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INVESTIGATION OF POTENTIALS OF KEROSENE AS AN ALTERNATIVE TO DIESEL IN FORMULATION OF DRILLING FLUID

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ABSTRACT

This study was aimed at investigating the potentials of kerosene as an alternative to diesel as base oil for drilling fluids. Oil-based drilling fluids were formulated using bentonite, guar gum, calcium chloride, primary and secondary emulsifiers, lime, water, hydroxyethylcellulose (HEC), barite, and base oils (diesel and kerosene). The oil to water ratios of the formulation were varied at 60/40, 70/30, 80/20, 90/10 100 (no water) when both diesel and kerosene were used as base oil. The Fann viscometer was used to study selected rheological properties and the mud balance was used for the mud weight analysis. The mud formulated using kerosene had the lowest apparent and plastic viscosities of 51 and 6 cP respectively at an oil/water ratio of 100 (no water), least mud density of 7.0 lb/gal at an oil/water ratio of 100 (no water), highest 10 sec and 10 min gel strength of 20 lb/100ft^2 and 21 lb/100ft^2 respectively. It was also observed that mud formulated with diesel had the highest mud density of 8.2 lb/gal at oil/water ratio of 60/40. Plastic viscosity of mud formulated using diesel as base oil decreased from 40 to 10 cP as the oil/water ratio was increased from 60/40 to 100; while that for mud formulated using kerosene as base oil decreased from 34 to 16 cP while yield points decreased from 145 to 101 lb/100 ft^2 when oil to water ratio was increased from 60/40 to 100. Also, yield point decreased from 150 to 108 lb/100 ft^2 as oil to water ratio was increased from 60/40 to 100 when kerosene was used as base oil. Kerosene has been found to present a better prospect as base oil for drilling mud than diesel with respect to plastic, apparent viscosities 10 sec and 10 min gel strengths.

Keywords: *Drilling mud, kerosene, diesel, oil-based mud*

INTRODUCTION

Drilling fluids are the complex fluids used for the drilling of oil and gas wells. The successful completion of an oil and gas well and production of hydrocarbons from the oil and gas reservoir depend to a considerable extent on the properties of drilling fluids selected during drilling operations. The selection of a right fluid and the maintenance of the properties primarily influence the production rate while drilling (Caenn *et al.,* 2011).

Drilling fluids are made to carry out several functions such as controlling formation pressures, removing cuttings from the borehole, cooling and lubricating the bit, transmitting hydraulic energy to the bit and downhole tools, and maintaining wellbore stability (Melbouci and Sau, 2008; Williamson 2013).

Drilling fluids are directly or indirectly linked with most drilling problems. This does not imply that drilling fluids are the sole cause or solution of the difficulties encountered in drilling technology. Rather, these difficulties encountered in drilling technology can be minimized through drilling fluids (Max and Martin, 1974).

Drilling fluids are categorized based on their composition and use. The choice for the drilling fluid used for a particular well is made based on cost, technical performance and environmental impact. About 80% of all wells are drilled using water-based fluids (WBFs), which are less expensive than oil-based fluids (OBFs) or synthetic-based fluids SBFs (Christiansen, 1991; Mao *et al.,* 2015; Rodrigues et al., 2006; Tehrani *et al.,* 2009). WBFs are formulated by combining fresh water and drilling fluid additives, mainly viscosifiers, water activity salts, filtrate reducers and hydrate resistant polymers. However, studies have shown that these additives cause unstable rheological properties at high pressure, high temperature (HPHT) down hole conditions (Ismail *et al.,* 2016; Mao *et al.,* 2015). To tackle this limitation of WBFs, OBFs are used (Adeleye *et al.,* 2012).

Environmental problems associated with complex drilling fluids in general, and oil-based mud (OBM) in particular, are among the major concerns of world communities. For this reason, the environmental protection agency (EPA) and other regulatory bodies are imposing increasingly stringent regulations to ensure the use of environmentally friendly mud (Fadairo *et al.,* 2012). Throughout the 1970s and 1980s, the EPA and other regulatory bodies imposed environmental laws and regulations affecting all aspects of petroleum-related operations from exploration, production and refining to distribution (Khodja *et al.*, 2010; Xie *et al.,* 2014). In particular, there has been new technologies in the oil and gas Industry increasing pressure on oil and gas industry stakeholders to find environmentally acceptable alternatives to OBMs. This has been reflected in the introduction of new legislation by government agencies in almost every part of the world. Stakeholders in the oil and gas industry have been tasked with the challenge of finding a solution to this problem by formulating optimum drilling fluids and reduce the handling costs and negative environmental effects of the conventional diesel oil based drilling fluid (Khodja *et al.,* 2010; Xie *et al.,* 2015).

This study investigated kerosene as an alternative to diesel in the formulation of oil based mud. The rheological properties of the mud formulation was the basis of comparison of formulation using kerosene and the mud formulated using diesel which is already in commercial use.

MATERIALS AND METHODS

Bentonite, guar gum, calcium chloride, primary and secondary emulsifiers, lime, water, HEC, barite, kerosene and diesel oil were used with diesel oil as the control mud. Triple beam balance (Sargent Welch), Fann viscometer (Model 35A), mud balance, single spindle Hamilton beach mixer were also used.

The mud samples were prepared by adding the component of the oil mud in their proper sequence during the initial mixing to optimize the performance of each product. Five mud samples each were prepared for each of the two base oils; the oil/water ratios were varied as 60/40, 70:30, 80:20, 90/10 and 100 for each base oil. The API recommended standard procedure was used for mixing the mud sample. The required quantity of base oil was placed in a mixer cup, and then the required quantity of primary emulsifier was added to it and was allowed to stir for five minutes. The secondary emulsifier was then added to the mixture and allowed to stir for about five minutes. Lime was also added to the mixture and allowed to stir for five minutes. HEC was then added to the mixture and allowed to stir for five minutes. Afterwards, bentonite was added to the mixture and was allowed to stir for 5 minutes. Finally, the required quantity of barite was slowly added to the mixture and allowed to stir for 10 minutes. A duplicate was analyzed for every sample to track experimental error and show capability of reproducing results and averages calculated (Marshall and Champagne, 1995)

Table 1: Mud Formulation for varying oil/water ratio

Component	**Oil/water ratio**				
	60/40	70/30	80/20	90/10	100
Oil, ml	210	245	280	315	350
10 emulsifier, g	7	6	6	5	-
20 emulsifier, g	5	4	3	2	-
Lime, g	6	7	9	9	-
Water ml	140	105	70	35	
$CaCl_2$, g	35	26.25	17.5	8.75	
HEC, g	0.3	0.35	0.4	0.5	0.6
Bentonite, g	2.5	3	4.5	5	5.5
Barite, g	10	10	10	10	10

The density of the drilling fluid was measured using the baroid mud balance. Apparent viscosity, plastic viscosity, yield point and gel strength were measured using the viscometer at 49^{o}C.

To determine the gel strength, the sample was stirred at 600 RPM for 10sec after which the gear was lifted to the neutral position and the toggle switch was flipped to the low (rear) position. The sample was allowed to stir for 10sec. The motor was then switched off and allowed to rest for 10 sec, after which, the toggle switch was flipped to the low speed position and the maximum dial deflection was then recorded in Ib/100ft^2 as the 10sec gel strength. The toggle switch was pulled to high and the red knob was positioned to 600-RPM speed. The mud was stirred for 10-seconds. After that, the red knob was positioned to the 300 RPM speed. The toggle switch was switched off and the mud was undisturbed for 10 minutes. Then the toggle switch was flipped to low position and the maximum dial deflection reading was recorded as the 10 minutes gel strength in lb/100ft^2.)

RESULTS AND DISCUSSION

The rheological properties of drilling mud using diesel and kerosene and base oils and at varying oil/water ratios are shown in Tables 2 – 6.

Table 2: Mud density of drilling mud at varying oil/water ratio

oil/water ratio	**Mud density, lb/gal**	
	Diesel oil	Kerosene
60/40	8.2	7.2
70/30	8.0	7.7
80/20	7.9	7.4
90/10	7.5	7.5
100	7.4	7

From Table 2, it was observed that the mud density decreased as the oil/water ratios were increased when diesel base oil was used. When kerosene was used as base oil, the mud density increased from 7.2 lb/gal to 7.7 lb/gal when oil/water ratio was increased from 60/40 to 70/30; and thereafter decreased to 7 lb/gal as the oil/water ratio was increased from 80/20 to 100 (purely oil). The mud density of the drilling mud formulated using kerosene and diesel as base oils had the same value of 7.5 lb/gal at oil/water ratio of 90/10. The highest mud density of the formulation was 8.2 lb/gal and this was obtained when diesel base oil was used and at an oil/water ratio of 60/40. Some reservoirs require a denser drilling mud especially when faced with problems like influx of other fluids into the bore. Whereas, some other conditions like lost circulation would require dense fluid to regulate it. Generally, the higher the density of mud sample the better it helps to maintain column or hydrostatic pressure and suspend cuttings in the mud leading to a better cleaning of the bore as shown in a related study (Anawe *et al.,* 2014) . It was however noticed that the values of mud densities formulated using diesel and kerosene as base oils were generally less than the API minimum mud density value of 8.65 lb/gal for drilling mud.

Table 3: Plastic viscosity of drilling mud at varying oil/water ratio

oil/water ratio	**Plastic viscosity, cP**	
	Diesel oil	Kerosene
60/40	40	34
70/30	38	30
80/20	25	21
90/10	16	12
100	10	6

From Table 3, it was observed that plastic viscosities generally decreased as the oil/water ratio was increased. The plastic viscosity of mud formulated using diesel as base oil gradually decreased from 40 to 10 cP as the oil/water ratio was increased from 60/40 to 100; while that for mud formulated using kerosene as base oil decreased from 34 to 16 cP. It was also observed that the values of plastic viscosity of mud using diesel as oil base were generally higher than their values when kerosene was used as base oil at the same oil/water ratio. The low viscosity will offer less resistance to fluid flow and therefore would lead to a turbulent flow at low pump pressure, which would result in good hole cleaning. The value of plastic viscosity of mud formulated had the highest value of 40 cp at an oil/water ratio of 60/40 when diesel was used as base oil. This would offer a greater resistance to fluid flow that will result in increased circulating pressures that can cause loss of circulation and increased pumping costs.

The mud formulated using kerosene as base oil generally had a lower plastic viscosity than that of mud formulated using diesel as base oil. This means that mud formulated using kerosene as base oil presents a lower resistance to fluid flow. Therefore kerosene presents a better prospect here as a base oil for drilling mud with respect to plastic viscosity as a low apparent viscosity will lead to reduction of wear and tear of drill string.

Table 4: Apparent viscosity of drilling mud at varying oil/water ratio

oil/water ratio	**Apparent viscosity, cP**	
	Diesel oil	Kerosene
60/40	95	72
70/30	82	65
80/20	76	61
90/10	70	56
100	64	51

The values of apparent viscosity generally decreased as the oil/water ratio was increased. The apparent viscosity of mud formulated using diesel as base oil gradually decreased from 95 to 64 cP as the oil/water ratio was increased from 60/40 to 100; while that for mud formulated using kerosene as base oil gradually decreased from 72 to 51 cP as the oil/water ratio was increased from 60/40 to 100.

The values of apparent viscosity generally decreased as the oil/water ratio was increased. The apparent viscosity of mud formulated using diesel as base oil gradually decreased from 95 to 64 cP as the oil/water ratio was increased from 60/40 to 100; while that for mud formulated using kerosene as base oil decreased from 72 to 51 cP. Apparent viscosity is a reflection of the plastic viscosity and yield point combined. An increase in either or both will cause a rise in apparent viscosity. Since the mud formulated using kerosene as base oil generally had a lower apparent viscosity than that of mud formulated using diesel as base oil, it gives lower a lower resistance to fluid flow and hence a better option than diesel in terms of apparent viscosity. The mud formulated using diesel and kerosene as base oils generally fell within the 30 cP API minimum value standard for drilling mud.

Table 5: Yield point of drilling mud at varying oil/water ratio

oil/water ratio	**Yield point (lb/100ft^2)**	
	Diesel oil	Kerosene
60/40	145	150
70/30	135	141
80/20	130	130
90/10	119	122
100	101	104

From Table 5, it was observed that yield points of drilling mud decreased steadily from 145 to 101 lb/100 ft^2 when oil to water ratio was increased from 60/40 to 100 when diesel was used as base oil; when kerosene was used as base oil, the yield point of the drilling mud decreased from 150 to 108 lb/100 ft^2 as oil to water ratio was increased from 60/40 to 100The highest value of yield point was 150 lb/100ft^2 at an oil to water ratio of 60/40 when kerosene was used as base oil. Yield Point is used to evaluate the ability of a mud to lift cuttings out of the annulus. A high yield Point implies a non-Newtonian fluid, one that carries cuttings better than a fluid of similar density but lower yield Point.

Table 6: 10 sec and 10 min gel strengths of drilling mud at different oil/water ratio

oil/water ratio	**10 sec gel strength(lb/100ft^2)**		**10 min gel strength(lb/100ft^2)**	
	Diesel oil	Kerosene	Diesel oil	Kerosene
60/40	14	14	14	15
70/30	15	16	15	16
80/20	16	18	16	18
90/10	17	19	17	20
100	18	20	19	21

Gel strengths (10 sec and 10 min) indicate strength of attractive forces (gelation) in a drilling fluid under static conditions. It is an indication of the drilling fluids ability to suspend cuttings when circulation is stopped. Excessive gel strength should not be encouraged as they can cause a number of drilling problems. From Tables 6, it was observed that the values of gel strengths at 10 sec and 10 min for mud formulated using diesel and kerosene as base oils generally increased as oil/water ratio increased from 60/40 to 100. Gel strengths at 10 sec of mud formulated with diesel oil and kerosene had the same value of 14 lb/100ft^2 at oil to water ratio of 60/40. At 10 sec, mud formulated with kerosene had the highest gel strength of 20 lb/100ft^2 while at 10mins, mud formulated with kerosene had the highest gel strength of 21 lb/100ft^2.With proper gel strength solids are well suspended in the hole and allow them to settle out on the surface. It was generally observed that the values of gel strength of mud at 10 sec and 10 min when kerosene was used as base oil were very close to those when diesel was used as base oil.

Gel strengths refer to the shear stress required to initiate flow after static periods of time. They are a measure of the degree of gelation that occurs due to the attractive forces between particles over time. High gel strength mud has the ability to suspend drill cuttings along the length of the drillpipe or bore annulus when the drilling mud circulation is stopped during pump tripping or any other secondary.

operations as shown in a related study (Shah *et al.,* 2010) A low gel strength mud on the other hand do not efficiently suspend cuttings thereby allowing cuttings to quickly drop leading to pump shutdown, stuck pipe, hole pack-off, barite sag as well as accumulation of cutting beds. From the results, it is clear that mud formulated using kerosene had better cutting transport capabilities.

CONCLUSION

In this study, the effects of varying oil/water ratio in the formulation of a drilling mud on selected rheological properties have revealed that, the mud density, plastic viscosity, yield point and 10-sec. and 10 min gel strengths have direct relationship due to the percentage weight of the individual sample. As oil/water increased, mud density, plastic viscosity, apparent viscosity and yield point of the formulated mud decreased. Also, as oil/water increased both the 10 sec and 10 min gel strengths of formulated mud also increased. Kerosene therefore presents a better option as a base oil for drilling mud than diesel with respect to plastic and apparent viscosities. The mud formulated using kerosene had better cutting transport capabilities than mud formulated using diesel as base oil.

REFERENCES

Adeleye S. A., Abdulaziz A. and Enamul M. H. (2012). Drilling fluid: State of the art and future trend. In: North Africa Technical Conference and Exhibition of Society of Petroleum Engineers; King Fahd University of Petroleum & Minerals.

Anawe, P.A.L., Efeovbokhan, V.E. , Ayoola, A.A. and Akpanobong, O. (2014). Investigating alternatives to diesel in oil based drilling mud formulations used in the oil Industry. *J. Environ Earth Sci., 4* (14):70-77

Caenn R, Darley, H.C.H., Gray, G.R.. (2011) Completion, Reservoir Drilling,Workover, and Packer Fluids Composition and Properties of Drilling and Completion Fluids. Sixth Edition, Boston: Gulf Professional Publishing

Christiansen, C. (1991) From oil-based mud to water-based mud. In: Proceedings of the SPE Health, Safety and Environment in Oil and Gas Exploration and Production Conference, 11–14 November, The Hague, Netherlands,

Fadairo A, Ameloko A., Adeyemi G., Ogidigbo, E. and Airende O. (2012) Environmental Impact Evaluation of a Safe Drilling Mud. In:SPE Middle East Health, Safety, Security, and Environment Conference and Exhibition, 2–4 April, Abu Dhabi, UAE.

Ismail AR, Aftab A, Ibupoto Z.H. and Zolkifile N, (2016) The novel approach for the enhancement of rheological properties of water-based drilling fluids by using multi-walled carbon nanotube, nanosilica and glass beads. *J. Pet Sci Eng., 3*(139) 264- 275.

Khodja M, a BergayaFa, Canselier JP, Khodja-Saber M. and Cohaut N. (2010) Drilling fluid technology: performances and environmental considerations. INTECH Open Access Publisher

Mao H., Qiu Z., Shen Z. and Huang W., (2015) Hydrophobic associated polymer based silica nanoparticles composite with core-shell structure as a filtrate reducer for drilling fluid at ultra-high temperature. *J. Pet Sci Eng., 129*:1–14

Max R.A. and Martin V.S. (1974) Exploration, Production, Drilling. Drilling Fluid Technology.

Melbouci, M. and Sau, A.C., (2008) Water-based drilling fluids. US Patent 7 384 892, assigned to Hercules Incorporated, Wilmington, DE.

Rodrigues J., Lachter, E. R., Mello, M. and Nascimento R.S.V. (2006) New. multifunctional polymeric additives for water-based muds. In:SPE Annual Technical Conference and Exhibition, San Antonio, TX, USA.

Shah, S.N., Narayan, P.E., Shanker H, Ogugbue, C.C. (2010). Future Challenges of Drilling Fluids and Their Rheological Measurements. In: American Association of Drilling Engineers Conference and Exhibition, 6 - 7 April, Houston Texas, USA.

Tehrani A.,Young S., Gerrard D.and Fernandez J. (2009) Environmentally friendly water-based fluid for HT/HP drilling. In: Proceedings of the SPE International Symposium on Oilfield Chemistry, 20–22 April, The Woodlands, TX.

Xie S, Jiang G, Chen M, Li Z, Huang X, and Liang C. (2014) Harmless Treatment Technology of Waste Oil-Based Drilling Fluids. *Pet. Sci. Technol., 32*(9):1043-1049.

Xie S, Jiang G, Chen M, Li Z, Mao H and Zhang M. (2015) Treatment Technology for Waste Drilling Fluids in Environmental Sensitivity Areas. Energy Sources, *Part A: Recovery, Utilization, and Environmental Effects, 37*(8):817-824.

Williamson, D. (2013). Drilling Fluid Basics. Oilfield Review Spring, 25, No. 1