., & Gray, G. R. (2017). Composition and Properties of Drilling and Completion Fluids (7th ed.). Gulf Professional Publishing.

Chen, Y., Liu, X., & Zhang, H. (2023). Recent advances in bentonite-based drilling fluids. *Applied Clay Science*, 227, 106626.

Chukwu, C. N., Nwokoro, C. U., & Okoro, O. N. (2021). Impact of Sand Content on the Rheological and Filtration Properties of Water-Based Muds. SPE Drilling & Completion, 36(2), 284-291. https://doi.org/10.2118/2021-DC-0123-MS

Gray, G. R., & Darley, H. C. H. (1988). Composition and Properties of Oil Well Drilling Fluids (5th ed.). Gulf Publishing.

Huang, J., Wang, L., & Li, Y. (2023). Enhancing drilling fluid performance with modified bentonite. *Journal of Petroleum Engineering*, 69(4), 340-356.

Jayaraman, S., Adejumo, O., & Kolawole, E. (2021). Biodegradable Additives in Drilling Mud Applications. *Journal of Environmental Petroleum Studies*, 55(4), 219-230.

Liao, Y., Wang, J., & Li, S. (2023). Rheological Modelling of Water-Based Drilling Fluids: Power Law Index and Consistency Index Analysis. Journal of Petroleum Science and Technology, 41(4), 489-500. https://doi.org/10.1080/10916466.2023.2167895

Liu, X., Zhou, F., & Chen, L. (2022). Influence of montmorillonite on the rheology of water-based drilling fluids. *Journal of Applied Geophysics*, 198, 104712.

Rabia, H. (2002). Oilwell Drilling Engineering: Principles and Practice. Graham & Trotman.

Singh, P., Kumar, R., & Mehta, P. (2022). Chemical Stability of Montmorillonite-Based Drilling Fluids at Elevated pH. Journal of Petroleum Engineering, 2022, 9847614. https://doi.org/10.1155/2022/9847614

Singh, R., Kumar, P., & Sharma, V. (2021). Advances in the application of clays in drilling fluids. *Clay Minerals*, 56(3), 450-468.