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Variation of Temperatures with Rheological Properties of Water Based Drilling Fluid Containing Rice Husk and Other Additives

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ABSTRACT

Drilling fluids rheological properties such as yield point (YP), plastic viscosity (PV), apparent viscosity (AV) and thixotropic property (Gel strength) are very important during drilling operations to prevent various drilling problems and improve the efficiency of the drilling process. Four water based drilling fluid samples containing different proportions of rice husk, xanthan gum and bentonite were investigated in this study to determine impacts of Sodium hydroxide (NaOH), Sodium chloride (NaCl), Sodium trioxocarbonate (IV) (Na_2CO_3) and Barite ($BaSO_4$) on their rheological properties and pH values at temperature ranging from 30^oC to 50^oC. The chemical additives were added to the four samples at a given composition of 1%,2%,3% for (NaOH, NaCl, Na_2CO_3) and 5%, 10%, 15% for ($BaSO_4$) by mass. The rheological properties of the samples were determined by FANN 35A viscometer using standard methods while pH meter and mud balance were used to measure their pH and density values respectively. The maximum pH, Shear- Stress, and AV corresponds to 11.6, 2.3985 Nm^{-2} and 112.5 cP respectively were observed in sample A with 10.5g of NaOH at 50^oC while the highest YP value of 170 $lbf/100ft^2$ was also observed at 35^oC. However, maximum gel strength, GS (10 sec) and 10(min) were observed in the sample A with 190 $lbf/100ft^2$ and 190 $lbf/100ft^2$ for 10.5g of NaOH and 189 $lbf/100ft^2$ and 191 $lbf/100ft^2$ for 52.5g of $BaSO_4$ respectively at temperature of 50^oC. Furthermore, the same sample gave the lowest value of mud weight when the sample contain 3.5g of each additive (NaOH, NaCl and Na_2CO_3) at 35^oC corresponds to 8.98 lb/gal. Drilling fluids produced with bentonite, rice husk, xanthan gum with appropriate proportion of NaOH and $BaSO_4$ could be effective water based drilling fluid that can serve effectively in drilling operations at reasonable high temperature.

Keywords-- Rice Husk, Xanthan Gum, Bentonite, Chemical Additives, Rheological Properties, Drilling Fluids

I. INTRODUCTION

Water base drilling fluids can be formed using bentonite clay, rice husk, xanthan gum and other additives (Akinyemi and Alausa 2020; Akinyemi and Fatai 2022; Akinyemi and Abdulhadi 2022). Drilling fluid primarily serve the goal of controlling subsurface pressures in combination with density and numerous other additional pressures operating on the fluid column (annular or surface imposed). Specifically, drilling fluids are used to carry drilled solids from the bottom of the hole to the surface, suspend drilled solids and weighting materials when the mud is static, provide a thin impermeable cake to seal pores and other openings in the formation and thereby restrict the movement of fluids, contain formation pressure, support the weight of casing and drill string, transmit hydraulic horse power to the bit, and assist with evaluation (Growcock and Harvey, 2005; Darley and Gray, 1988). To retain the necessary qualities during drilling, water-based drilling fluid is primarily made of water, bentonite, polymers, salts, and other ingredients (Zhang *et al.*, 2021). However, a rise in temperature can cause water-based drilling fluid to lose some of its qualities, which may have negative impact on the viscosifying agents in the fluid and reduce the fluid's velocity (Akinyemi & Alausa, 2020; Ismail *et al.*,2014). Also, any slack of the rheology of the drilling fluid can leads to inability to dispersed solids within it such as the weighting agent or the drill cuttings; thus resulting in serious problems during drilling operations such as difficulty in removing cuttings, high fluid loss formations, reduction yield and high permeability to water. It is paramount to consider the use of Sodium hydroxide (NaOH), Sodium Chloride (NaCl), Sodium Carbonate (Na_2CO_3), Barium sulphate or barite ($BaSO_4$), xanthan gum, rice husk and bentonite clay to improve the rheological properties such as viscosity etc. of water-based drilling fluids in a drilling process. Furthermore, it is common knowledge that a properly designed drilling fluid enables operators to reach the desired results ore at a lower cost, with improved bit and drill string penetration, easier penetration, faster bit cooling, minimal hole damage, and easier transport of cuttings to the surface at the end of the drilling operation. Hence, this study focused on investigating the impacts of variation of temperature on the rheological properties of drilling fluid developed from the combination of Sodium

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hydroxide (NaOH), Sodium Chloride (NaCl), Sodium Carbonate (Na_2CO_3), xanthan gum, rice husk and bentonite Clay.

II. MATERIALS AND METHOD

2.1 Materials

The bentonite sample used for the study was collected from Ashaka, Funakaye LGA in Gombe State, while. the Rice Husks was obtained from local rice mills in Kafur LGA Katsina state. The xanthan gum was product from Fluka Chemicals AG, Switzerland, while the NaOH, NaCl, Na_2CO_3 and $BaSO_4$ were analytical products of Central Drug House (CDH) India. The major equipment used for the study were Jaw crusher (DR 80B/4Q), Fann viscometer (FANN 35A), siveve and sieve shaker (Sieve-Tronic), Mud balance (LEUTERT), weighing balance (METLAR MT-501), Homogeniser (L2R-3577), Ball Mill machine (Kera BV).

2.2 Methods

2.2.1 Sample Preparation

To produce the drilling fluid sample, the bentonite was surface dried for about one week to dry the moisture content of the clay, while the rice husk was surface dried for about 3 days to remove the moisture content. The recipe of the dried rice husk was later ground in to small size with jaw crusher and ball mill and sieve to an average of 120-125 microns to obtain the fine particles (Angaji *et al.,* 2013). The blends of the rice bentonite, rice husk and the xanthan gum were prepared into containers in accordance with compositions given in Table 1 to generate samples A to D. The blends were mixed thoroughly with homogenizer and mixer to obtain a homogeneous mixture. Using the standard laboratory barrel (350ml) method, a 350 ml of de-ionized water was poured in to each of the blends in the container and mixed for about 10 mins. The drilling fluid samples were left for about 24hrs to age (Akinyemi and Alausa, 2020; Ahmed *et al.*, 2012).

Table 1: Compositions of Samples A to D

Sample	Bentonite (g)	Xanthan gum (g)	Rice husk (g)
A	24.5	5	0
B	24.5	1	20
C	24.5	2	10
D	24.5	2	15

2.2.2 Determination of Rheological Properties of Drilling Mud Samples

Determination of the rheological properties (plastic viscosity, yield point, Thixotropic property (gel strength) and share stress-share rate relations) of the drilling fluid samples A to D were carried out using the FANN 35A viscometer as described by Akinyemi and Abdulhadi (2022). Each of the drilling fluid samples was poured in to the viscometer cup to the scribed mark and placed on the stand of the viscometer as it was lifted to immerse the rotating sleeve. Rotor speed of 300 and 600 rpm were used throughout the analysis (i.e. two point data approach) (Labe *et al.,* 2015) for all the samples. The plastic viscosity and yield point of the sample were measured using the readings from rotor sleeve speeds of 300 and 600 rpm. Furthermore, the gel strengths of the drilling fluid samples were determined using FANN 35A viscometer for 10 seconds and 10 minute gel strength. Each drilling fluid sample was poured into the sample holder and mounted to position and the base lifted until the drilling mud reach the scribe line and the lock screw tightened. The sample was then subjected to shear at 600 rpm for 10 seconds and the gear was set to neutral position. Thereafter the motor was shut off and waited for 10 seconds and the deflection at 3 rpm was recorded as 10 seconds gel strength in lb/100 ft^2. The same procedure was repeated for the 10 minute gel strength (Hussaini *et al.,* 1983) using 10 minutes instead of 10 seconds. Yield point was determined by computationally taking the difference between dial readings 300 rpm and plastic viscosity. The same procedure was repeated for all the samples A to D. The impact of the chemical additives on the rheological properties of the drilling mud samples was determine by repeating the entire procedures for each of the samples mixed with 3.5 g (1%), 7g (2%), 10.5 g (3%) of NaOH, as set 1, samples mixed with 3.5 g (1%), 7g (2%), 10.5 g (3%) of NaCl as set two, the samples mixed with 3.5 g (1%), 7g (2%), 10.5 g (3%) of Na_2CO_3 as set 3 and the samples with 17.5g (5 %), 35g (10%), 52.5 g (15%) of $BaSO_4$ additive separately as set 4. The whole procedures were carried out at the temperature range of 30^oC, 35^oC, 40^oC and 50^oC in order to determine the impact of variation of temperature on the properties of drilling fluid samples mixed with the chemical additives in different proportions.

III. RESULTS

3.1 Rheological Properties

It was observed that there is general decrease in shear rate as dial readings decrease for all the samples tested. This behavior characterizes the drilling fluids as shear thinning fluids. The shear stress values of the samples A, B, C and D after introducing the additives showed an increasing trends which is agreement with the findings of Chilling and Vorabutr (1981). However, the same samples showed a trend of increase in shear- stress upon heating to a temperature of 35°C, 40°C and 50°C. Furthermore, Sample A with 10.5g of NaOH at 50°C showed the highest shear stress value of 2.3985 Nm^{-2} at 600rpm while the lowest Shear stress value was recorded in sample C with a value of 0.08528 Nm^{-2} with 7g of NaCl and 3.5g NaOH at 30°C and 3rpm.

3.1.1 Apparent Viscosity

From the plots of apparent viscosity (AV) and temperatures for all the additives at different temperatures and compositions the maximum value of AV was recorded to be 112.5 cP in sample A at 50^oC with 10.5g NaOH meanwhile the minimum value of AV was recorded to be 15cP in sample 14 with 3.5g of NaCl at 30^oC (Awele, 2014). AV for sample A was constant between 30^oC and 35^oC with all the chemical additives added in the range of 3.5g for NaOH, NaCl and Na_2CO_3 and 17.5g $BaSO_4$, increased between 35^oC and 40^oC for NaCl, Na_2CO_3 and $BaSO_4$ and decreased between 40^oC and 50^oC for NaCl, Na_2CO_3 and $BaSO_4$ while it was almost constant for NaOH throughout the temperature range (Figure 1). Sample A exhibited the highest AV with 17.5g $BaSO_4$ followed by sample A with 3.5g Na_2CO_3 and then sample A with 3.5g NaCl at all the temperatures considered (Figure 1). Sample A with 3.5g NaOH exhibited the lowest apparent viscosity at all the temperatures (Figure 1). As the composition of the additives in sample A increased the its viscosity decreased for NaCl, Na_2CO_3 and $BaSO_4$ additives at all temperatures while its apparent viscosity was almost constant with increased in composition of NaOH (Figure 1 to 3). The trend of variation of the apparent viscosity of sample A with temperature in the presence of additives as their compositions increased followed the same pattern as that at 3.5g NaOH, NaCl and Na_2CO_3 and 17.5g $BaSO_4$ (Figures 1 to 3).

For sample B, it exhibited the least apparent viscosity across the various compositions of NaCl addition (3.5g to 10.5g) at all temperature when compared with impact of other additives (Figures 4 to 6). Apparent viscosity of sample B was the highest with $BaSO_4$ additive of 17.5 g and 35 g at all temperatures when compared with other additives (Figure 4 and 5). The apparent viscosity of sample B with 10.5g NaOH was the highest between 30^oC and 40^oC while the sample B containing 52.5g $BaSO_4$ overtook it from 40^oC and above (Figure 6). Sample B displayed increased in apparent viscosity with increase in temperature for all the additives added in different compositions (Figures 4 to 6).

Sample C followed the same trend as sample B in the behavior of its apparent viscosity with changes in temperature for all the additives at various compositions except that addition of 52.5g $BaSO_4$ maintain the highest apparent viscosity and 10.5g NaCl maintained the least apparent viscosity across all the temperatures considered (Figures 7 to 9). Sample D mixed with $BaSO_4$ displayed highest apparent viscosity across the temperatures range of 30^oC to 50^oC for all the compositions considered (Figures 10 to 12). The sample D mixed NaCl across all the compositions tested exhibited increased in apparent viscosity with increase in temperature between 30^oC and 35^oC, decreased in apparent viscosity with increase in temperature from 35^oC to 40^oC and further increase in apparent viscosity with increase in temperature between 40^oC and 50^oC (Figures 10 to 12). As in sample C, sample D containing NaCl in various composition tested exhibited the least apparent viscosity across all the temperatures considered in the study (Figures 10 to 12).

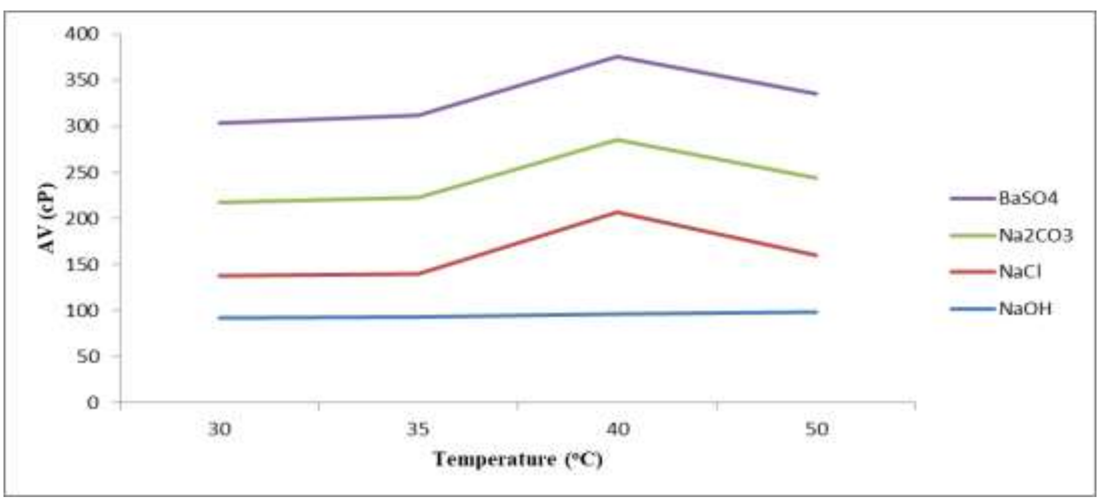

Figure 1: Variation of Apparent viscosity with temperature for Sample A with 3.5g each of (NaOH, NaCl, Na_2CO_3) and 17.5g of $BaSO_4$

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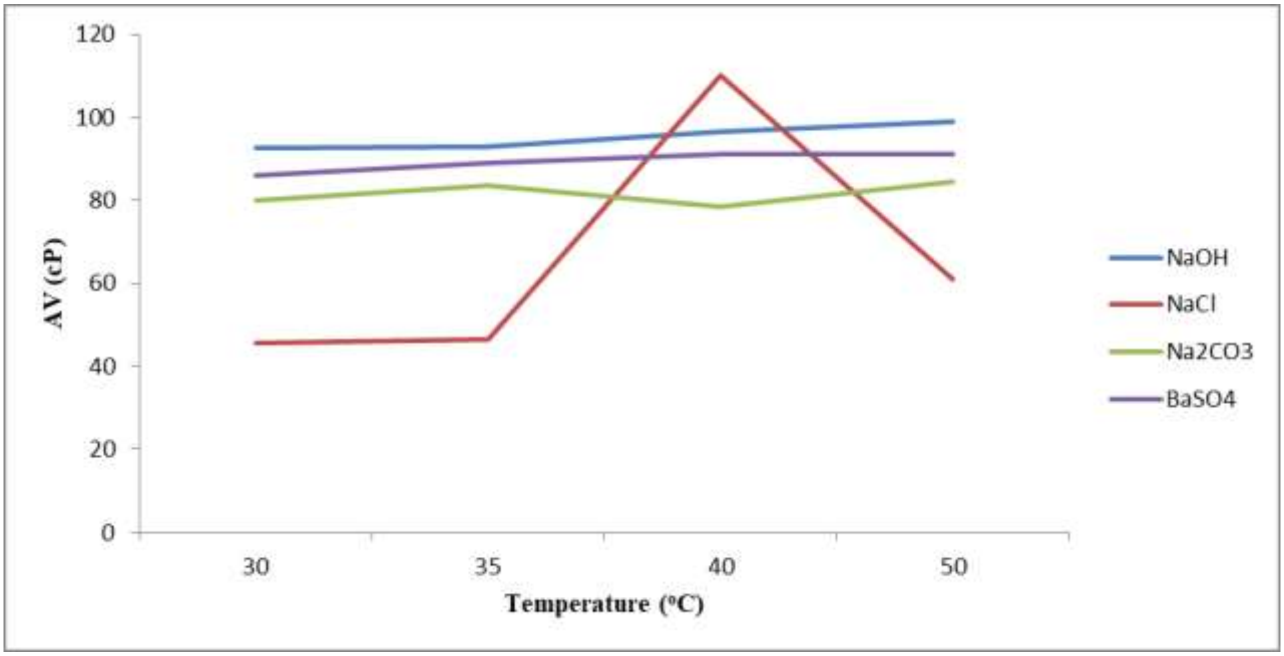

Figure 2: Variation of Apparent viscosity with temperature for Sample A with 7g each of (NaOH, NaCl, Na_2CO_3) and 35g of $BaSO_4$

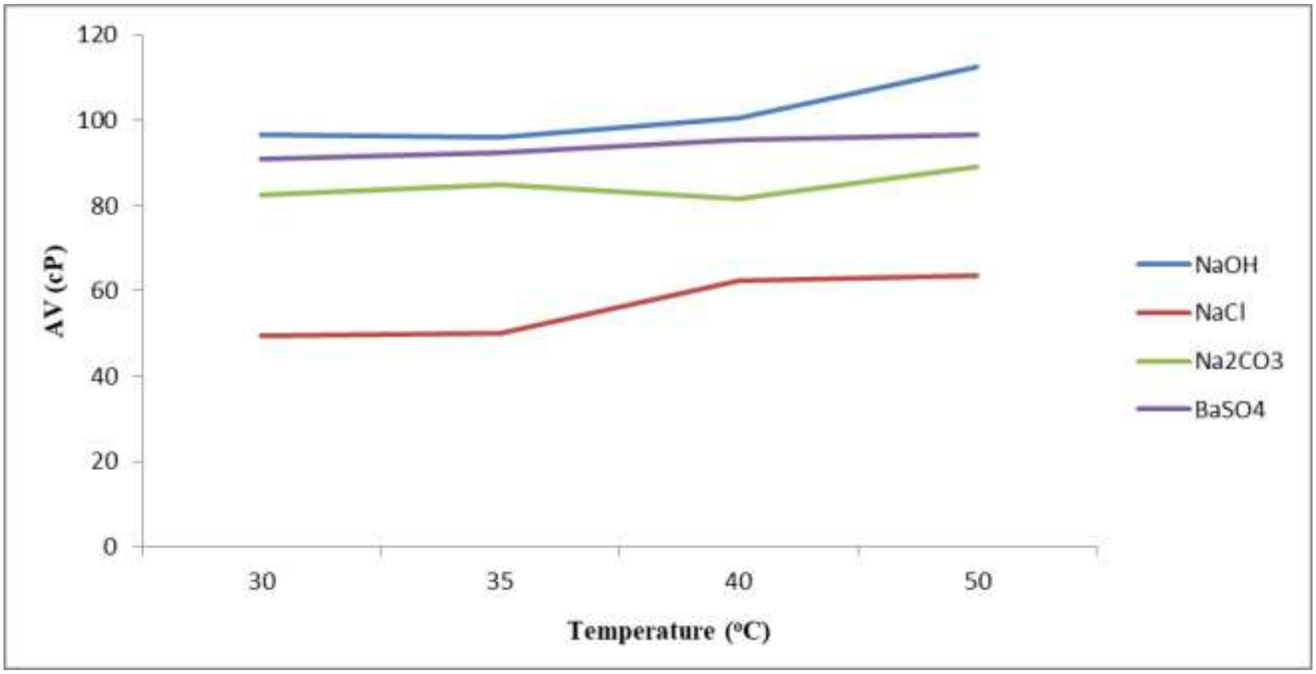

Figure 3: Variation of Apparent viscosity with temperature for Sample A with 10.5g each of (NaOH, NaCl, Na_2CO_3) and 52.5g of

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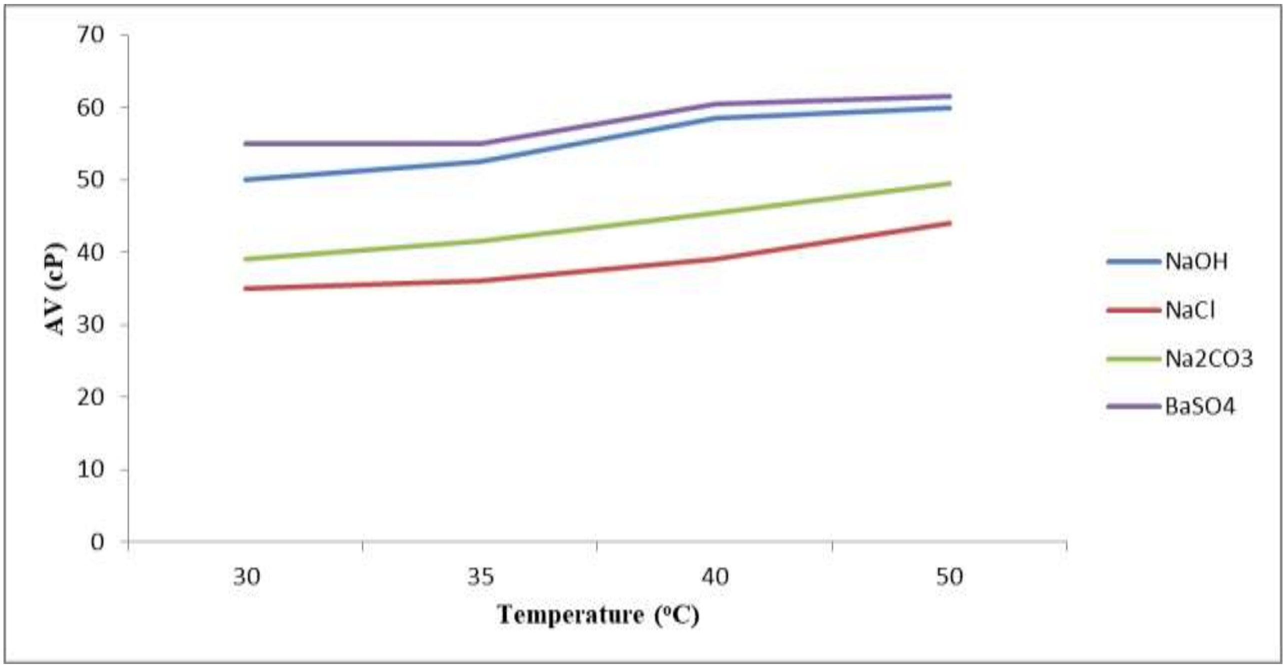

Figure 4: Variation of Apparent viscosity with temperature for Sample B with 3.5g each of (NaOH, NaCl, Na_2CO_3) and 17.5g of $BaSO_4$

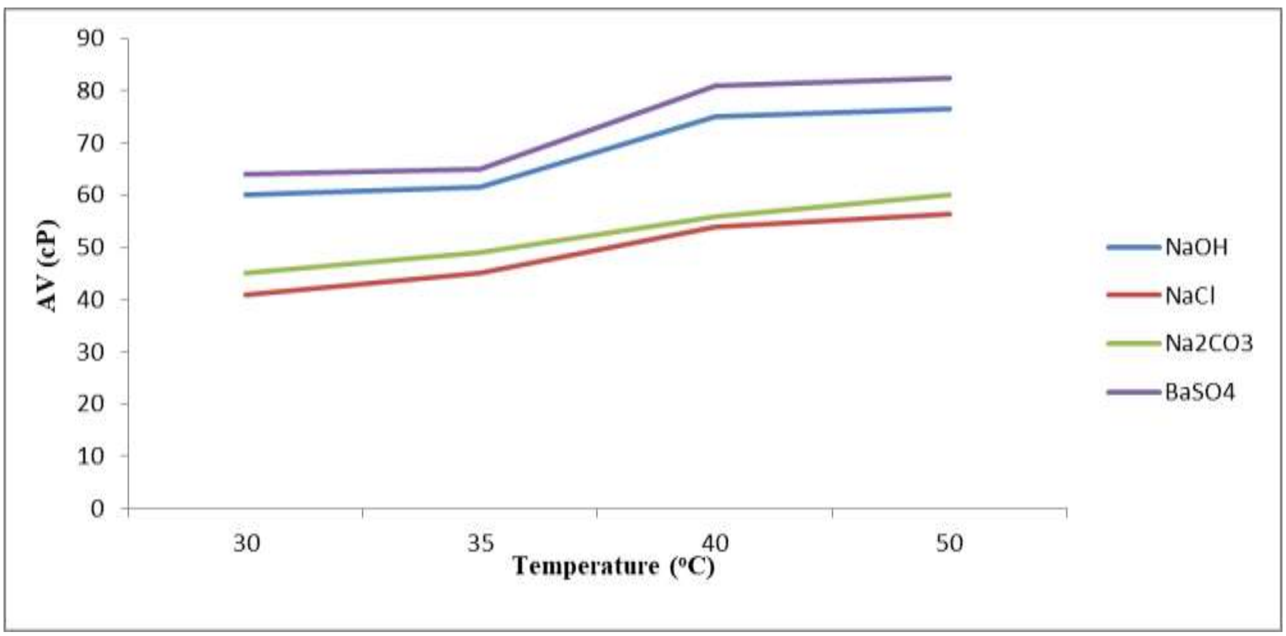

Figure 5: Variation of Apparent viscosity with temperature for Sample B with 7g each of (NaOH, NaCl, Na_2CO_3) and 35g of $BaSO_4$

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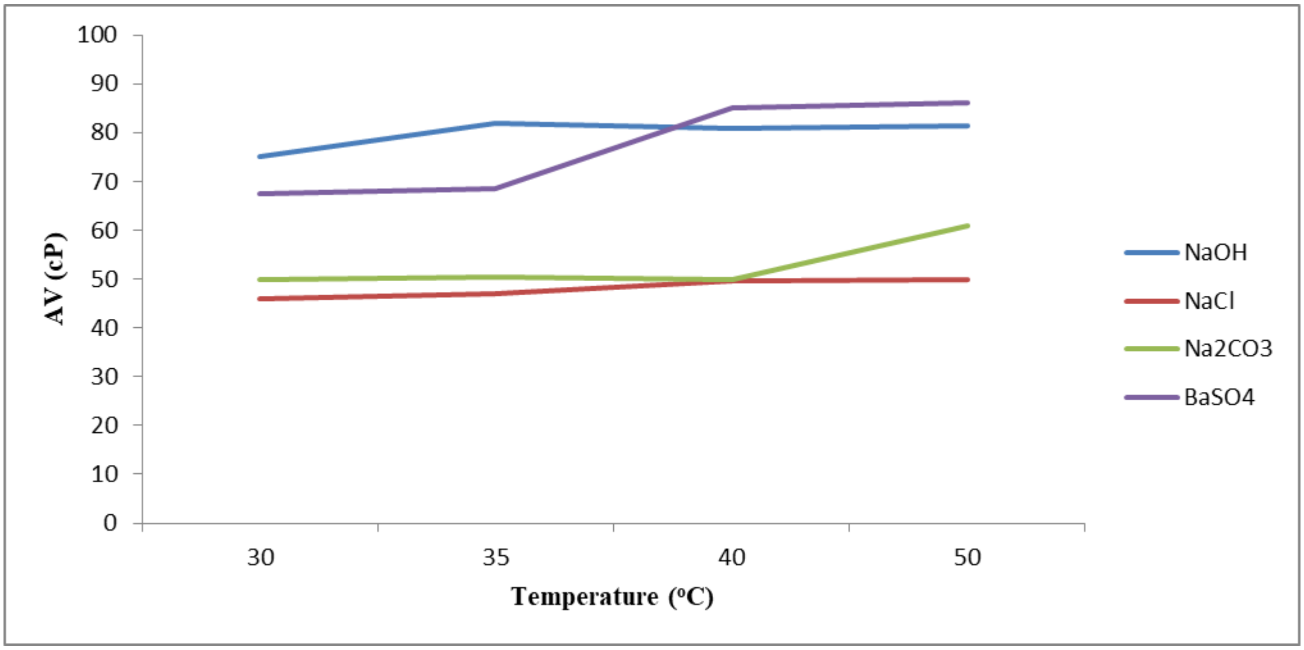

Figure 6: Variation of Apparent viscosity with temperature for Sample B with 10.5g each of (NaOH, NaCl, Na_2CO_3) and 52.5g of $BaSO_4$ 0

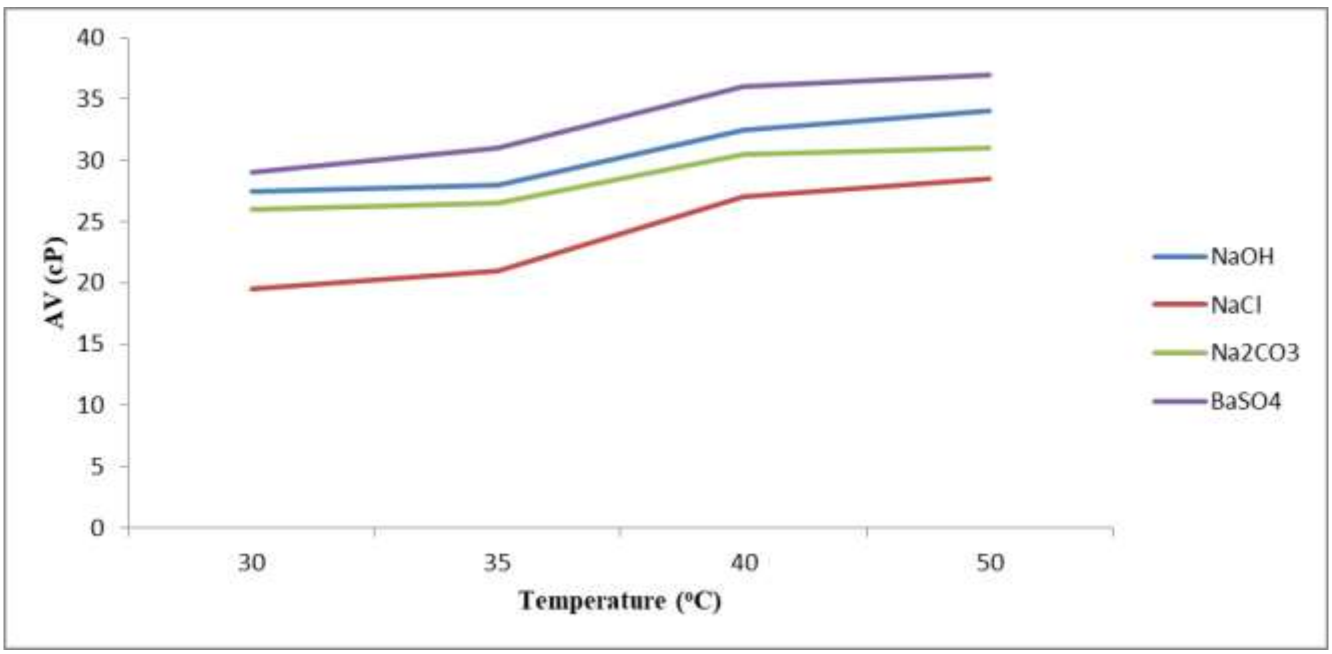

Figure 7: Variation of Apparent viscosity with temperature for Sample C with 3.5g each of (NaOH, NaCl, Na_2CO_3) and 17.5g of $BaSO_4$

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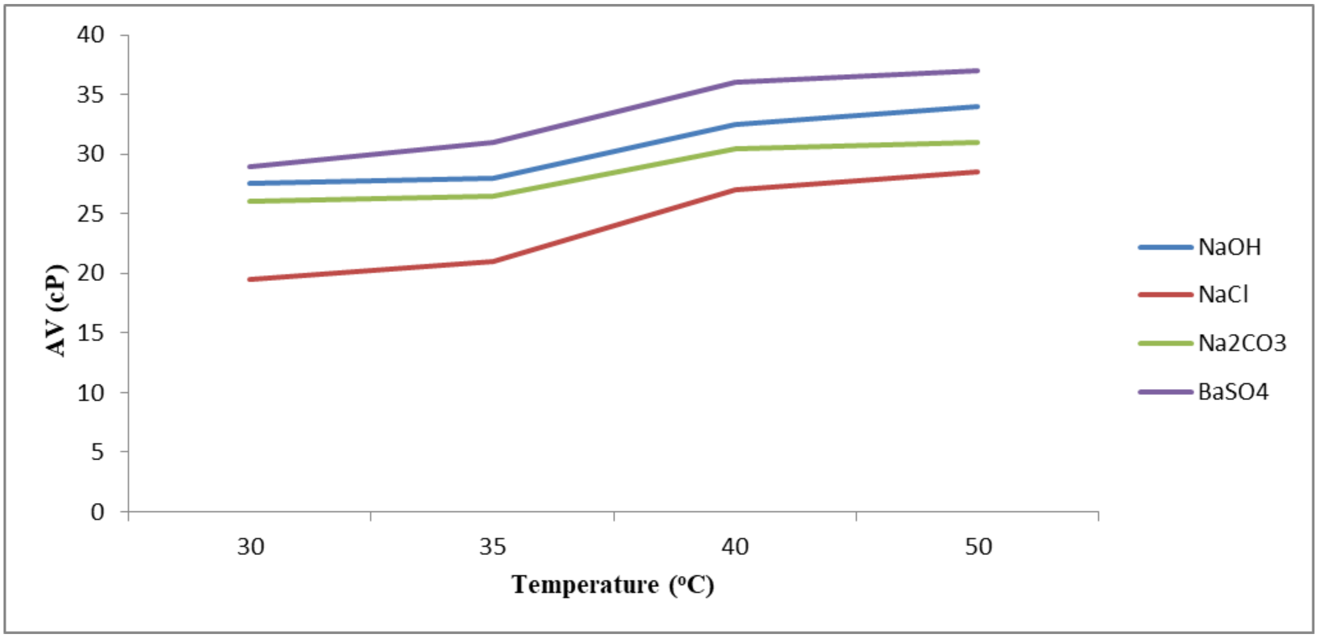

Figure 8: Variation of Apparent viscosity with temperature for Sample C with 7g each of (NaOH, NaCl, Na_2CO_3) and 35g of $BaSO_4$

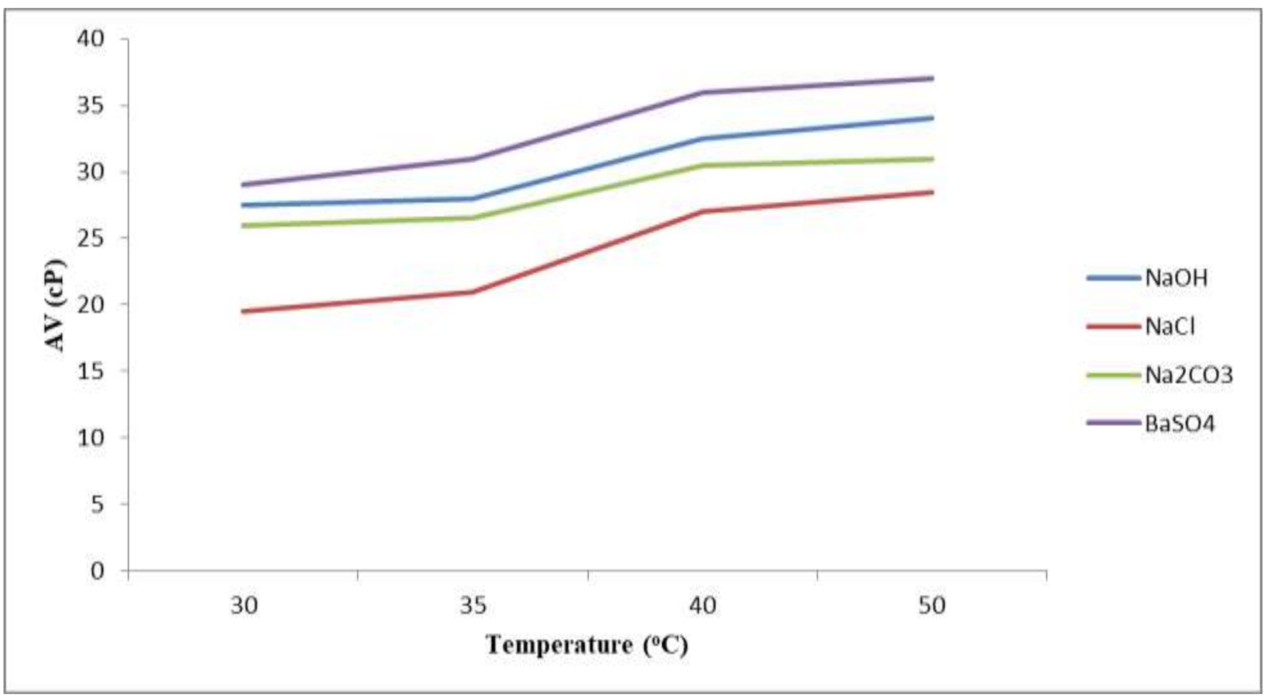

Figure 9: Variation of Apparent viscosity with temperature for Sample C with 10.5g each of (NaOH, NaCl, Na_2CO_3) and 52.5g of

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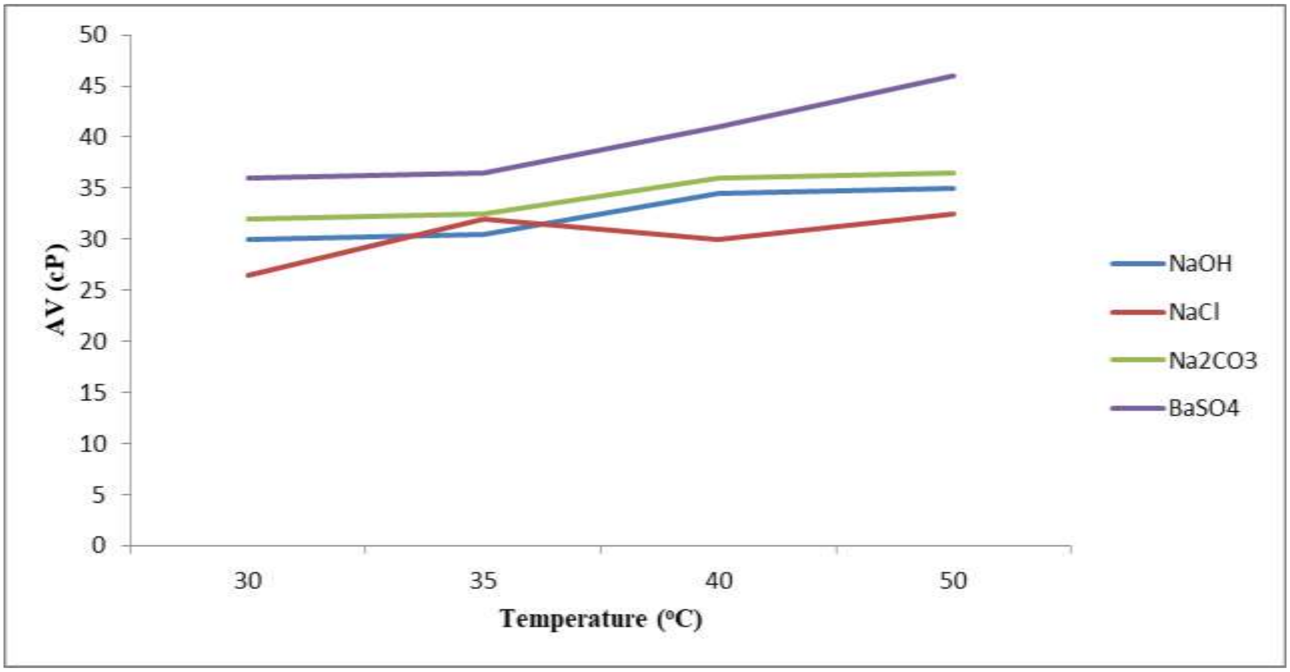

Figure 10: Variation of Apparent viscosity with temperature for Sample D with 3.5g each of (NaOH, NaCl, Na_2CO_3) and 17.5g of $BaSO_4$

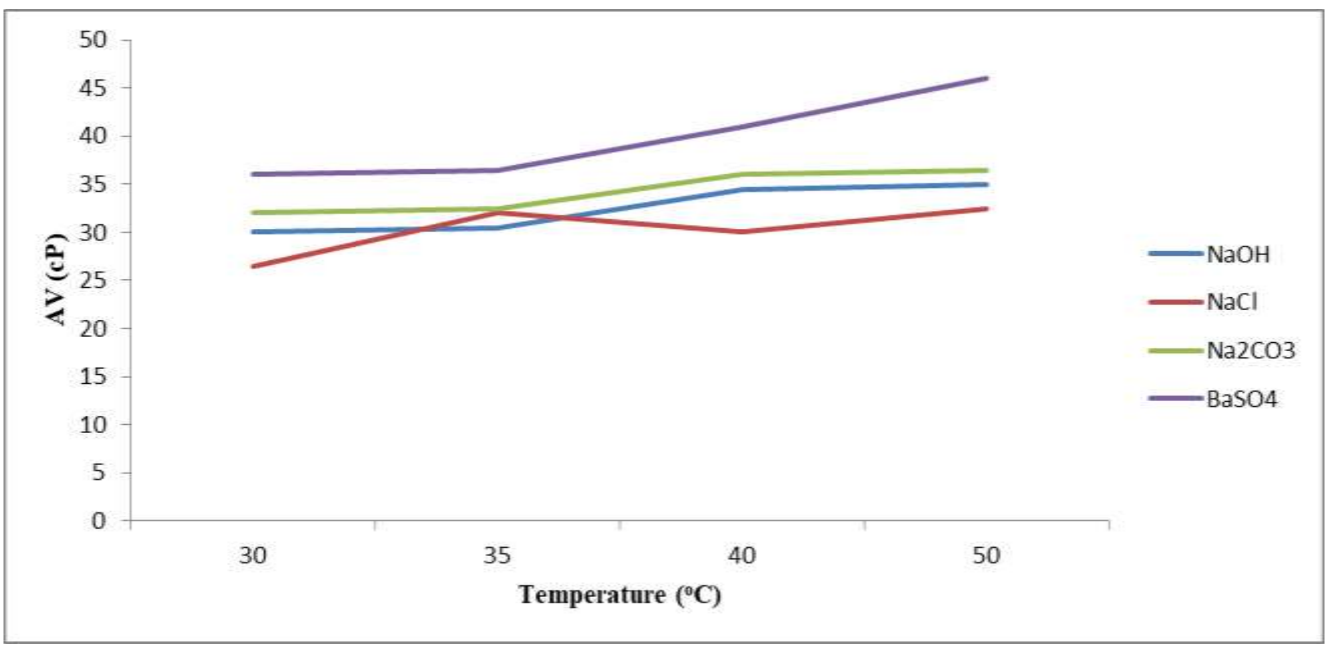

Figure 11: Variation of Apparent viscosity with temperature for Sample D with 10.5g each of (NaOH, NaCl, Na_2CO_3) and 52.5g of $BaSO_4$

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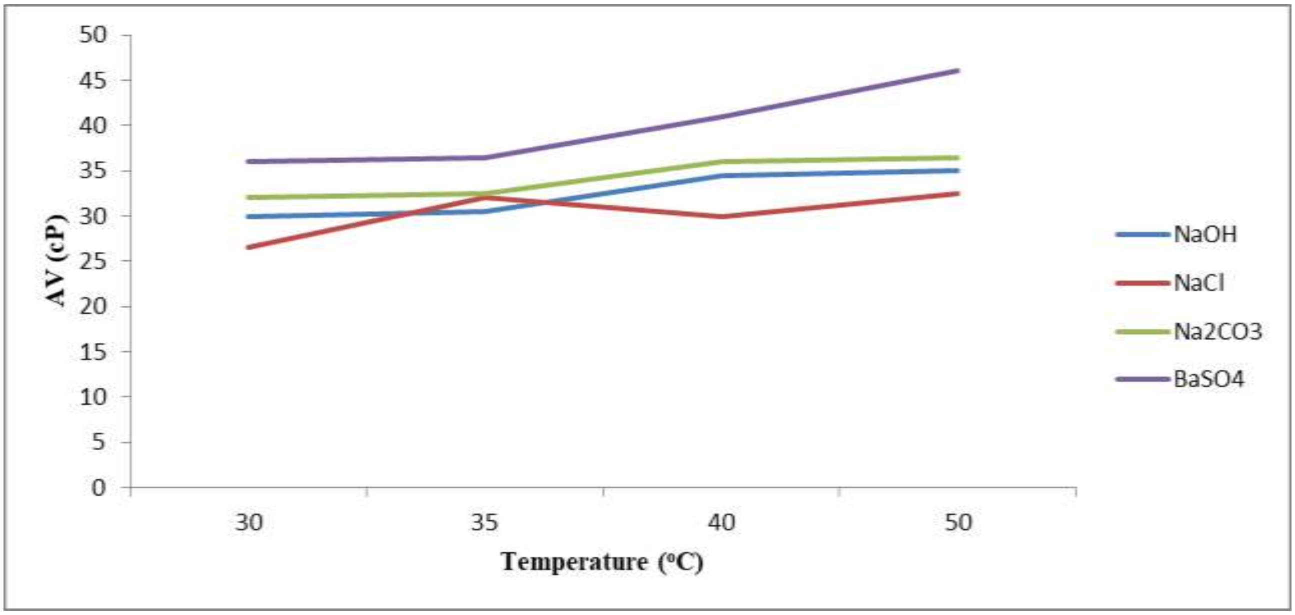

Figure.12: Variation of Apparent viscosity with temperature for Sample D with 10.5g each of (NaOH, NaCl, Na_2CO_3) and 52.5g of $BaSO_4$

3.1.2 Gel Strength

This is a parameter indicating the electrochemical forces in the fluid under static conditions (Garcia et al., 2017). Introduction of the additives showed an increase in the mud samples GS values. The highest 10(sec) GS and (10mins) GS values were obtained in sample A with 10.5g of NaOH and sample A with 52.5g $BaSO_4$ corresponding to 190 lbf/100ft^2 and 192 lbf/100ft^2 for sample A with 10.5g of NaOH and 189 lbf/100ft^2 and 191 lbf/100ft^2 for sample A with 52.5g $BaSO_4$ at 50°C respectively while the lowest value 10(sec) GS and (10mins) GS observed to be in sample C with 3.5g of NaCl at 30°C corresponding to 30 lbf/100ft^2 and 30 lbf/100ft^2 respectively. It was observed that the gel strength of the samples at 10 sec and 10 minutes increased with increased in temperature for all the samples tested in the presence of the chemical additives.

3.1.3 Plastic Viscosity

Plastic viscosity expresses the fluid resistance to flow due to mechanical friction. From the results obtained, the maximum plastic viscosity value was found to be 40 cP, which was observed in sample B with 10.5g NaOH at 35°C while the minimum value was found to be 5 cP, which was observed in sample D with 7g NaCl at 50°C. It was observed that the plastic viscosity of samples remained the same or decreased a little with increased in temperature between 30°C and 35°C for all the chemical additives. The plastic viscosities of the samples, however, increased with increased in temperature from 35°C through to 50°C for all the chemical additives.

3.1.4 Yield Point

Yield point (YP) is the resistance to the initial flow of the drilling fluid (Shah *et al*., 2010). From the results obtained, maximum Yield point value was observed in sample A with 10.5g NaOH at 35°C which show a value of 170 lbf/100ft^2 while the minimum value was to be in sample C with 7g of Na_2CO_3 at 30°C which is recorded to be 3 lbf/100ft^2. This is in agreement the findings of previous researcher who noted that yield point is influence by mud solid properties and solid volume, concentrations and type and concentration of ions in mud fluid (Magzoub, 2014). The YP was observed to followed the same trend like that of plastic viscosity for all the samples mixed with the chemical additives: it decreased with increased in temperature at low temperatures (30°C to 35°C) and increased with increased in temperature at higher temperatures (35°C to 50°C).

3.2 Drilling Fluid Samples pH Treated with Additives (NaOH, NaCl, Na_2CO_3 and $BaSO_4$)

The pH value of the drilling fluid for sample A, B, C and D were found to be 9.1, 8.8, 8.8 and 8.7 respectively as shown in Table 2. It was observed that after introducing the various additives for the first given compositions, the pH values of sample A with additives of 3.5g of (NaOH, NaCl and Na_2CO_3) and 17.5g of $BaSO_4$ were found to be (9.5,8.6,8.4) and 8.3 (Figure 13) respectively at 30°C, that of B were found to be (9.1,7.8,8.5) and 8.3 (Figure 16),that of C were found to be (8.9,7.6,9.1) and 8.3 (Figure 19) and that of D were found to be (8.7,7.4,9.0) and 8.1 (Figure 22) respectively. It was observed that the pH values were significantly controlled

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by NaOH due to increase in the pH values for all the samples as concentration of NaOH were added (Figures 13 to 24). The pH values of the samples A, B, C and D increased at 30°C from 9.1, 8.8, 8.8 and 8.7 to 9.5, 9.1, 8.9 and 8.8 with addition of 3.5g NaOH respectively. When the concentration of NaOH was further increased to 7g, the pH values increased from 9.1, 8.8, 8.8 and 8.7 to 10.0, 9.3, 9.1 and 8.9 (Figures 13, 14, 16, 17, 19, 20, 22, 23) while the pH values increased from 9.1, 8.8, 8.8 and 8.7 to 11.5, 10.1, 9.5 and 9.3 when the NaOH concentration increased to 10.5g at 30°C respectively (Figures 14, 15, 17, 18, 20. 21, 23, 24) . The results further revealed that there was no much significant effect of temperature observed in the pH values (Figures 13 to 24). The highest pH values recorded is found to be 11.6 in sample A when the concentration of NaOH is 10.5g at 50°C. However, this indicates that there is increase in the rheology of the sample at this pH values which agrees with the fact that increase in pH value tends to increase the rheology of the given mud sample (Gamal *et al.*,2019).

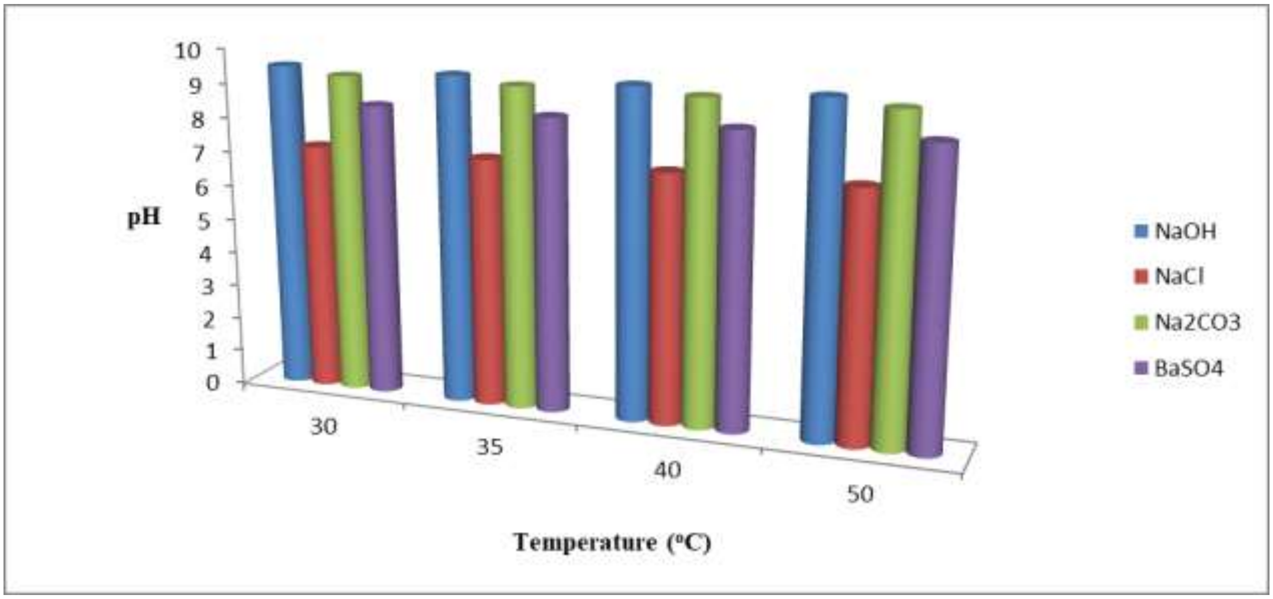

Figure 13: Variation of pH with temperature for Sample A with 3.5g each of (NaOH, NaCl, Na_2CO_3) and 17.5g of $BaSO_4$

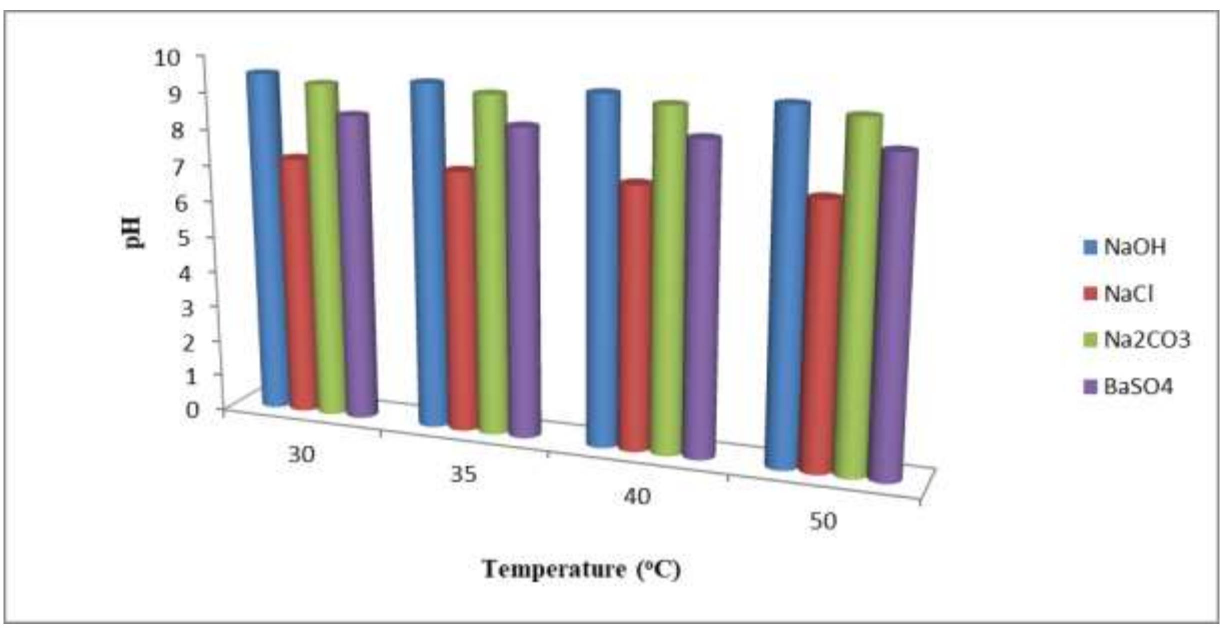

Figure 14: Variation of pH with temperature for Sample A with 7g each of (NaOH, NaCl, Na_2CO_3) and 35g of $BaSO_4$

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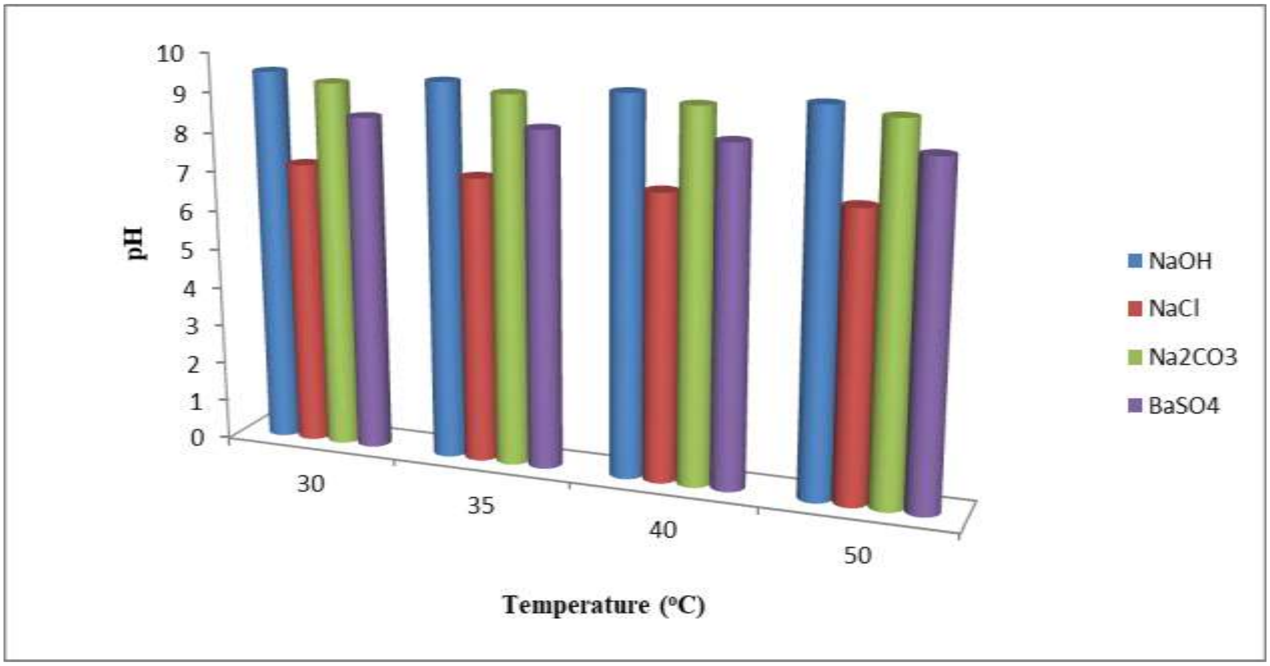

Figure 15: Variation of pH with temperature for Sample A with 10.5g each of (NaOH, NaCl, Na_2CO_3) and 52.5g of $BaSO_4$

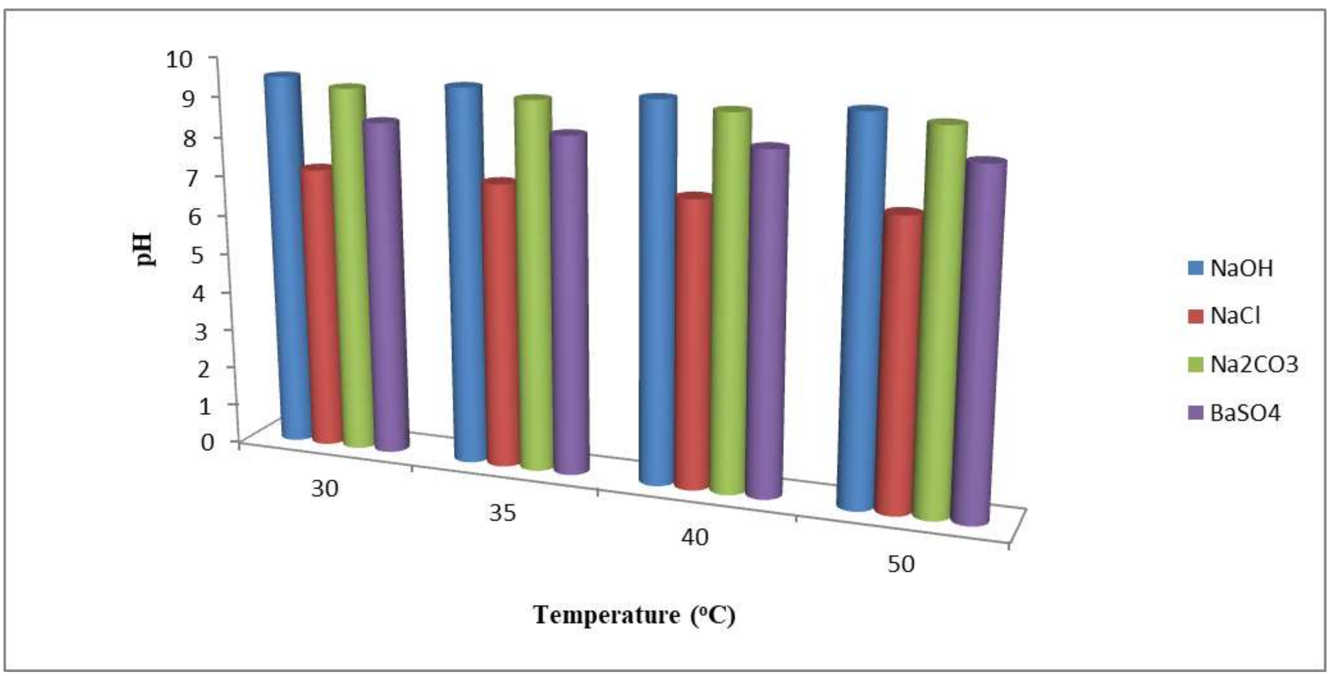

Figure 16: Variation of pH with temperature for Sample B with 3.5g each of (NaOH, NaCl, Na_2CO_3) and 17.5g of $BaSO_4$

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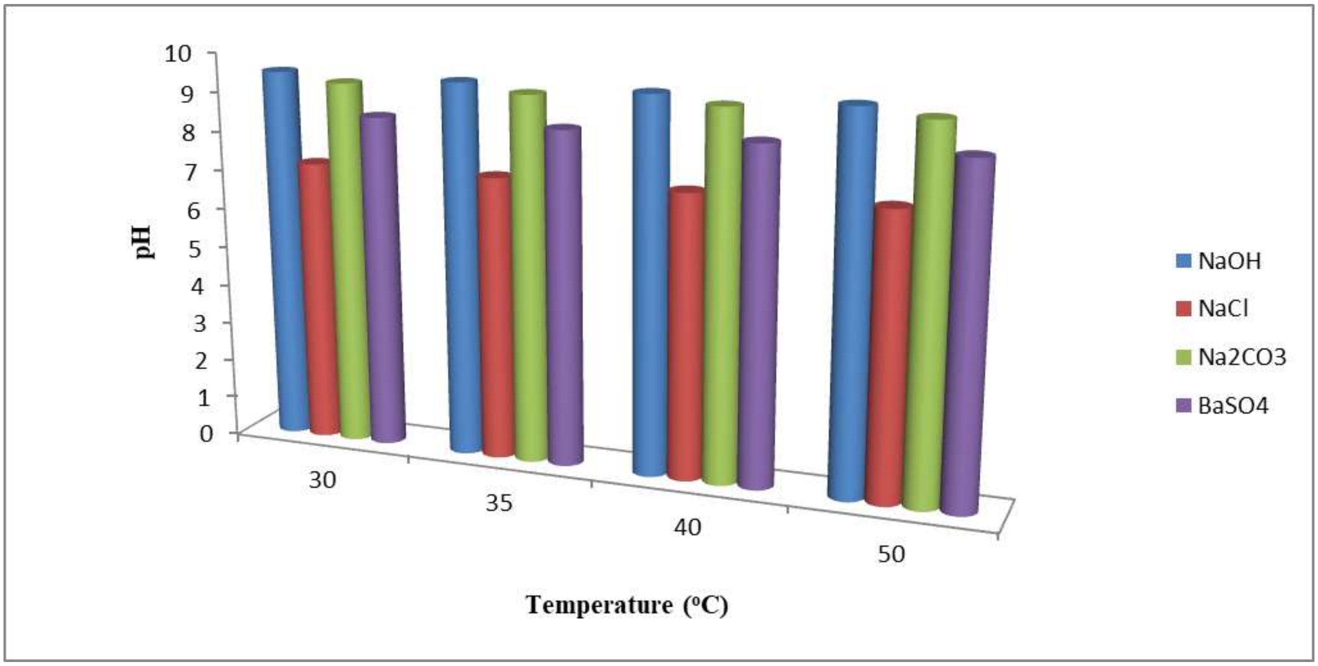

Figure 17: Variation of pH with temperature for Sample B with 7g each of (NaOH, NaCl, Na_2CO_3) and 35g of $BaSO_4$

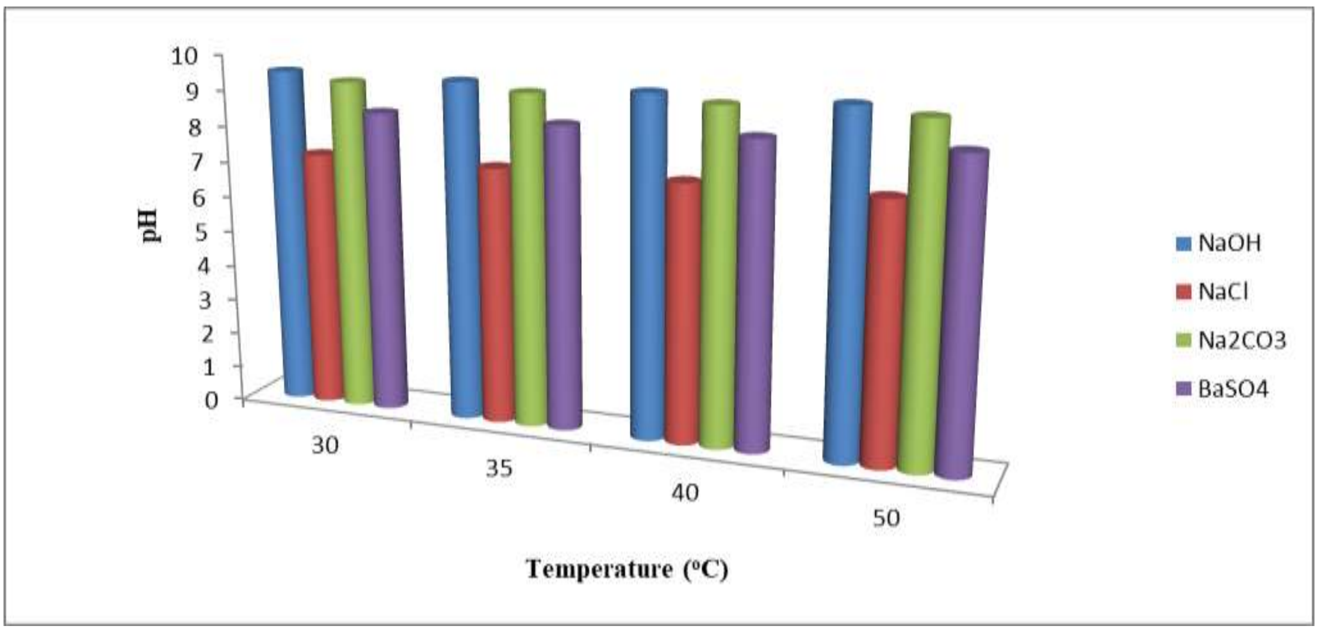

Figure 18: Variation of pH with temperature for Sample B with 10.5g each of (NaOH, NaCl, Na_2CO_3) and 52.5g of $BaSO_4$

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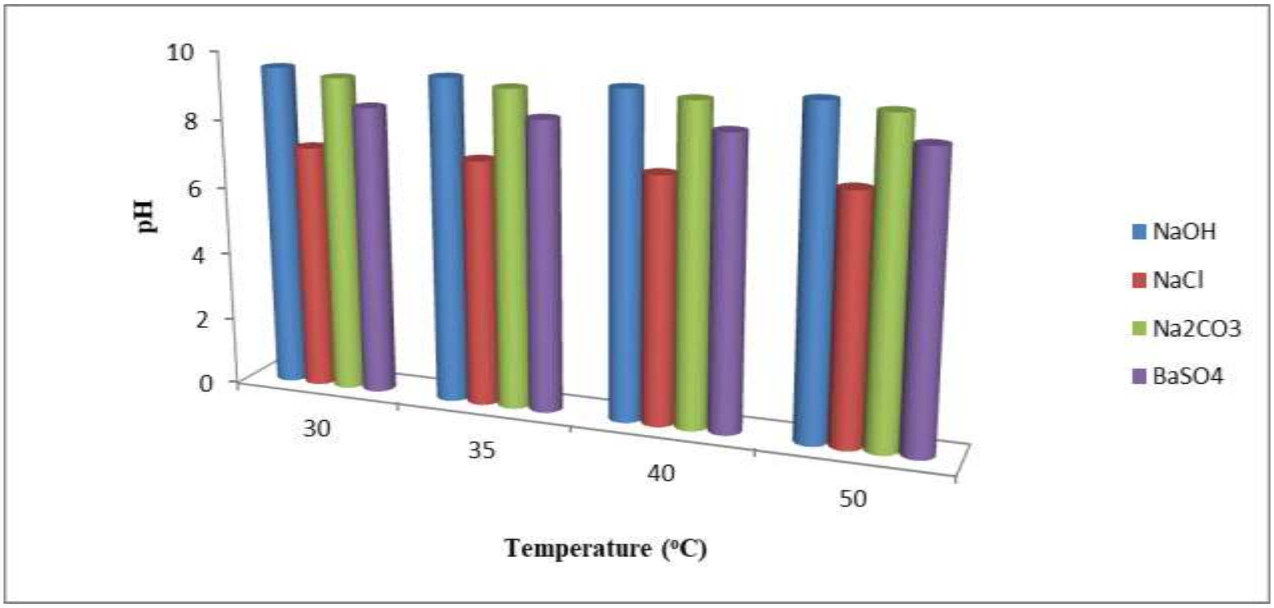

Figure 19: Variation of pH with temperature for Sample C with 3.5g each of (NaOH, NaCl, Na_2CO_3) and 17.5g of $BaSO_4$

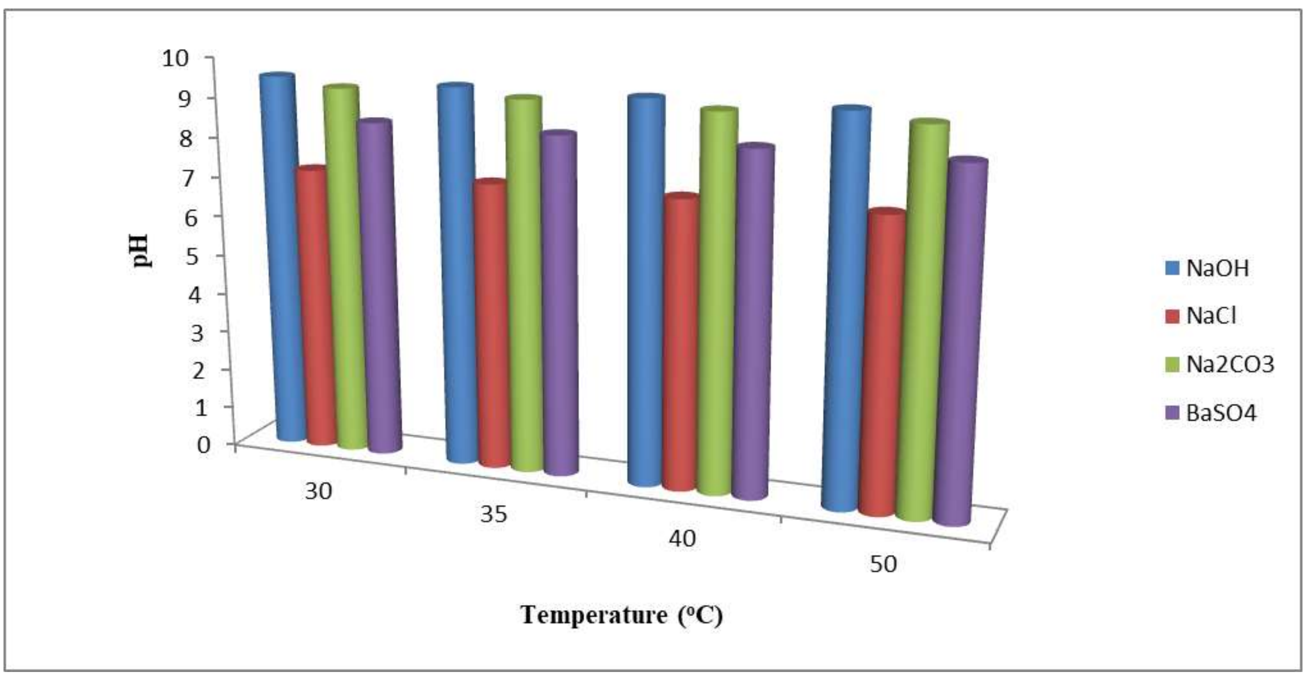

Figure 20: Variation of pH with temperature for Sample C with 7g each of (NaOH, NaCl, Na_2CO_3) and 35g of $BaSO_4$

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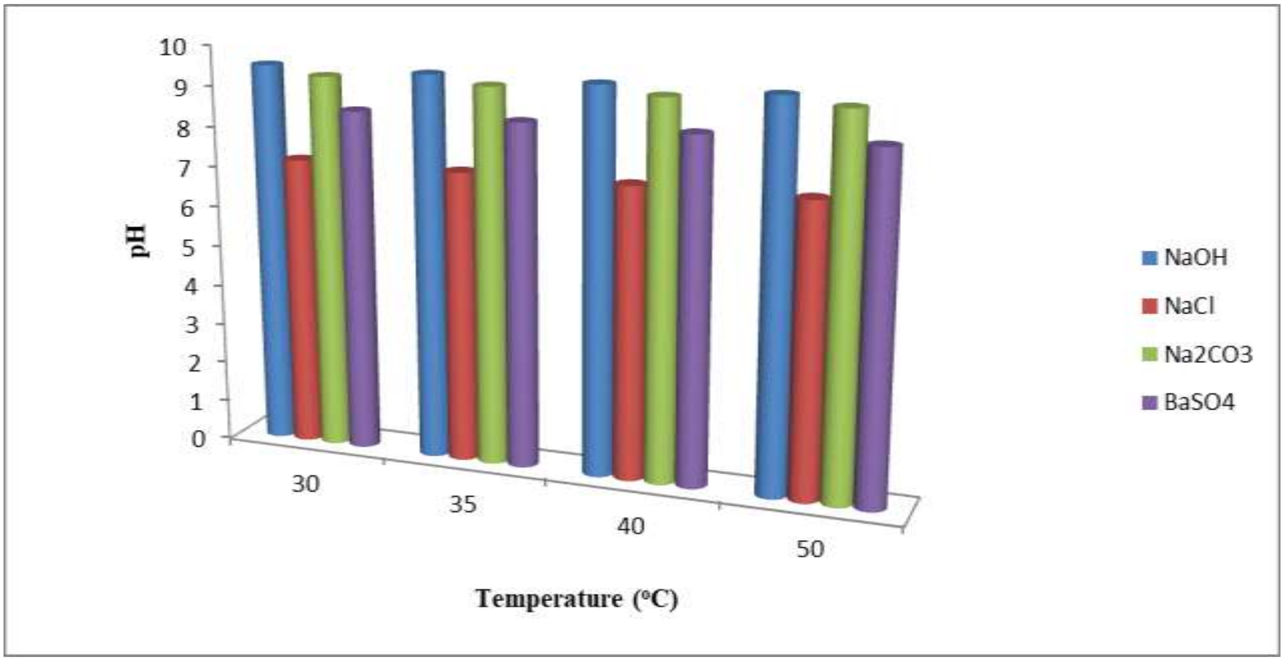

Figure 21: Variation of pH with temperature for Sample C with 10.5 each of (NaOH, NaCl, Na_2CO_3) and 52.5g of $BaSO_4$

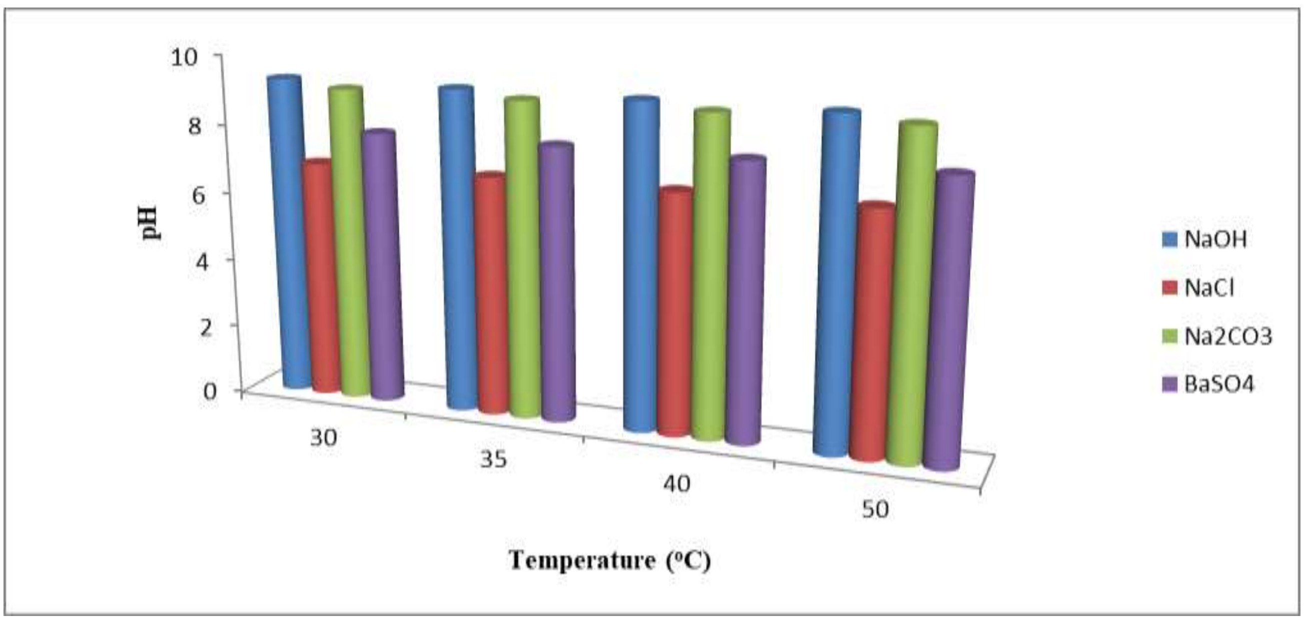

Figure 22: Variation of pH with temperature for Sample D with 3.5g each of (NaOH, NaCl, Na_2CO_3) and 17.5g of $BaSO_4$

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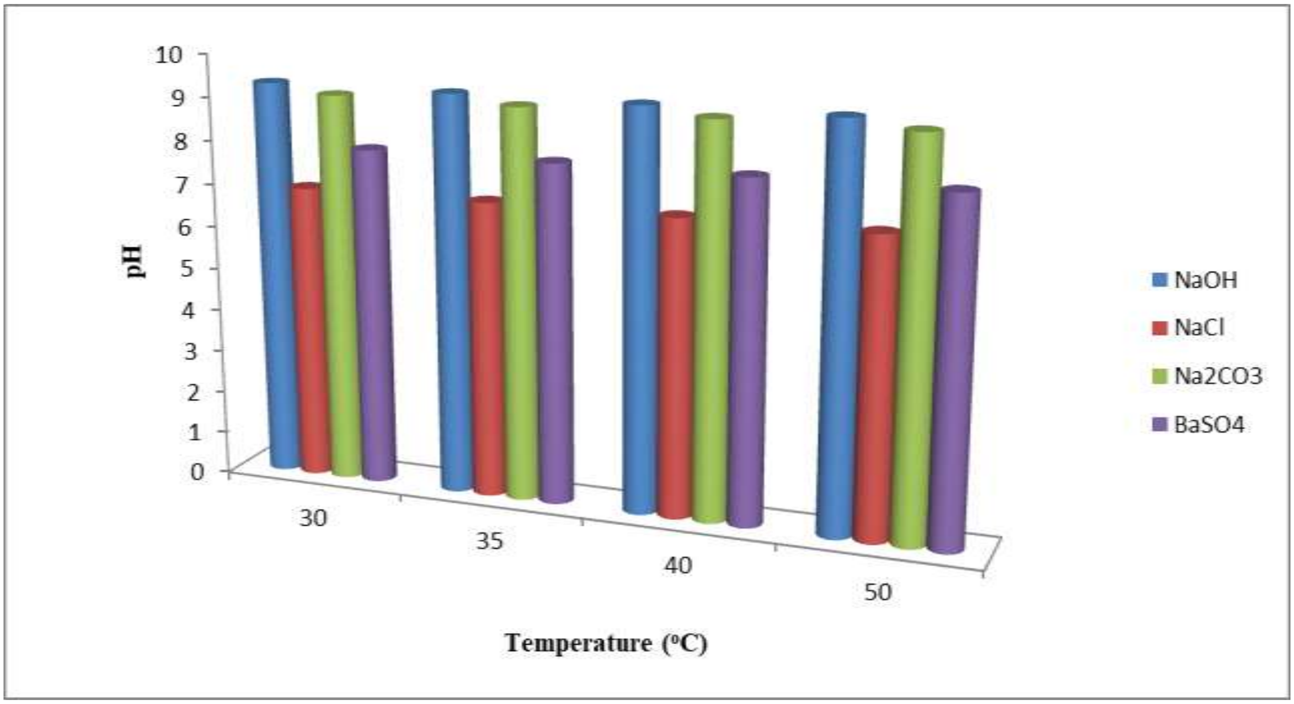

Figure 23: Variation of pH with temperature for Sample D with 7g each of (NaOH, NaCl, Na_2CO_3) and 35g of $BaSO_4$

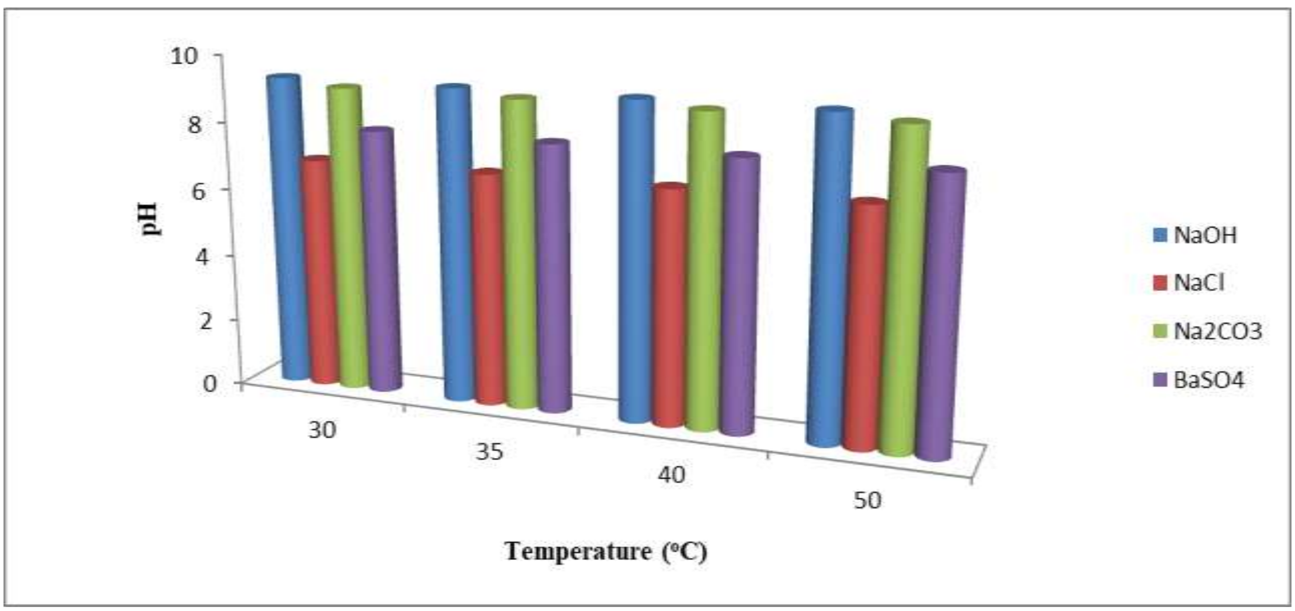

Figure 24: Variation of pH with temperature for Sample D with 10.5g each of (NaOH, NaCl, Na_2CO_3) and 52.5g of BaSO

3.3 Mud Weight

The results obtained from the study showed that mud weight (fluid density) of drilling fluid samples ranges from 8.98lb/gal to 10.82 lb/gal. The drilling fluid samples with barite ($BaSO_4$) showed significant variation in density unlike the other additives (NaOH, NaCl and Na_2CO_3) which showed slight change even with increase in their concentrations. Barite concentration range from 17.5g to 52.5g with samples A, B, C and D showed maximum value of mud weight at 50°C.The values of the mud weight for Sample A with 17.5g, 35g and 52.5g of $BaSO_4$ corresponds to 9.57 lb/gal, 9.59lb/gal and 9.74 lb/gal respectively, sample B with the same amount of barite corresponds to 10.49lb/gal,10.50 lb/gal and 10.82lb/gal,

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sample C corresponds to 10.12 lb/gal,10.44lb/gal, and 10.57 lb/gal while sample D corresponds to 10.09 lb/gal, 10.39 lb/gal and 10.53 lb/gal respectively.

The maximum mud weight was observed in sample B with 10.82lb/gal which contains 52.5g of $BaSO_4$ while the minimum mud weight was observed in sample A which have 3.5g (NaOH, NaCl and Na_2CO_3) at 35^oC corresponds to 8.98 lb/gal. The results indicate that increase in the amount of barite in all the drilling fluids tends to increase the mud weight which is in agreement with the findings of Ammani & Hassiba (2012).

IV. CONCLUSION

In this study four samples of drilling fluids containing bentonite, rice husk and xanthan gum in different proportions were investigated for impact of chemical additives on their rheological properties at different temperatures. The chemical additives were added to the four samples at a given composition of 1%,2%,3% for (NaOH, NaCl, Na_2CO_3) and 5%, 10%, 15% for ($BaSO_4$) by mass. It could be concluded that $BaSO_4$ con function effectively as mud weight improver at temperatures range of 30^oC to 50^oC. The maximum mud weight was observed in sample B with 10.82lb/gal which contains 52.5g of $BaSO_4$ while the minimum mud weight was observed in sample A which have 3.5g (NaOH, NaCl and Na_2CO_3) at 35^oC corresponds to 8.98 lb/gal. The pH of drilling fluid containing xanthan gum, rice husk and bentonite can be raised to alkaline condition by addition of appropriate proportion of NaOH. The apparent viscosity of the drilling fluid with the chemical additives NaOH, Na_2CO_3 and $BaSO_4$ were not negatively affected by the rise in temperature. Thus, the drilling fluids produced with bentonite, rice husk, xanthan gum with appropriate proportion of NaOH and $BaSO_4$ could be effective water based drilling fluid that can serve effectively in drilling operations at reasonable high temperature.

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