

The Effect of pH and Salinity on the Rheological Properties of Drilling Mud Formulation from Natural Polymers

Inemugha O.¹, Chukwuma F.², Akaranta, O.³ and Uyigwe L.⁴

¹Student, Department of Chemical Engineering, World Bank Africa Center of Excellence, Center for Oilfield Chemicals Research, University of Port Harcourt, NIGERIA

²Lecturer, Department of Chemical Engineering, University of Port Harcourt, NIGERIA

³Lecturer, Department of Industrial Chemistry, World Bank Africa Center of Excellence, Center for Oilfield Chemicals Research, University of Port Harcourt, NIGERIA

⁴Lecturer, Department of Chemical Engineering, World Bank Africa Center of Excellence, Center for Oilfield Chemicals Research, University of Port Harcourt, NIGERIA

¹Corresponding Author: oinemugha@yahoo.com

ABSTRACT

Drilling muds are designed to perform certain functions of drilling operation. Some of the functions are to cool and lubricate the drilling bit, transmit hydraulic power to drill bit, provide filter cake and remove drilling cuttings and maintaining wellbore stability. Various additives with specific properties are added in the mud to help prevent the challenges encountered during drilling process. The work studies the effect of pH and salt on the rheological properties of drilling mud formulation from two natural polymers (Terminaliamantaly(TM) exudate and Guar gum) with the use of Model 35 viscometer. Drilling mud formulation with these polymers was investigated at pH of (7.05, 8.15, 10.07, and 11.13) and salt concentrations of (2, 4, 6, 8 and 10g/ml). Results obtained from drilling mud with TM exudate were compared with drilling mud with guar gum. It was found that the rheological properties of drilling mud with Terminaliamantaly exudates increased for higher pH as compared to drilling mud with Guar gum. The increase in salinity reduced the effectiveness of the rheological properties of the mud such that as the salinity in drilling mud increased, the rheological properties of drilling mud with Terminaliamantaly and Guar gum decreased. The performance is attributed to flocculation, dispersion and hydration behavior of particles in the mud.

Keywords— Drilling Mud, Rheological Properties, Natural Polymers, Salinity, pH

I. INTRODUCTION

Drilling mud which is also called drilling fluid, is a very important fluid used in the oil and gas drilling industries. It is used to perform specific functions such as removing cuttings from the base of the hole to the surface, maintaining the cuttings in suspension, transmitting hydraulic power to the drill bit, providing sufficient hydrostatic pressure to prevent the influx of formation fluid into the well, and prevent the wall of the formation from

collapsing, reducing filtrate rate, cooling and lubrication of drill bit etc.

Drilling mud formulation usually begins with a base fluid which can be either water, non-aqueous or Pneumatic depending on the type of drilling mud formulation. The nature of the different types of base fluid produces different composition and performance of the drilling mud being formulated. The base fluid forms the continuous phase responsible for carrying all other component and influences the properties and technical performance of the drilling mud. Other components are solids which can be active or Inactive (inert) and additives which are used to maintain the properties of the drilling mud. It is important to know that oil and gas drilling operations relies almost on drilling mud and its properties for excellent drilling performance (Caenn et al. 2017).

Generally, drilling muds are categorized into Water based mud, Oil based mud and Air/Gas based mud. Water based mud utilizes either salt, fresh or sea water as its continuous phase. The formulation starts with water, then clay and other chemical components are added to it. The clay mostly Bentonite is used to provide the necessary viscosity suitable for the drilling operation while the chemical components are used to create homogenous blend and carry out numerous functions including shale stability, viscosity controls, enhanced drilling rate of penetration etc. Oil based mud, instead of water, uses oil such as diesel or synthetic oil as liquid phase. They are made up of invert emulsions of brine in a continuous phase of majorly oil and become stable by surfactant with the use of other additives. The third category of drilling fluids consists of gas, aerated muds or aqueous foams. The fluids are usually applied when their pressure is lower than that utilized by the petroleum located in the pores of the rock formation. They are known as under-balanced fluids. Under-balanced drilling technology is generally adopted for poorly consolidated and/or fractured formations. Air mud is normally used in low permeability and porosity reservoir

intervals where oil or water is not expected to be encountered during drilling (Crowo, 1990). Compared to all the other drilling fluids, water based drilling fluid is more preferable for drilling because they are easier to use and less expensive than oil mud or compressed air (Behnamanhar et al. 2014).

Water-based drilling muds are important and more useful in places where oil-based muds may be prohibitive due to high cost, logistical or ecological constraints. The outstanding properties of water based drilling mud are associated with the incorporation of a base fluid, suspended solid particles and chemicals. The suspended solid particles react chemically with the base fluid to control the properties of the mud. The mud derives its viscosity from suspended solid particle phase, usually clay materials. However, the use of polymers to supplement or replace clay materials is better because it modifies the properties of drilling muds and also maintains the viscosity in the annulus at reduced circulating pressure (Saboor et al. 2016). Thus, polymers, especially water soluble polymers have become a subject for exhaustive research because they are more environmental friendly (Weikey et al. 2018)

There are two categories of water soluble polymer; synthetic polymer such as vinyl acetate-maleic anhydride co-polymers and hydrolyzed poly-acrylate and natural polymers such as Guar gum, Xanthan gum, CMC, HEC etc. Synthetic polymers may be more stable in thermal environment but are generally sensitive to salt and saline environment. Also, they are more expensive when they are compared to natural polymers (Arinkoola et al. 2017).

In this study, an unexplored water soluble polymer (Terminaliamantaly exudates) was studied experimentally on the basis of rheology, pH and salinity. Terminaliamantaly exudates have been widely used in the pharmaceutical industry as binding agent in tablet formulation (Oluyemisi et al., 2012; Michael et al., 2017). Its suitability as a viscosifier in water-based drilling mud have also been studied (Inemugha et al. 2019). Studies have shown that the molecular structure of this exudates contain highly branched polysaccharides consisting of galacturonic, glucuronic and 4-O-methylglucuronic acids, as well as galactose, arabinose, rhamnose, mannose and xylose but neutral sugars and total uronic acid content may vary with different type of Terminalia gum.

Table 1: Properties of the dry sample of TM Exudate

S/N	Properties	Unit	Values
1	Moisture Content	Weight %	6.7
2	pH	-	7.05
3	Bulk Density	g/ml	0.749
4	Water Absorbtion Capacity	-	2.03`
5	Particle Size	µm	75

II. MATERIALS AND METHOD

A. Purification of TerminaliaMantaly Gum

Firstly, TM exudates were on the tree was allowed to dry before it was collected from the tree. The dried TM exudate was soaked in water double strength chloroform mixture in the ratio 0.5%:95.5% for 5 days to soften and extract the mucilage. A straining exercise was carried out with use of a white muslin cloth to further remove the remaining viscous mucilage from the gum. Precipitation of the gum was conducted with use of an absolute ethanol for extra purification process. 100ml of Dimethyl ether was used to wash the precipitated gum after that the gum was kept at a temperature of 50°C in a hot air oven for 10 hours. The precipitated gum was pulverized with the use of blender into powdery form. 50.0g of the powdery TM gum was stored in an air tight container. The purification method

on the purification TM exudate was first reported by Michael et al. (2017)

B. Water-based mud Formulation

The additives for the formulation of the water-based mud are Pre-hydrated bentonite, soda Ash, caustic soda, terminaliamantaly gum, xanthan gum, potassium chloride, low viscosity poly anionic cellulose and barite. 22.5 g of betonite was put in a weighing plate and weighed with electronic balance. 350 ml of deionized water was poured in the mixer and mixed for 15 minutes to prepare pre-hydrated bentonite. Thereafter, 0.1 grams of soda ash and caustic soda was added and allowed to mix for five minutes. After 5 minutes, 1.5 g of Terminaliamantaly gum and PAC L and 10.5 grams of barite was added in every five minutes respectively. The same procedure was used to formulation of Xanthan gum and Guar gum.

C. Rheological Measurement

Water based mud formulation with TM exudate, Xanthan gum and Guar gum were prepared and the rheological measurements were conducted on their various concentrations at 1.5g. The measurements were conducted with use of Fann VG Viscometer in six speeds (such as 600,300, 200, 100. 6, 3 rpm). Rheological data such as apparent viscosity, plastic viscosity, and yield point were provided through this analysis. These rheological properties were calculated from 600 and 300 rpm readings using the following equations 1, 2 and 3 from from API Specification for drilling fluid material. In other to ensure the accuracy of the experimental results, API standard procedures for preparing mud and determining the mud properties were followed throughout the experimental work.

$$\text{Apparent Viscosity (AP)} = \frac{1}{2} \theta_{600} \quad [1]$$

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

$$\text{Yield point (YP)} = \theta_{300} - PV \quad [3]$$

where, θ is the dial reading at 600 rpm and is the dial reading at 300 rpm

D. Salinity and pH Measurement

Various amount of salt concentration (2g/ml, 4g/ml, 6g/ml, 8g/ml 10g/ml) were added to four water based mud. Water based without polymer, with TM exudate, Xanthan and Guar gum respectively. Rheological measurements were conducted on each of the mud. Also, 1.0 N NaOH of various amounts was used to adjust the pH

from 7.5 to 10.5. Rheological measurement was conducted on each gram of salt and pH. The data were recorded analyzed.

III. RESULTS AND DISCUSSION

A. Shear flow Behavior

The shear stress rheological behavior of the drilling mud with three water soluble polymers is presented in Fig. 1. From the figure, Drilling mud with TM exudate has the highest shear stress at increasing shear rate. The shear stress of both drilling mud with TM exudate and Guar gum are almost identical with a slight higher shear stress for TM gum. Drilling mud with only bentonite had the lowest shear stress at increasing shear rate. All these observation indicates that drilling mud with water-soluble polymers exhibit more shear thinning behavior than fluid with only bentonite. This shear thinning behavior is attributed to the ability of the polymer chain to disentangle during flow. At rest, higher molecular weight polymers are always entangled and randomly oriented. However, as they are sheared their polymer chain disentangle to align which may be responsible for drop in viscosity. The rate of disentanglement is a function of the shear rate. Therefore, drilling mud with TM exudate had the highest shear thinning behavior when compared to the other mud in Fig. 1.

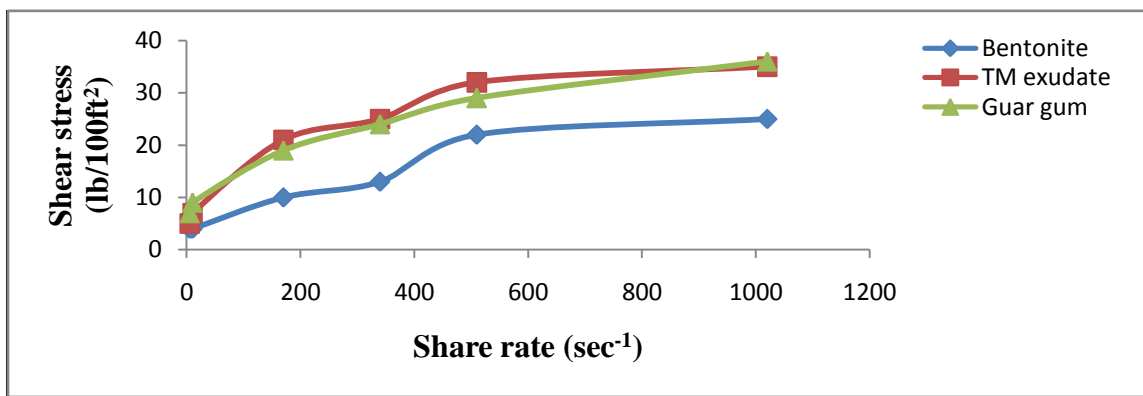


Fig.1. Shear stress flow behavior of water based mud with different water soluble polymers

B. Effect of Salinity on Rheological Properties

The effect of salt on the rheological properties of drilling mud with two natural water soluble polymers at a particular concentration are shown in Fig. 2 to 4. Fig 2., the plastic viscosity decreased initially for drilling mud with Guar gum and bentonite but slightly decreased for drilling mud with TM exudate but later decreased as salinity increased. In Fig 3-4, Also early decrease in apparent viscosity and yield point was observed as salinity increased for all mud with a slight higher yield point for drilling mud with TM exudates. The overall decrease of drilling mud

with the addition of salt to the mud is in line with Alaskari and Teymoori, (2007). The addition of the salt to the mud compressed the double layer of the clay particles which enhanced the flocculation of suspension. As the salt increased, the suspension between the clay platelets was reduced. Also, polymers are known to hydrate water and swells. In the presence of salt, the availability of water is limited which can disrupt the hydration of water by polymer thereby upsetting the hydrogen bond formed between polymer chain and water molecules which leads to the reduction in viscosity as salt increases.

Table 1a. Effect of Salinity on the Rheological Properties of Drilling Mud with Bentonite

NaCl g/ml	600 rpm	300 rpm	200 rpm	100 rpm	6 rpm	3 rpm	AV cp	PV cp	YP lb/100ft ²
2	26	23	22	19	11	10	13	3	20
4	23	21	19	17	10	8	11.5	2	20
6	20	17	15	15	9	8	10	3	14
8	19	16	15	13	9	8	9.5	3	13
10	17	14	12	11	8	6	8.5	3	11

Table 1b. Effect of Salinity on the Rheological Properties of Drilling Mud with TM exudate

NaCl g/ml	600 rpm	300 rpm	200 rpm	100 rpm	6 rpm	3 rpm	AV cp	PV cp	YP lb/100ft ²
2	30	27	25	23	13	11	15	3	24
4	27	24	22	18	10	9	13.5	3	21
6	24	20	18	16	10	9	12	4	16
8	20	16	15	14	9	7	10	4	12
10	20	18	17	16	9	7	10	2	16

Table 1c. Effect of Salinity on the Rheological Properties of Drilling Mud with Guar gum

NaCl g/ml	600 rpm	300 rpm	200 rpm	100 rpm	6 rpm	3 rpm	AV cp	PV cp	YP lb/100ft ²
2	29	22	18	15	8	7	14.5	7	15
4	27	22	18	14	7	6	13.5	5	17
6	27	20	17	14	8	6	13.5	7	13
8	29	22	18	15	8	4	14.5	7	15
10	26	20	17	14	8	5	12.5	6	14

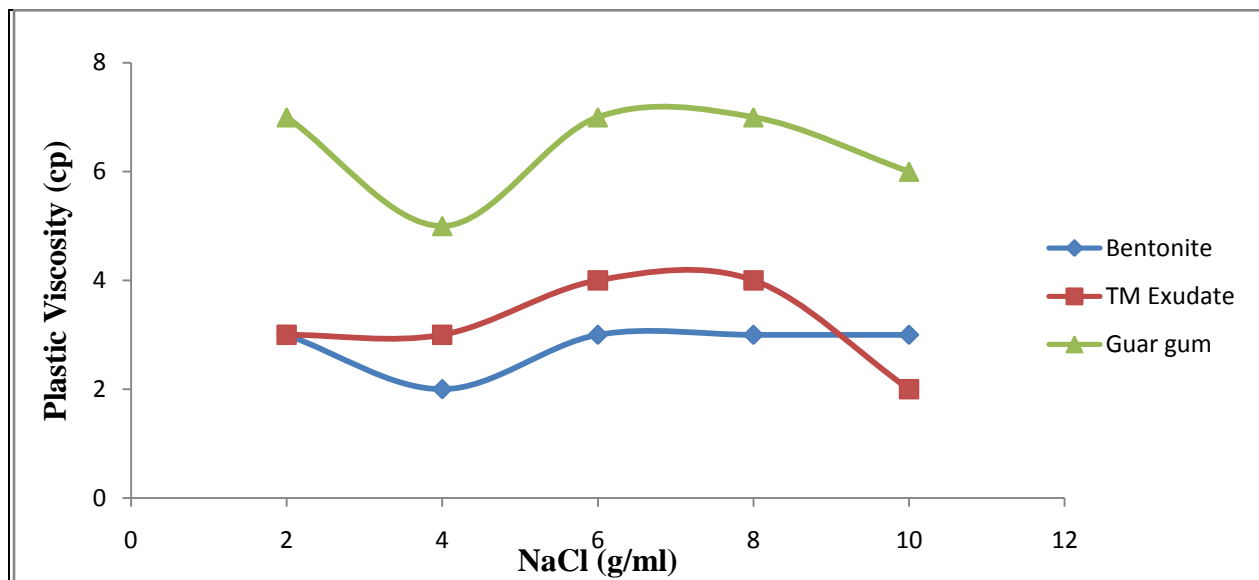


Fig.2. Effect of Salt on plastic viscosity of drilling mud with bentonite, TM exudate and Guar gum

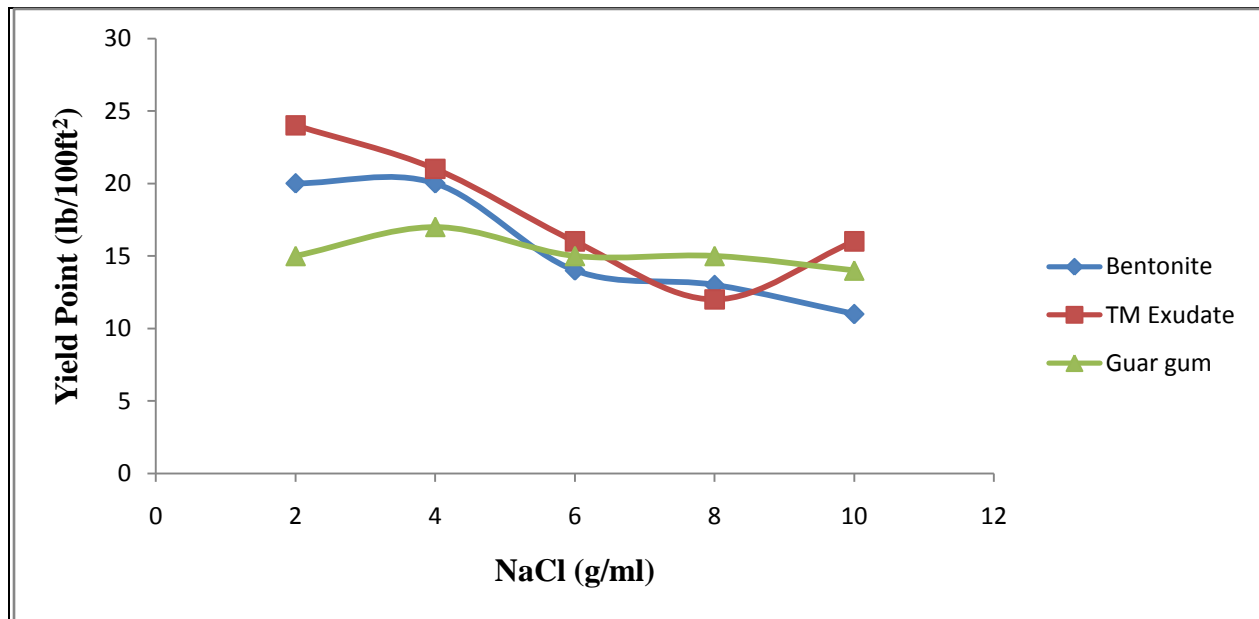


Fig.3. Effect of Salt on yield viscosity of drilling mud with bentonite, TM exudate and Guar gum

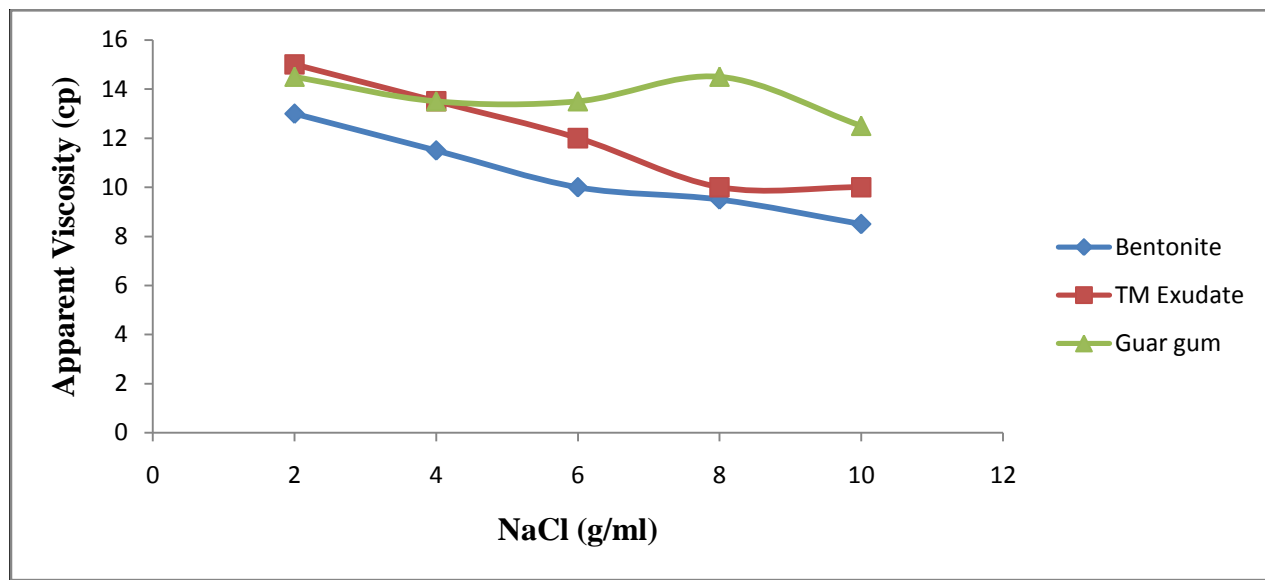


Fig.4. Effect of Salt on plastic viscosity of drilling mud with bentonite, TM exudate and Guar gum

C. Effect of pH on Rheological Properties

The effect of salt on the rheological properties of drilling mud with only Bentonite, TM exudate, Guar gum is presented in Fig. 5 to 7. The Apparent viscosity of drilling mud TM exudate increased higher than mud with Guar gum and only bentonite. For the plastic viscosity, the Guar gum increased higher than mud with TM exudates and bentonite while drilling mud with TM exudate had the highest

increase at increase pH. All drilling muds showed gradually increase in rheological properties as pH increased. This is also line with the work of Alaskari and Teymoori, (2007). The addition of NaOH increased the attractive forces between platelets which allowed water to penetrate between platelets. Therefore, an increase NaOH lead to an increase in rheological properties of all the drilling mud with slight decrease at extremepH.

Table 2a. Effect of pH on the Rheological Properties of Drilling Mud with Bentonite

pH	600 rpm	300 rpm	200 rpm	100 rpm	6 rpm	3 rpm	AV cp	PV cp	YP lb/100ft ²
7.05	20	18	16	14	8	7	10	2	16
8.15	23	20	18	14	7	5	11.5	3	17
10.07	25	22	20	16	7	6	12.5	3	19
11.13	25	19	18	13	8	5	12.5	4	15

Table 2b. Effect of pH on the Rheological Properties of Drilling Mud with TM exudate

pH	600 rpm	300 rpm	200 rpm	100 rpm	6 rpm	3 rpm	AV cp	PV cp	YP lb/100ft ²
7.05	37	35	31	28	17	14	18.5	2	33
8.15	45	41	40	35	19	14	22.5	4	37

10.07	50	44	41	35	19	16	25	6	38
11.13	50	43	41	35	18	15	25	7	36

Table 2c. Effect of pH on the Rheological Properties of Drilling Mud with Guar gum

pH	600 rpm	300 rpm	200 rpm	100 rpm	6 rpm	3 rpm	AV cp	PV cp	YP lb/100ft ²
7.05	27	20	19	14	12	5	13.5	7	23
8.15	26	19	15	12	6	5	18	7	12
10.07	26	18	16	13	7	5	13	8	10
11.13	24	17	14	11	5	4	12	7	10

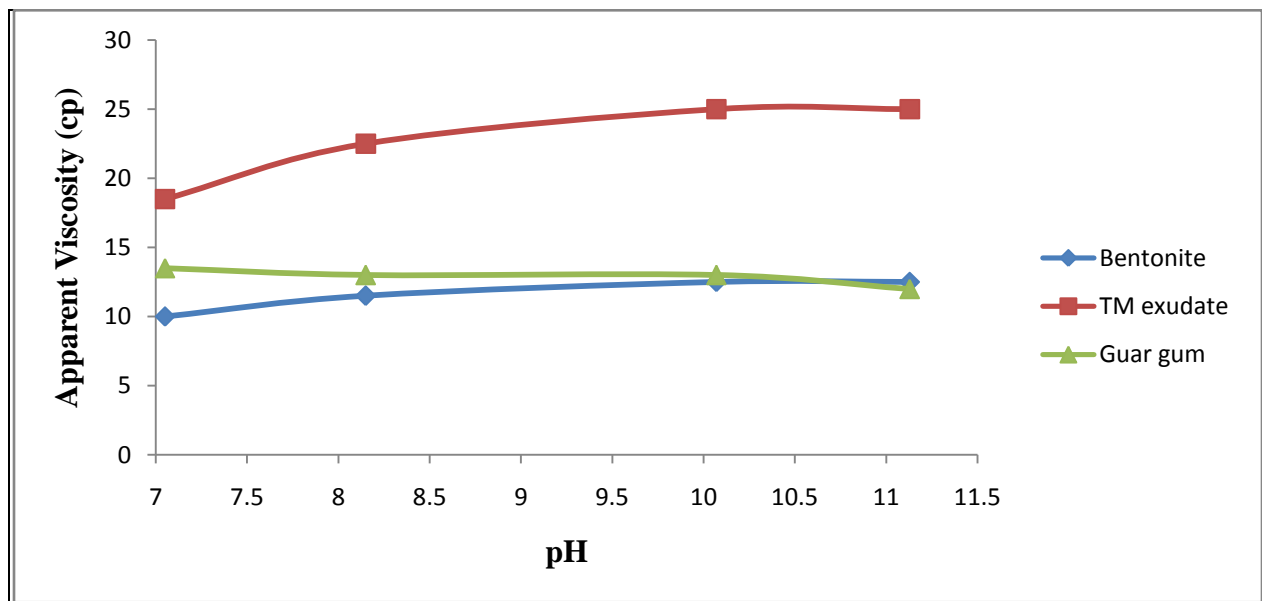


Fig.5. Effect of pH on apparent viscosity of drilling mud with bentonite, TM exudate and Guar gum

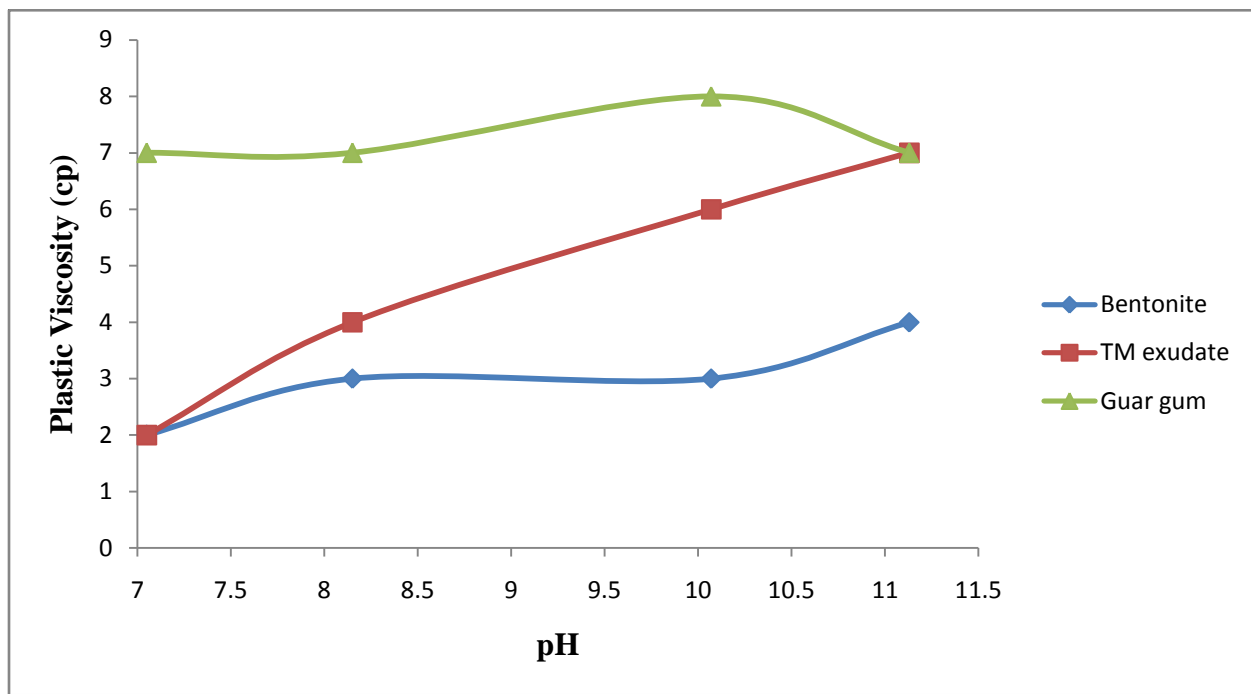


Fig.6. Effect of pH on the plastic viscosity of drilling mud with bentonite, TM exudate and Guar gum

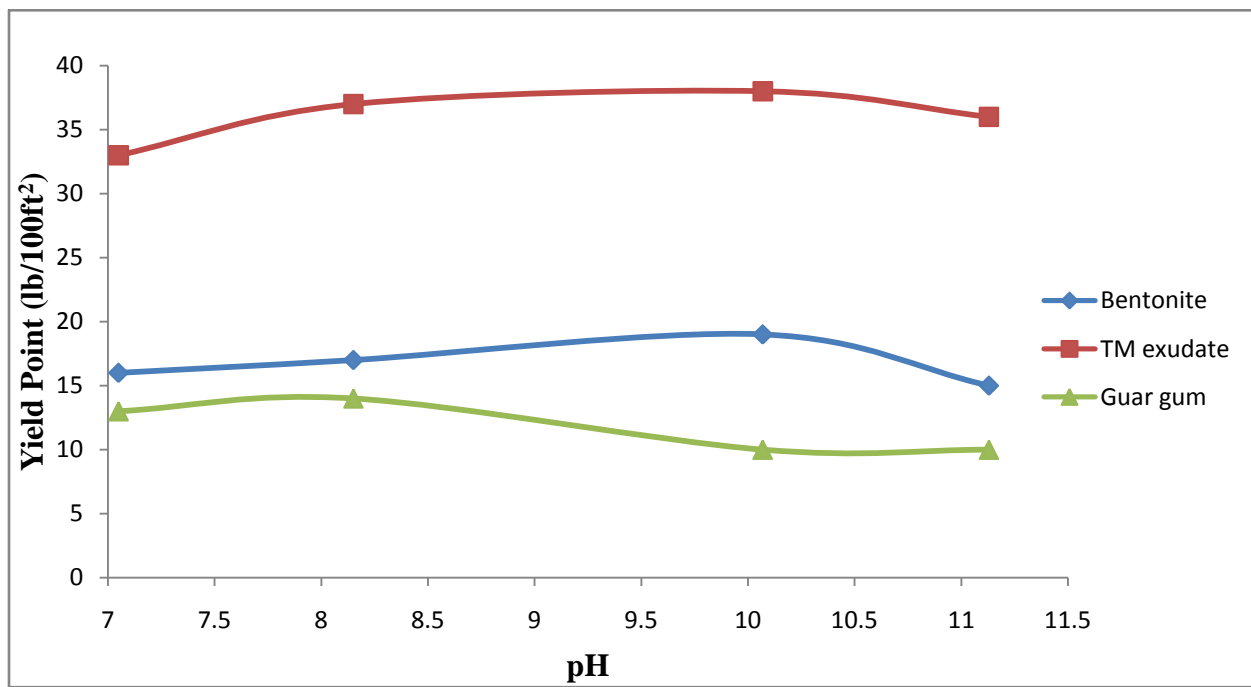


Fig.7. Effect of pH on the yield point of drilling mud with bentonite, TM exudate and Guar gum

IV. CONCLUSION

The work has demonstrated the effect of pH and salt on the rheological properties of drilling mud formulation with bentonite, TM exudate and Guar gum.

From the result, drilling mud with TM exudate had better shear thinning behaviour than muds with Guar gum and just bentonite without any polymer. The effect of increasing pH, increased the rheological properties of the three drilling mud with slight decrease at higher pH while the effect of

salt decrease the rheological properties of the drilling. The plastic viscosity showed instability for muds formulation with Guar gum but decreased as high salt concentrations. The yield point and apparent viscosity decreased for all muds with increased salt. Plastic viscosity, apparent viscosity and yield point increased with increase in pH for all muds. Therefore the effect of salt will decrease the properties of drilling mud formulation with polymers while the effect of pH will increase properties of drilling muds with water soluble polymers.

REFERENCES

- [1] Caenn, Ryen, Darley, H C H, & George, Gray R. (2017). *Composition and properties of drilling and completion fluids*. (7th ed.). Oxford : Elsevier.
- [2] Crowo, A. (1990). Ultrasound measurements on oilbased drilling mud. *Flow Measurement and Instrumentation*, 1(2), 113-117.
- [3] Behnamanhar, H., Noorbakhsh, S. S., & Maghsoudloojafari, H. (2014). Environmentally friendly water-based drilling fluid for drilling of water-sensitive formations. *Journal of Petroleum and Gas Exploration Research*, 4(4), 60-71.
- [4] Saboor, A., Khan, A. N., Cheema, H. M., Yaqoob, K., & Shafqat, A. (2016). Effect of polyaniline on the dielectric and EMI shielding behaviors of styrene acrylonitrile. *Journal of Materials Science: Materials in Electronics*, 27(9), 9634-9641.
- [5] Weikey, Y., Sinha, S. L., & Dewangan, S. K. (2018). Effect of Different Gums on Rheological Properties of Slurry. *IOP Conference Series: Materials Science and Engineering* 310(1), 012068.
- [6] Arinkoola, O. A., Olalekan, S. T., Salem, K. K., Omola, J. M., & Gafar, A. O. (2018). Potential evaluation and optimization of natural. *Journal of Chemical and Petroleum Engineering*, 52(1), 01-12.
- [7] Oluyemisi, B.A., Oluwatoyin, O.A., Vivek, S.R. & Ruchita, K.. (2012). Terminalia Gum as a Directly Compressible Excipient for Controlled Drug. *AAPS PharmSciTech*, 13(1), 16 -23.
- [8] Michael, A.O., Babatunde, M.O. & Oluyemisi, A.B. (2017). Native and microwave-modified Terminaliamantaly gums as sustained-release and bioadhesive excipients in naproxen matrix tablet formulations. *Polymers in Medicine*, 47(1), 35-42.
- [9] Inemugha O., Chukwuma F., Akaranta, O., & Ajenka J A. (2019). Rheological Properties of Terminalia Mantaly Exudate as Drilling Mud Additive. *Nigeria Annual International Conference and Exhibition, Society of Petroleum Engineers*, SPE-198827-MS.
- [10] Alaskari, M. K. G & Teymoori, R. (2007). Effects of salinity, pH and temperature on CMC polymer and XC polymer performance. *IJE Transactions B: Applications*, 20(3), 283-290.