Global Journal of Researches in Engineering
Chemical Engineering
Volume 12 Issue 1 Version 1.0 Year 2012
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN: 2249-4596 Print ISSN:0975-5861

Effect of KCL on Rheological Properties of Shale Contaminated Water-Based MUD(WBM)

By Joel, O.F, Durueke, U.J & Nwokoye C.U
University of Port Harcourt, Nigeria.

Abstract - Interests in the design of water-based muds(WBM) have escalated due to wellbore instability issues that arise from the abundance of problematic shales encountered while drilling. Conventional water-based muds(WBMs) that are used to drill through water sensitive shale formations cause a high degree of wellbore instability. Consequently, oil based muds(OBMs) were adopted to solve the wellbore instability problems due to their superior shale stabilization properties. Unfortunately, high costs, environmental restrictions, cuttings and used mud disposal difficulties and safety have largely limited the use of OBMs. As a result of these challenges with OBMs, WBMs that have the ability to effectively reduce shale instability problems have once again come under the lime light to replace the OBMs. Potassium-based (KCL)muds are used in areas where inhibition is required to limit chemical alteration of shales. This research study therefore was undertaken to evaluate the inhibition effects of different concentrations of KCL on the rheological properties of water-based mud(WBM) contaminated with shale.

GJRE-C Classification : FOR Code : 090408

EFFECT OF KCL ON RHEOLOGICAL PROPERTIES OF SHALE CONTAMINATED WATER-BASED MUDWBM

Effect of KCL on Rheological Properties of Shale Contaminated Water-Based MUD(WBM)

Joel, O.F [α], Durueke, U.J [σ] & Nwokoye C.U [ρ]

Abstract - Interests in the design of water-based muds(WBM) have escalated due to wellbore instability issues that arise from the abundance of problematic shales encountered while drilling. Conventional water-based muds(WBMs) that are used to drill through water sensitive shale formations cause a high degree of wellbore instability. Consequently, oil based muds(OBMs) were adopted to solve the wellbore instability problems due to their superior shale stabilization properties. Unfortunately, high costs, environmental restrictions, cuttings and used mud disposal difficulties and safety have largely limited the use of OBMs. As a result of these challenges with OBMs, WBMs that have the ability to effectively reduce shale instability problems have once again come under the lime light to replace the OBMs. Potassium-based (KCL)muds are used in areas where inhibition is required to limit chemical alteration of shales. This research study therefore was undertaken to evaluate the inhibition effects of different concentrations of KCL on the rheological properties of water-based mud(WBM) contaminated with shale. The rheological values using FANN viscometer with different concentrations of KCl((0.2%, 0.4%,1.0%,2.0% and 4.0%) respectively by weight of contaminated 8.5PPG WBM with typical shale sample from the Niger Delta Region of Nigeria were evaluated. Test results indicated that the KCl inhibited the swelling tendencies of the shale and the rheological values reduced drastically. The reduction in rheological values considering the 600rpm reading were 0%, 36%, 60%, 94% and 181% respectively compared to results without KCL in the mud as indicated above. Therefore, to avoid non-productive time resulting from hole instability problems caused by shale, when drilling is expected to encounter shale zones, proper design of the drilling fluids using WBMs with KCL that will inhibit shale swelling is imperative.

I. Introduction

The art and science of drilling wells require the use of drilling fluids for several reasons including cuttings carrying and maintenance of wellbore stability. Drilling fluid selection is dependent on the behaviour of the formation to be drilled. Shale, the most abundant rock type in the earth interacts variably with the fluids used. Shales are low-permeability sedimentary rocks with small pore radii that characterized by low permeability, medium to high clay content, and medium porosity in addition to other minerals, such as quartz, feldspar, and calcite. Shale types range from soft Gumbo shale in offshore Louisiana, Gulf of Mexico to hard brittle shale in South Louisiana with each type presenting its own set of problems. They account for over 75% of formations drilled all over the world and cause over 90% of wellbore instability problems. The distinguishing features of shale are its clay content and low permeability, which results in poor connectivity through narrow pore throats. Shales are also fairly porous and are normally saturated with formation water, with several factors affecting their properties, such as burial depth, water activity, and the amount and type of minerals present(Joel, et al).

Interests in the design of water-based muds (WBM) have escalated due to wellbore instability issues that arise from the abundance of problematic shales encountered while drilling. Conventional water-based muds (WBMs) that are used to drill through water sensitive shale formations cause a high degree of wellbore instability. Consequently, oil based muds (OBMs) were adopted to solve the wellbore instability problems due to their superior shale stabilization properties. Unfortunately, high costs, environmental restrictions, cuttings and used mud disposal difficulties, and safety have largely limited the use of Oil base muds. Consequently, WBMs that have the ability to effectively reduce shale instability problems have once again come under the lime light to replace the OBMs. The limited availability of models to adequately describe shale fluid interaction has hindered the growth of inhibitive WBM development. Models based on chemical potential and hydraulic pressure had been developed by Osisanya (1991), and further work by V Osisanya, et al (1996) have indicated the complexity of theoretical analysis of driving forces and mechanisms that govern shale stability in the borehole.

The use of conventional WBMs in drilling shale formations results in the adsorption of water associated with the drilling mud onto the surface of shale (Chenevert 1970). Depending on the shale type, water adsorption may lead to various reactions such as swelling, cuttings dispersion, and increase in pore pressure (Chenevert 1973) creating wellbore instability to varying degrees. Common failures that occur from shale instability using conventional WBMs include sloughing, caving, stuck pipe, bit balling and increased torque and drag. These failures can grow into massive expenses due to lost non-productive time. In general, drilling fluid weight and chemical compositions are the elements that are manipulated in order to control such

Author α σ : Department of Petroleum and Gas Engineering, Faculty of Engineering, University of Port Harcourt, Nigeria.
E-mail : Ogbonna.joel@yahoo.com
Author ρ : POCEMA Consultants , Plot 6 Azunda Wobo, Port Harcourt, Rivers State, Nigeria.

instabilities. However, instabilities in shale may be caused by a complex mechanism of shale drilling fluid interaction ranging from mechanical to chemical reasons(Al-Bazali, 2005). Therefore proper selection of the drilling fluids to be used on a particular well site is an essential phase of any carefully planned drilling operation. When this drilling is expected to encounter shale zones, the selection of the fluid becomes even more important. To maintain a stable borehole through such zones, a carefully designed mud will be required. The design of successful fluids for this type of application depends largely on a knowledge of the physical and mineralogical characteristics of the shale and its behavior when in contact with drilling mud.

Potassium-based muds are used in areas where inhibition is required to limit chemical alteration of shales. Potassium performance is based on cationic exchange of potassium for sodium or calcium ions on smectites and interlayered clays. The potassium ion compared to calcium ion or other inhibitive ions, fits more closely into the clay lattice structure, thereby greatly reducing hydration of clays . Potassium-based muds perform best on shales containing large quantities of smectite or interlayered clays in the total clay fraction. Shallow shales, containing large amounts of montmorillonite, however, still swell in a potassium-based system. In recent years, muds containing potassium chloride and a suitable polymer have been the subject of publications from several areas. Laboratory studies of the effects of several salt solutions on the hardness of cores from water-sensitive sands showed that 2% potassium chloride was a more effective stabilizing agent than was 2% calcium chloride or 10% sodium chloride.

In 1960, while drilling steeply dipping shales in the Cerro Pelado area of Venezuela, noted improved hole stability when mud containing potassium ion replaced the commonly used sodium or calcium ions to inhibit clay swelling. Hole enlargement in the shale section was significantly reduced a result attributed to the inhibitive properties potassium ion and cited in a patent application filed in September 1963.

The objective of this work, therefore, is to evaluate experimentally the degree of inhibition of different concentrations of KCl on Shale contaminated WBM.

II. Materials and Research Methodology

341grams of water was measured and poured into the Hamilton mixing cup. 4.0grams of bentonite was added and prehydrated for 30 minutes under stirring condition. After 30 minutes, 0.2grams of xanthan gum, 0.4grams of Pac-R, 0.6grams Pac-L respectively were added to the mixing cup. These with prehydrated bentonite was stirred for 15 minutes before 0.25grams of Soda ash was added and stirred for another 10 minutes. Then 13.0 grams of barite was finally added and the mixture was stirred further for another 20 minutes for homogeneity before taking the rheological readings and(10 seconds/minutes) gel strength using VG meter.

The mixing procedure was repeated using the grounded sample of shale. Different weights of the shale (1%,2%,4%,7%,10%) respectively by weight of the formulated mud were added. Thereafter, the KCL(0.2%, 0.4%,1.0%, 2.0% and 4.0%) by weight of the formulated mud were added respectively. The rheological readings and(10 seconds/minutes) gel strength values were recorded as well. The plastic viscosity and Yield Point values were evaluated as applicable.

Table 1 : Additives and Functions

S/N	ADDITIVE(S)	FUNCTION(S)
1	Water	Base fluid
2	Soda Ash	Calcium precipitant and pH reducer in cement contaminated mud
3	Bentonite	Viscosity and Filtration control
4	XCD	Viscosity and Filtration control
5	Par R	Fluid loss control and Viscosifier
6	Par L	Fluid loss control and Viscosifier
9	Barite	Weighting agent
10	KCl	Clay inhibitor

III. Results and Discussion

The results of the various tests are recorded in the tables below.

Table 2 : Rheological properties of formulated mud(8.5PPG)

S/N	RPM	DIAL READING
1	Ø600	21(Cp)
2	Ø300	14(Cp)
3	Ø6	2(Cp)
4	Ø3	2(Cp)
5	Plastic Viscosity(Cp)	7(Cp)
6	Yield Point (lb/100Ft^2)	7(Cp)
7	10Sec Gel strength(lb/100Ft^2)	1
8	10Mins Gel strength(lb/100Ft^2)	2

Table 3 : Shale Components

S/N	PARAMETER	RESULT
1	Native moisture content %	13.83
2	Cation Exchange Capacity Meq/100g	2.92

Table 4 : Rheology results for the shale/mud at different concentrations

MIXTURE	600 RPM (Cp)	300 RPM (Cp)	6RPM (Cp)	3RPM (Cp)	10sec gel(Cp)	10mingel(Cp)	PV (Cp)	YP (lb/100ft^2)
Mud+1.0% shale	23	15	2	1	1	1	8	7
Mud+2.0% shale	30	18	2	1	1	2	12	6
Mud+4.0% shale	32	21	5	3	4	7	11	10
Mud+7% shale	35	25	11	10	10	10	10	10
Mud+10% shale	45	24	12	11	11	13	21	3

Table 5 : Rheology results for the shale/mixture at different concentrations with KCl

MIXTURE	600 RPM (Cp)	300 RPM (Cp)	6RPM (Cp)	3RPM (Cp)	10sec gel(Cp)	10mingel(Cp)	PV (Cp)	YP (lb/100ft^2)
Mud+1.0% shale+0.2%kCl	23	17	2	1.5	2	3	6	1
Mud+2.0% shale+0.4% KCl	22	13	2	1	1.5	2	9	4
Mud+4.0% shale+1.0%KCl	20	12	2	1	1	2	8	4
Mud+7% shale+2.0% KCl	18	11	2	1	1	2	7	4
Mud+10% shale+4.0% KCl	16	12	3	2	2	3	4	8

Global Journal of Researches in Engineering (C) Volume XII Issue I Version I Year 2012

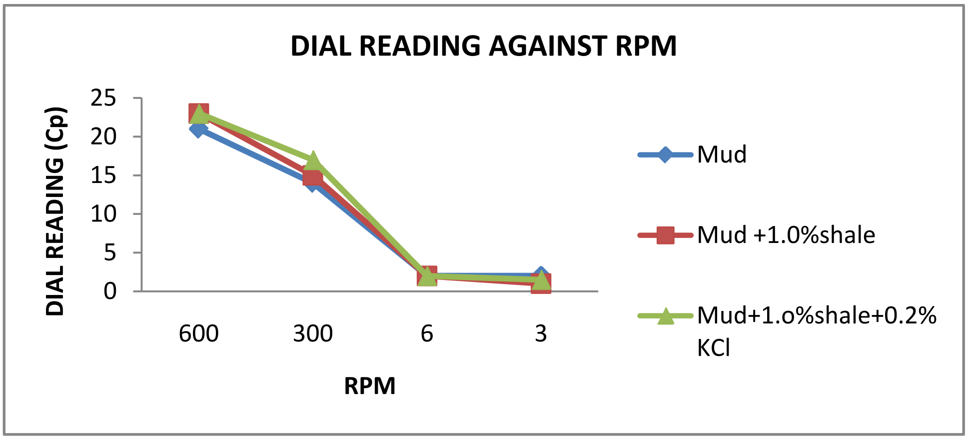

Fig 1 : Dial Reading Against RPM

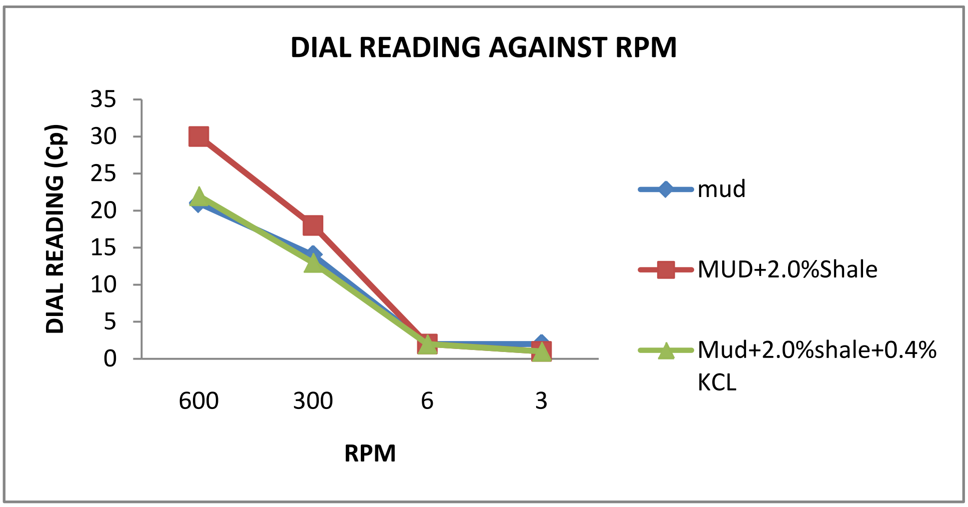

Fig 2 : Dial Reading Against RPM

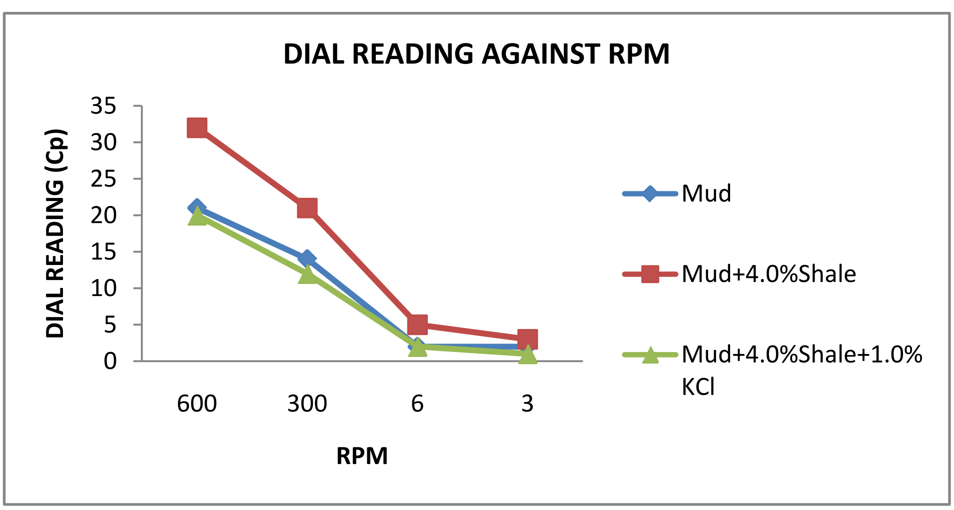

Fig 3 : Dial Reading Against RPM

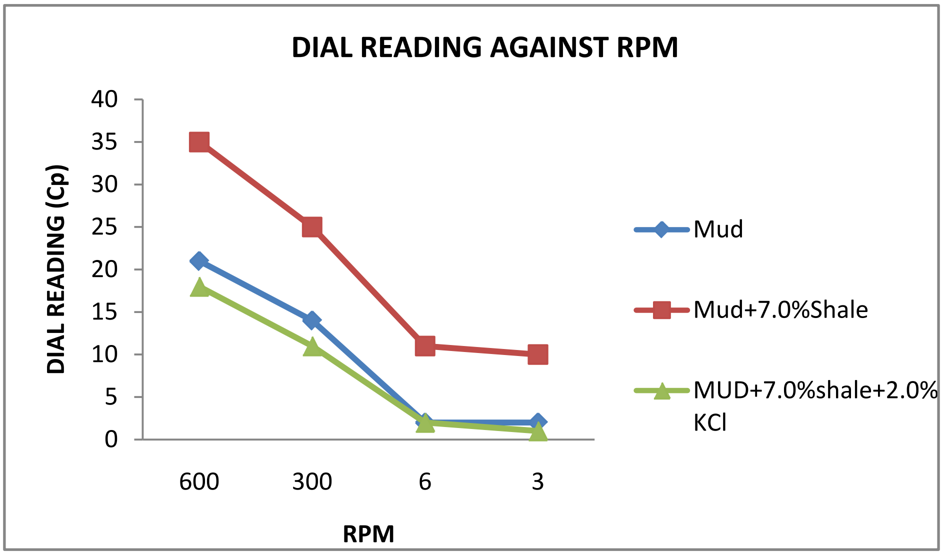

Fig 4 : Dial Reading Against RPM

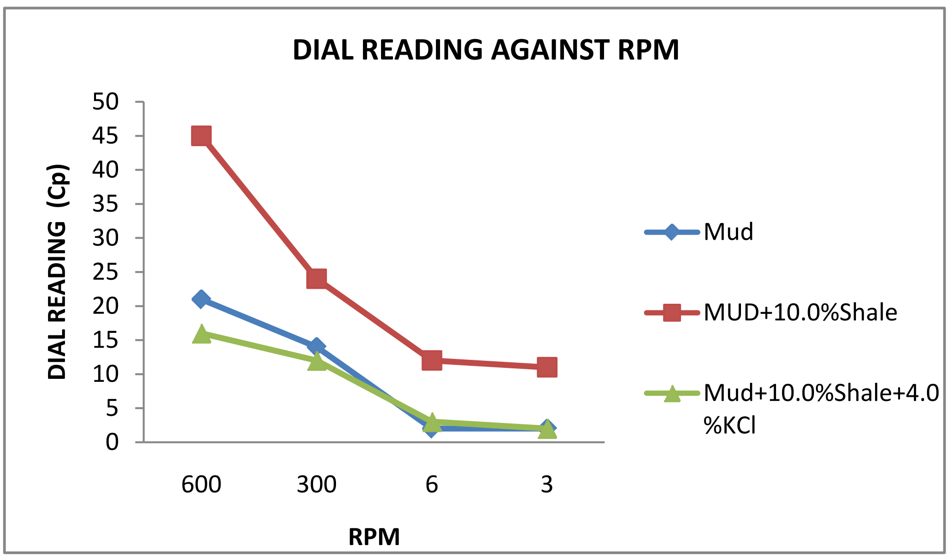

Fig 5 : Dial Reading Against RPM

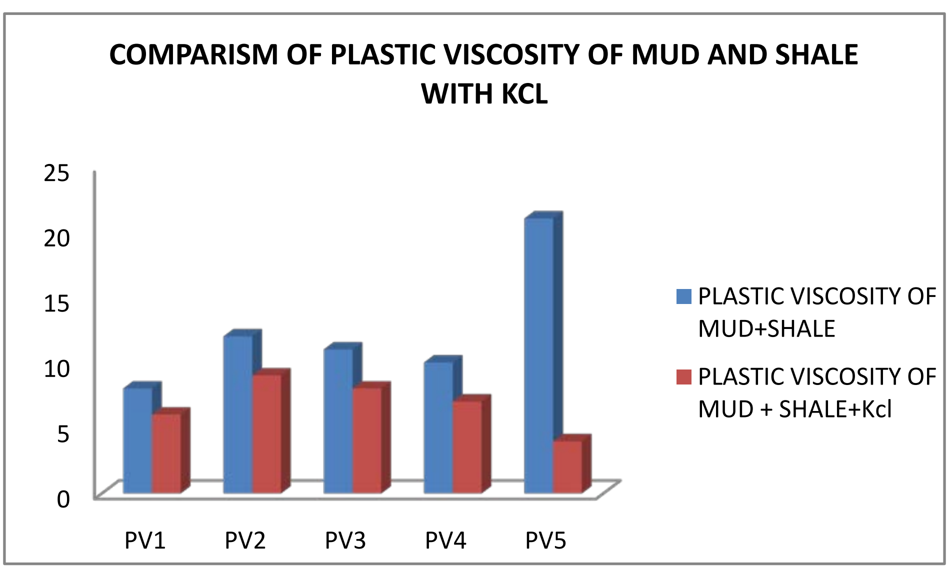

Fig 6 : Coparism of Plastic Viscosity of Mud and Shale With Kcl

© 2012 Global Journals Inc. (US)

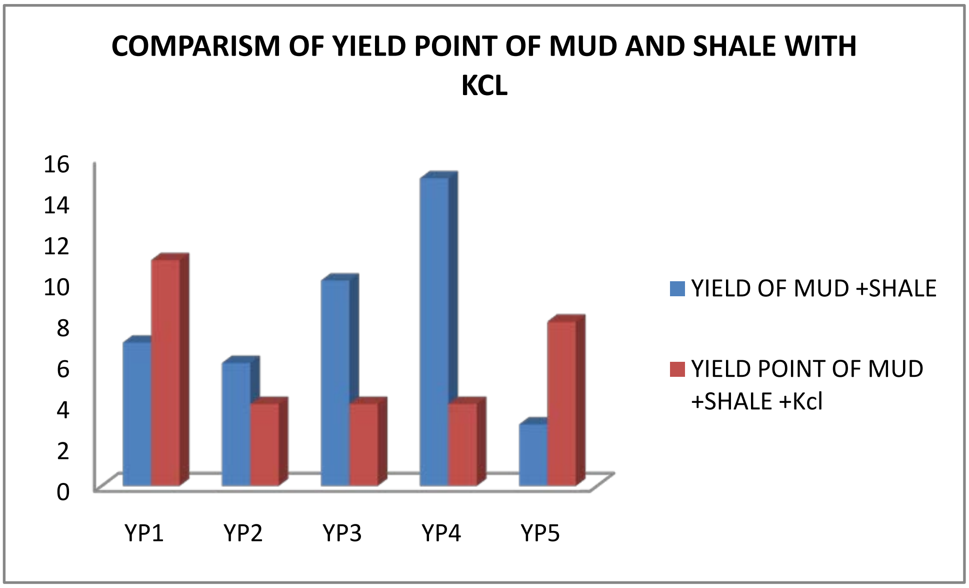

Fig 7 : Coparism of Yield Point of Mud and Shale With Kcl

Table-1 shows the composition of the 8.5PPG mud recipe and various functions of the additives. Results of the formulated mud recipe is reflected on Table-2 while Table -3 details the result for the shale composition, indicating a native moisture content of 13.83% and Cation exchange capacity of 2.92Meg/100g. The 13.83% moisture content indicates high presence of expandable clays with the ability to store moisture easily.

Table-4 gives results with mud contamination with different shale weights. Looking at Table-4 and figures 1-5, with 1.0%,2.0%, 4.0%, 7.0% and 10.0% shale contamination respectively and considering the 600rpm reading, test results indicated that the rheological values increased progressively showing a spike as the shale concentration increased. The increase in rheological values were 9.5%(from 21 to 23 Cp), 42.9%(from 21 to 30 Cp), 52.4%(from 21 to 32 Cp),66.7% (from 21 to 35 Cp) and 114.3%(from 21 to 45 Cp), respectively for the various contaminations as indicated above. This agrees with previous findings on this phenomenon(Joel,2012). The use of conventional WBMs in drilling shale formations results in the adsorption of water associated with the drilling mud onto the surface of shale (Chenevert 1970). However, when KCl was introduced(0.2%, 0.4%,1.0%, 2.0% and 4.0%) by weight of the formulated mud sample respectively, there was progressive reduction in the rheological values with increase in KCl concentration, no increase for 0.2% KCl, (30cP to 22cP for 0.4%KCL), (32cP to 20cP for 1.0%KCl), (35cP to 18cP for 2% KCl) and (45cP to 16Cp for 4%KCL). Test results indicated that the KCl inhibited the swelling tendencies of the shale and the rheological values reduced drastically and considering the 600rpm reading, the percentage reductions were 0%, 36%, 60%, 94% and 181% respectively compared to results without KCL in the mud as indicated above. This agrees with previous studies that potassium chloride is very effective stabilizing agent in shale sensitive formation.

Fig-6 shows the Plastic Viscosity result of the mud with different concentrations of the shale. The test result indicated that as the concentration of shales increased, the plastic viscosity increases, however, there was a noticeable reduction in the plastic viscosity values with introduction of KCl.

Fig-7 shows the yield point results with the different concentrations of shale. The highest shale concentration gave the least yield point value. This is an indication of dispersion and settling tendency of the solid particles in the mixture. Depending on the shale type, water adsorption may lead to various reactions such as swelling, cuttings dispersion, and increase in pore pressure (Chenevert 1973) creating wellbore instability to varying degrees. However, the introduction of KCL resulted to reduction in the yield point values.

References Références Referencias

1. Adamson A.W(1982): "Physical Chemistry of Surfaces", 4th Edition, John Wiley & Sons, pp 521-534.
2. Al-Awad N.J. and Smart B.G.D(1996): "Characterization of Shale-Drilling Fluid Interaction Mechanisms Related to Wellbore Instability", J. King Saud Univ., Vol.8, Eng. Sci. (2), pp 187-215.
3. Ayoub R.F., Tan C.P., Clennell B., Yang J., Tohidi, B(2004): "Wellbore Stability Issues in Shales or Hydrate Bearing Sediments". AAPG Hedberg

Research Conference, Vancouver, September, 2004.
4. Baver L.D(1956).: "Soil Physics", 3rd Edition, John Wiley & Sons, pp 36-37.
5. Borgoyne A.T., Chenevert M.E., Millheim K.K, Young F.S.(1986): "Applied Drilling Engineering", SPE Textbook Series, Vol. **2**, pp 53, 76-77.
6. Chenevert M.E. and Pernot V(1998): "Control of Shale Swelling Pressures Using Inhibitive Water Based Muds", SPE 49263 presented at the SPE Annual Technical Conference and Exhibition, New Orleans, September 27-30.
7. Chenevert, M.E. and Osisanya, S.O(1992): "Shale Swelling at Elevated Temperature and Pressure", presented at the 33rd Symposium in Rock Mechanics, Santa Fe, New Mexico, June 8-10.
8. Chenevert M.E. and Osisanya S.O(1989): "Shale/Mud Inhibition Defined with Rig-Site Methods", SPE Drilling Engineering, September, 1989.
9. Clark R.K., Scheurman R.F., Rath H., Van Larr H.G(1976): "Polyacrylamide/Potassium- Chloride Mud for Drilling Water-Sensitive Shales", SPE 5514, Journal of Petroleum Technology, June 7-9, pp 86.
10. David R. Lide, 2004: "Hand Book of Chemistry and Physics: A Ready Reference Book of Chemistry and Physics data", 85th Edition,
11. Darley H.C.H(1969): "A Laboratory Investigation of Borehole Stability", JPT Trans, AIME, July, 1969,PP 883-892**,**
12. Darley H.C.H and Gray G.R(1991): "Composition and Properties of Drilling and Completion fluids", Fifth Edition, Houston, Texas, Gulf Publishing Company, 1991. Procedure for native moisture content determination
13. Joel, O.F, Durueke, U.J and Nwokoye C.U(2012): Evaluation of Effect of Different Concentrations of Shale on Rheological Properties of Water-based Mud, 36th Annual SPE International Technical Conference and Exhibition, in Lagos-Nigeria, August 6-8,, 2012.

This page is intentionally left blank