

117. Investigation of Polyvinyl Alcohol & Potato Additives for the Improvement of Rheological Properties of Water Based Drilling Mud System

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Abstract

Drilling fluid is one of the most important parameter of Drilling process. The role of the drilling fluid is the transportation of drill cuttings and provide cooling, lubrication to the drill bit and also stabilize the bore hole and increase the penetration rate. Drilling fluid is generally composed of bentonite & barite in addition to different kinds of additives to maintain the properties of drilling fluid for effective and efficient drilling process.

The research work was focused on the comparison and investigation of the rheological properties of different concentration of additives. The analysis was carried out as per API standards by using rotational viscometer, mud balance, multi mixer, Shearometer and pH meter.

In the research, Potato starch and polyvinyl alcohol additives were used for the improvement of rheological properties and gel strength. Another additive, barite was used for maintaining the mud density while caustic soda was used for maintaining the pH value of drilling mud. The experimental results showed different behavior of PVA and potato starch as an additive. PVA has variable effect on drilling mud system. When drilling mud was formulated with 5gm PVA, drilling mud density and rheological properties were increased. As the concentration of PVA were increased to 10gm, 15gm, 20gm, the density & rheological properties decreased. However, when 5gm, 10gm, 15gm and 20gm potato starch were added in to the drilling mud system, the rheological properties and mud density were increased progressively. From the research work, it was concluded that potato starch improved the rheological properties of drilling mud effectively.

Keywords: *Water base mud, rheological properties, mud density and pH value.*

1. Introduction

Drilling fluid can be considered blood in oil and gas drilling play the most key role in drilling operation [1]. Demand of oil and gas increasingly more precisely issue faced by petroleum drilling [2]. Drilling fluid categories in to three types 1. oil based mud 2. water based mud and foam or air based drilling mud system based mud 3. Fruitful completion of oil well drilling depends on the cost and rheological and filtration properties of drilling fluid [3]. Drilling fluid typically colloidal suspension of solids, that contain solid phase, chemical phase and usually muddy mixture of water and different types of additives such as, bentonite, viscosity increaser, fluid loss reducer, lubricants commonly known as Drilling mud [4]. Water based drilling fluid are harmless to the environment, cutting disposal polymer used synthetic polymer, biopolymer, crosslinked polymer is added in to the water based drilling fluid as viscofying agent [5]. Oil is main component in oil based drilling fluid development of oil based drilling fluid is complex and expensive as compared to water based mud the advantages of oil based mud include good fluid loss control, no clay swelling, good lubrication to the drill bit, good cutting carrying ability their disadvantages poor filter cake, difficult cutting disposal and not friendly to the environment [5]. Main function of drilling fluid is to 1. Transport the drill cuttings 2. To cool and lubricate the drill bit to

stabilize the well bore. 3. Reduce the friction between the drill string and side of the well bore. 4. Form thin and less filter cake that block the pores and other opening in the Formation. [6] Drilling process represent about 25% of the oil field manipulation cost and drilling fluid shows about 15 to 18% of the over-all charges at oil and gas drilling [7]. Drilling fluid must be cost effective because no any harmful effect to the environment, must be easy to use [8]. Drilling fluid rheological properties play very important role in drilling operation supports and help in cleaning and transportation of small piece of the rock sample rock provide cooling and lubrication to the drill bit properties such as plastic viscosity, yield point, apparent viscosity, and gel strength play very vital role for designing appropriate and improved drilling operation the main purpose of these properties [9]. In drilling operation drilling fluid is the essential part of entire drilling process many drilling hazard occurs during drilling operation of well unswervingly or indirectly connected to the drilling fluid. Hence, it is very important drilling fluid must be selected effusively and formulated carefully to fulfill their requirement in drilling operation. In order to enhance the performance and properties of drilling fluid additives are commonly used in drilling mud described as follows. [10- 11]

- Weighting materials (barite, galena, iron oxide, calcium carbonate)
- Viscofier (bentonite, polyacrylates, Xanthan gum, copolymers, sepiolite clay)
- Corrosion inhibitors (zinc carbonate, cationic amines, sodium hydroxide)
- Foaming agents (detergents, non-ionic agents)
- Emulsifiers (lignite, fatty acids)
- Thinners (tannins, quebrachos, pyrophosphates)
- Lost circulation materials (sawdust, mica, synthetic polymers)
- pH maintaining material (caustic soda, lime, bicarbonate of soda, potassium hydroxide)
- Lubricants (graphite, diesel oil)

Main parameter of water based drilling fluid is water. Bentonite and barite are additives that are used in drilling mud. Bentonite is the most important additives of drilling fluid used as Viscofiers and filtration control [12]. Starch, gaur gum, polyacrylamide, polyethylene glycol, polyacrylates, xanthan gum are the different types of polymer classification that are used for buildup of drilling fluid system. Basically, these polymer helps to modify rheological properties. The appropriate study of rheological properties support in energetic act of the drilling fluid during the cuttings suspension hole cleaning cutting and drilling hydraulics. Drilling fluid having good rheological properties low yield point and plastic viscosity good gel strength offer good rate of penetrations [13]. Introduction of nano composite material in to the drilling mud is an substitute to the polymer and different types of clay based mud used for the alter and maintain the rheological properties of mud system [14]. The major constituent of water based mud is water all other constituents such as bentonite and barite are regarded as additives.

Bentonite is often considered as an important drilling fluid additive because it gives proper viscosity and filtration control [15]. Kaolin is one of the most important industrial clay is found commonly in Nigeria it has one deposit of the kaolin clay it is similar to the bentonite [16]. K.A Fattah et al. (2016) The experiment was carried on drilling fluid density. the additives which were used in this research work was barium sulphate and calcium carbonate drilling fluid density play important role many problems encountered during drilling related to the mud density Omotioma et al. (2015). It was reported that cassava starch is used for enhancement of the rheological properties of drilling fluid. Experiment were performed on cassava starch and checked the rheological properties (Annudeep s.dhiman et. al (2012) This research work has been carried out on the drilling fluid to checked the properties and the material which were used in this experimental work barite and hematite. It were observed that that Barite and hematite were useful for density improvement and bentonite for viscosity control Th.s.Milhalakis et. al (2004). Experiment were performed on Greek lignites the purpose of this research work were to study the effect of Greek lignites in drilling mud. Following conclusion were drawn from this experimental work that when 3 perc lignites added to drilling mud Large improvement were observed in the property. Experimental results were compared with Greek lignites to the commercially available lignite. O. Olatunde et. al (2012) it was reported that experiment was performed on water based drilling fluid and checked the properties of water based drilling mud. It was observed that guar gum had high gel strength and good rheological control and less effect on filtration property. Whereas, Arabic gum had not shaky rheological properties with suitable gel strength and good filtration Property (K. N Dagde et. al) Experiment were performed on the formulation of drilling fluid. The material which were used in this experimental work cellulose from ground husk, various other local materials were used at the different concentration. The experimental result indicates that cellulose from ground husk give good density, pH, specific gravity decreases the loss circulation than that of the standard mud standard Jamaal nasseer et. al (2013). In this research study experiment were performed on drilling fluid by using nano particle in order to increase the performance of drilling fluid.

2. MATERIALS AND METHODOLOGY

2.1 Materials or reagents

In this experimental work Following are the materials used for the preparation of drilling mud similar composition of drilling mud as shown in the table 1.

Table, 1 raw material used for the composition of drilling mud

Components	Function	Quantity
Water	Base fluid	625 ml
Bentonite	Viscofiers and filtration control	41 g
Barite	Maintaining density	40g, 35g, 25g, 20g
Caustic soda	Alkanity control	4g
CaoH	Corrosion control	0.5g
KOH	Shale inhibition	0.5g
Sawdust	Loss circulation	1g

Polyvinyl alcohol	Viscofiers	5g, 10g,15g, 20g
Potato starch	Gelling agent	5g, 10g, 15g , 20g

2.1.1 PREPARATION OF DRILLING MUD

Samples were prepared at drilling fluid laboratory in the IPNGE institute of muet of jamshoro. In first step measure the weight of the additives in the electronic weight balance and the weight of water with measuring cylinder after that put the water in the steel glass fix it in the multimixer mix the one by one additives' in to the water. after the mixing of additives sample were found even in to the water. Mixing time of additives were 30 minutes. Whereas, polyvinyl alcohol has on hour mixing time after that viscometer reading takes place rapidly. In first four test the concentration of barite and polyvinyl alcohol were varied at four different value PVA 5g, 10g, 15g, 20g and barite 25g, 30g, 35g, 40g all other raw material added in to the water based Driliing mud at the fix concentration and another four tests were done on the of potato starch and barite was varied at four different concentration p. starch 5g, 10g, 15g, 20g and barite concentration 25g, 30g, 35g, 40g as shown in the table1. Similar composition of drilling mud was prepared by wamiEmeniKeNyecheet et. al (2015).

Table, 2 Composition of Drilling mud

Sample design	Concentration of additives
Sample A	Mud + 5 gm PVA + 40 gm barite
Sample B	Mud + 10 gm PVA +35 gm barite
sample C	Mud +15 gm PVA + 30 gm barite
Sample D	Mud + 20 gm PVA + 25 gm barite
Sample E	Mud + 5 gm potato starch+ 40 gm barite
Sample F	Mud + 10 gm potato starch + 35 gm barite
Sample G	Mud + 15 gm potato starch+ 30 gm barite
Sample H	Mud + 20 gm potato starch + 25 gm barite

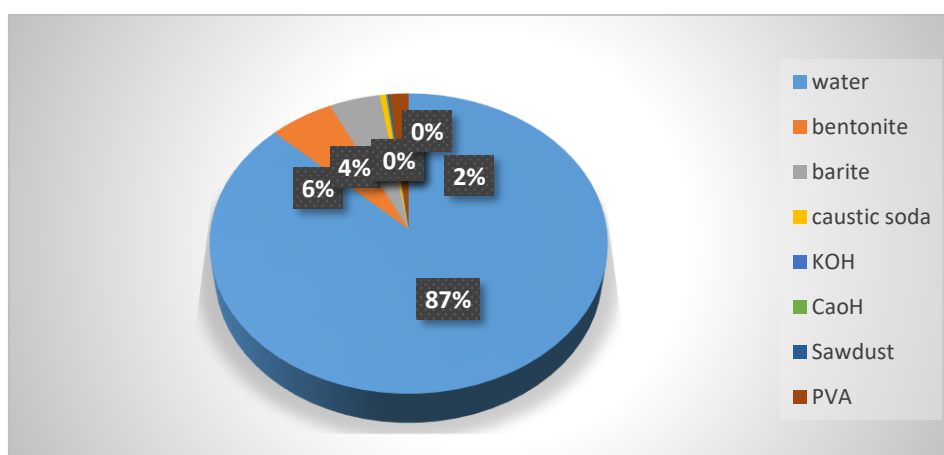


Fig:-1 Composition of PVA water based mud

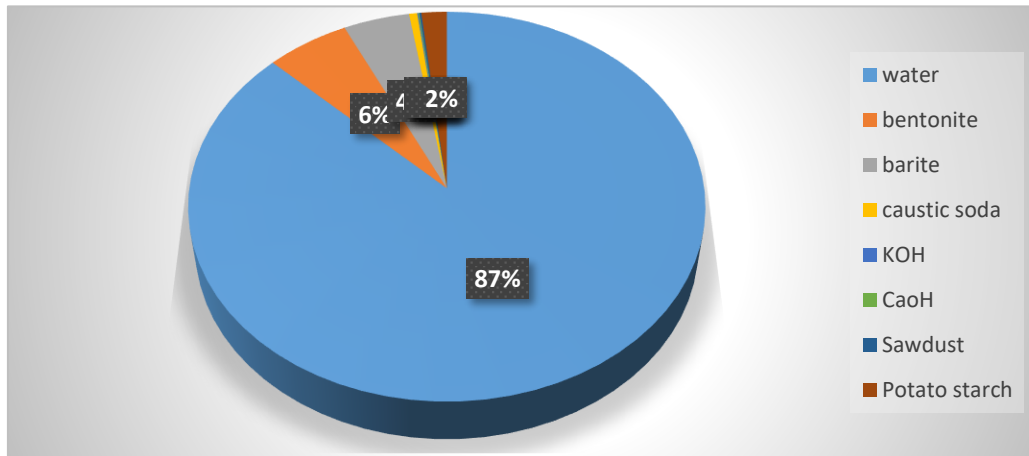


Fig:- 2 Composition of potato starch water based mud

3. Methodology:

Step wise step program to design drilling fluid system

1. Drilling fluid weight determination
2. Drilling fluid rheology determination
3. Determination of funnel viscosity:
4. Drilling mud PH and mud temperature determination

The equipment used in this research work are measuring cylinder, beaker, stop watch, electronic weighting balance, and multimixer. Experiment were performed IPNGE at the MUET Jamshoro.

3.1 Mixing of Mud Sample

Multi mixer is a laboratory equipment which is used for the mixing of mud sample multiply as shown in the figure, 3.



Fig:-3 multimixer



Fig:-4 mud balance

3.1.2 Mud Weight Determination

Mud balance is the laboratory equipment determine the weight of drilling mud sample. Density is most

important property to maintain the hydrostatic pressure. Mud density should kept at high level to prevent the well from loss circulation. Mud balance is used to measure the density of drilling fluid. Density is expressed in pound per gallon as shown in the figure, 4.

It is number of seconds required for quart of mud 350 cc to flow the size of specific funnel. The number of second required for drainage is described as funnel viscosity as shown in the figure, 5.



Fig:- 5 Marsh funnel

3.1.3 Rheological Properties Measurement

Rotational viscometer used to measure the rheological properties of drilling mud as shown in fig, 6
Rheological divided in three sections given in the following equation

$$Ap = \phi \frac{600}{2}$$

$$Pv = \phi 600 - \phi 300$$

$$YP = \phi 300 - Pv$$



Fig:-6 rotational viscometer

3.1.4 Mud Alkanity Determination

pH meter determines the alkanity and acidity of drilling fluid. The pH is signified a scale from 0 to 14

if the PH of any fluid is 7 is termed as neutral. If the PH is below 7 is represented as acidic in nature. If the PH is above 7 is termed as alkaline in nature as shown in the fig, 7.



Fig:-7 pH meter

3.1.5 Gel strength Determination

Shearometer is the laboratory equipment measure the gel strength of the drilling mud as shown in the fig, 8.



Fig:-8 Shearometer

4. RESULTS AND DISCUSSION

Table, 3 dial reading of formulated drilling mud at the different concentration of PVA

Parameter	Sample A	Sample B	Sample C	Sample D
Dial reading at 600 RPM	115	63	45	32
Dial reading at 300 RPM	85	42	32	18

Rheological properties power law index and consistency index can be calculated by using the following equation.

$$Ap = \frac{\phi 600}{2}$$

$$PV = \phi 600 \text{ RPM} - \phi 300 \text{ RPM}$$

$$yp = \phi 300 \text{ RPM} - PV$$

$$\text{power law index "n"} = 3.32 \frac{\log R2}{R1}$$

$$\text{Consistency Index "K"} = 5.1 * R2/Yn$$

Table, 4 shows effect of PVA on the rheological properties of drilling mud on the flow index behavior and consistency index and on the gel strength of drilling mud

Parameter	Sample A	Sample B	Sample C	Sample D
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Plastic viscosity cp	31	21	13	12
Yield point Ib/100 ft2	55	21	19	14
Gelstrength Ib/100 ft2	14	7	6.5	3.59
Apparent viscosity (cp)	57.5	31.5	22.5	16
Power law index " n"	0.435	0.5846	0.491	0.8295
Consistency index " K"	28.76	5.58	7.61	0.5202
Funnel viscosity = Density (t -25)	28	27.5	27	26.59

4.1.1 Effect of concentration of polyvinyl alcohol on the rheological properties of drilling mud

The polyvinyl is synthetic material has effect on the drilling mud rheology 5gm of polyvinyl alcohol makes drilling fluid more viscous. Viscosity is the resistance to flow hence thickener mud has more resistance to flow whereas mud sample formulated with 10 gm 15 gm and 20gm decrease the viscosity of formulated drilling mud. The viscosity of drilling mud sample composed of 20gm of polyvinyl alcohol is the optimum value that increase the rheological properties of drilling mud as shown in the fig, 10.

4.1.2 Effect of concentration of barite on the density of formulated polyvinyl alcoholic mud

Density is the most important property which maintain the entire drilling process. Many problems encountered during drilling process related directly and indirectly this property of drilling fluid. However, 40gms of barite added in to the formulated polyvinyl alcoholic drilling mud density were obtained 9 Ib/ga which is suitable for appropriate drilling as shown in the fig, 9.

4.1.3 Effect of concentration of additives on the gel strength (Ib/100 ft2)

Gel strength is the ability of drilling mud to suspend the drill cuttings and other. Gel strength is increase at the 5 gm of poly vinyl alcohol as compared to the other PVA. Whereas, the concentration of PVA were increase the rheological properties were decrease and gel strength were decrease as shown in the table, 4.

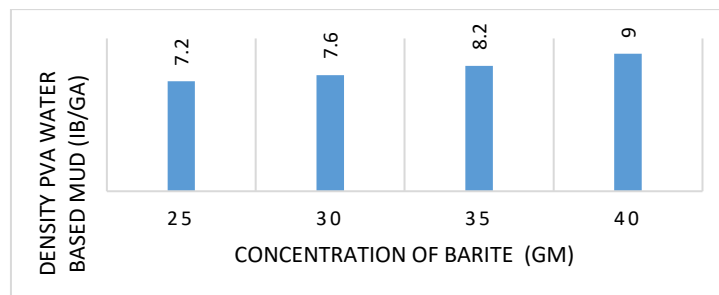


Fig. 9 Effect of concentration of barite on the density of PVA based mud

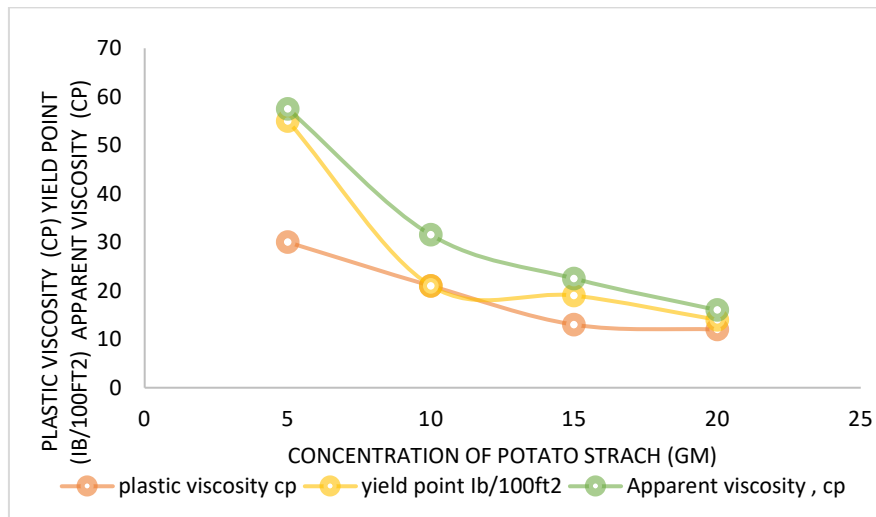


Fig:-10 Effect of concentration of PVA on the rheological parameter of drilling mud

Table, 5 show the effect of Concentration of barite on the density PVA based mud.

Parameter	Sample A	Sample B	Sample C	Sample D
Density Ib/ga	9	8.2	7.6	7.2

4.1.4 Effect of concentration of barite on the density of formulated polyvinyl alcoholic mud

Density is the most important property which maintain the entire drilling process. Many problems encountered during drilling process related directly and indirectly this property of drilling fluid. However, 40 gms of barite added in to the formulated polyvinyl alcoholic drilling mud density were obtained 9 Ib/ga which is suitable and appropriate for drilling as shown in the fig, 9.

Table, 6 show the pH of PVA based mud

Parameter	Sample A	Sample B	Sample C	Sample D
pH	10.46	10.32	9.71	9.5
Mud temperature	34.2	34.4	35.3	35.5

4.1.5 Effect caustic soda on the pH of formulated polyvinyl alcoholic mud

pH tells about the alkaline and the basic nature of drilling mud. pH of drilling mud must be alkaline in to prevent from the corrosion of the well bore. it was observed that At the 5 gm of formulated polyvinyl alcoholic mud pH value were increase then slightly decrease at the 10 gm 15 gm 20 gm pH were obtained from PVA based mud slightly alkaline in nature result were support by API (1993) as shown in the table, 6.

Table, 7 dial reading of formulated drilling mud at the different concentration of PVA

Parameter	Sample E	Sample F	Sample G	Sample H
Dial reading at 600 RPM	23	28	33	35
Dial reading at 300 RPM	14	18	19	20

Table, 8 shows effect of Potato starch on the rheological properties of drilling mud flow index behavior and consistency index and on the gel strength

Parameter	Sample E	Sample F	Sample G	Sample H
Funnel viscosity= Density (t -25)	25.59	26.3	26.7	27.2

Plastic viscosity (cp)	9	10	13	13
Yield point (lb/100 ft²)	5	6	7	9
Gel strength (lb/100 ft²)	3.5	5.5	6.5	7
Apparent viscosity (cp)	11.5	14	16.5	17.5
Consistency index "K"	0.82	1.72	0.676	0.669
Power law index "n"	0.715	0.637	0.796	0.689

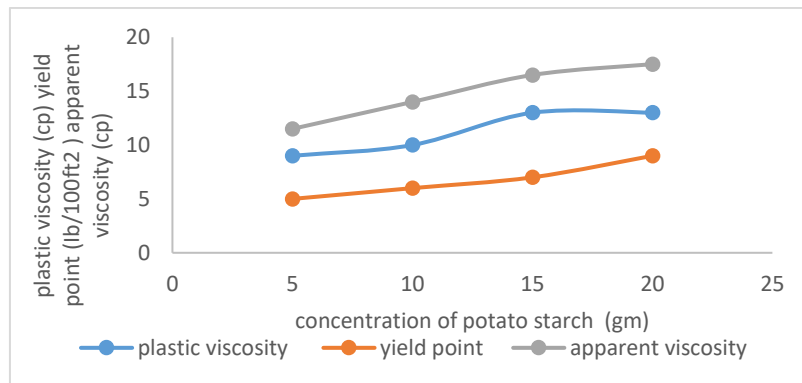


Fig:- 11 Effect of concentration of potato starch on the rheological properties of drilling mud

4.1.6 Effect of concentration of potato starch on the Drilling mud rheology

Potato starch is the natural material which increase the rheological properties the concentration of potato starch is increase which directly increase the rheological properties. 15 gm of potato starch is the optimum value of the potato starch for the rheological properties improvement as shown in the fig, 11. Result were supported by (Omotioma et, al 2012)

4.1.7 Effect of concentration of potato starch on the gel strength

As discuss in the previous session gel strength is the important property which hold the particle in suspensions concentration of potato starch is directly proportional to the gel strength from the experimental result it was observed as the quantity of potato starch increase the gel Strength increase directly as shown in the table, 8.

Table, 9 Effect of concentration of barite on the density of starch based mud

Parameter	Sample E	Sample F	Sample G	Sample H
Density (lb/ga)	7.6	8.1	8.3	8.5

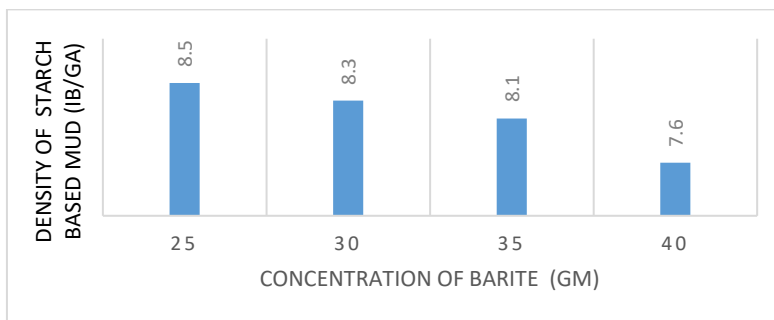


Fig:-12 Effect of concentration of barite on the density of starch based mud

4.1.9 Effect of concentration of barite on the density of potato starch based mud

Density is most important property which maintain the hydrostatic pressure. However, concentration of barite has not profound effect on the density potato starch based mud 25 gm of barite is the optimum concentration of barite for the density of potato starch based mud as shown in the graph, 12 result were supported by API (1993).

Table, 10 shows the effect of caustic soda on the pH and mud temperature of starch based mud

Parameter	Sample E	Sample F	Sample G	Sample H
pH	10.24	9.86	9.5	9
Mud temperature	34.2	34.4	34.9	35.5

Effect of caustic soda on the pH of formulated starch based mud

pH tells about the alkaline and the basic nature of drilling mud. pH of drilling mud must be alkaline in to prevent from the corrosion of the well bore. pH were obtained from potato starch based mud slightly alkaline in nature result were support by API (1993) as shown in the table, 10.

POWER LAW INDEX AND CONSISTANCY INDEX: When the k value is large the n value is decrease. If the value of k is large effective annular velocity were increase which increase the effective hole cleaning ability and suspend the solid particle at the smaller value of shear rate (university of Texas) as shown in the table, 8 and

5. CONCLUSION:

The potato starch improves the rheological property of water based drilling mud. Mud sample formulated with 15 gm of potato starch is the optimum level of potato starch for the yield point and plastic viscosity and the 25 gm of barite is the optimum value of barite concentration that improve the density of starch based mud. The mud sample formulated with 20 gm of PVA is the optimum value of PVA that improve the rheological properties of PVA based mud. However, 40 gm of barite is the suitable concentration of barite that improve the density of PVA based mud.

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