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ASSESSING THE EFFECTS OF MONOVALENT AND DIVALENT SALTS ON THE RHEOLOGICAL PROPERTIES OF WATER BASED MUD

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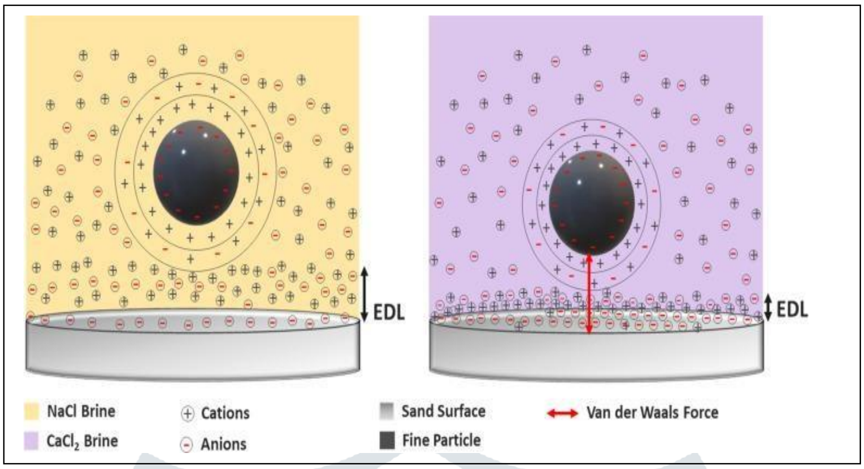
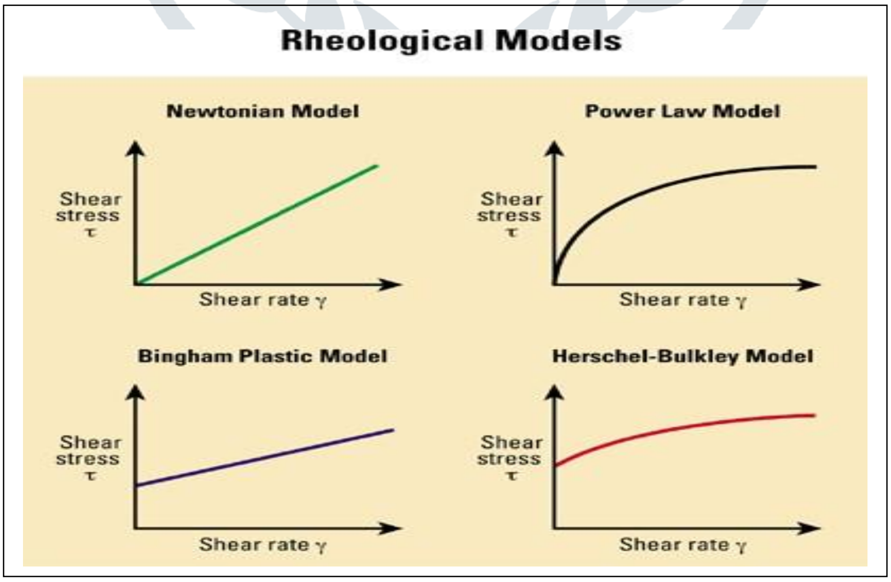
Abstract:

Drilling fluid selection is critical in preventing major problems during drilling operations such as hole pack-off, stuck pipe, and loss circulation. Mud contamination occurs when the mud system is overtreated with additives or when foreign material enters the mud system during drilling operations, causing undesirable changes in the mud's properties. This results in the mud system is ineffective at performing its primary functions.

This study looks at the effects of monovalent and divalent salts, specifically. the effects of potassium chloride, calcium chloride, and magnesium chloride on the rheological properties of a water- based mud system most prone to contamination.



The drilling engineer must understand how the drilling fluid's stability varies as a result of salt contamination encountered throughout the drilling process. To explore the effect of magnesium chloride salt (MgCl2) on the rheological properties of drilling fluid at both ambient and increased temperatures, two mud samples with varied concentrations of MgCl2 were generated. This study shows that the effectiveness of drilling mud is altered by temperature as a result of thermal degradation till the mud fails. it is revealed that Gypsum mud tolerates higher temperatures than Lignite mud. The rheological parameters of drilling mud, such as viscosity, yield point, and gel strength, were found to decrease as the content of magnesium salt increased.



Drilling muds are chemical blends of manufactured and natural chemicals that serve a variety of purposes. Cool and lubricate the drill bit, clean the hole bottom of cuttings generated by the drill bit and transfer cuttings to the surface, and aid in the gathering

and interpretation of information accessible from cores, drilling cuttings, and electrical logs are the most prevalent functions. Maintaining downhole formation pressures while minimising damage to the producing formation is a difficult task. Based on the specified rheological qualities and bore-hole circumstances, the engineer selects the suitable type of drilling fluid. Water-based drilling fluids are less expensive and less harmful to the environment, but they are very sensitive to formation
features, encourage clay swelling and hydration, and increase well building costs. Water-based mud contains viscosifiers, fluid loss control agents, lubricants, weighting agents, corrosion inhibitors, emulsifiers, and pH control agents.

Introduction:

During drilling, pollution inclusive of salts, drill solids, and cement are picked up via way of means of the drilling dust. As an end result of severe pollution blanketed within side the dust machine, the drilling dust features have grown to be unstable. As an end result, an excessive stage of pollution in a drilling dust machine has a terrible effect at the machine’s performance.

Mud is polluted in preferred whilst any fabric enters the dust machine that alters the drilling dust's traits in a detrimental way. Solids, cement, sodium chloride, calcium or magnesium, salts, carbonates and bicarbonates, and anhydrite-gypsum are not unusual place contaminants encountered at some point of drilling operations, whether or not from the drilling or from the water. The maximum usually encountered salt at some point of drilling operations is sodium chloride (NaCl). When this salt comes into contact with the drilling fluid, it creates a chemical reaction.

During drilling, pollution inclusive of salts, drill solids, and cement are picked up via way of means of the drilling dust. Although several academics have looked into the impact of salt contamination on drilling fluid performance, few have looked into the impact of magnesium salt contaminants on drilling fluid parameters. The current research looks at how different quantities of magnesium salt impurities affect the efficiency of two drilling fluid samples.
The experiment was carried out at both ambient and higher temperatures in order to see how thermal temperature affected drilling mud behaviour.

During the drilling process, drilling mud gathers up pollutants such as salts, drill solids, and cement. Salt contamination of drilling mud can arise due to formation water intrusion or during drilling salt beds. At high temperatures, the drilling mud cure is commonly required because the mud may be unable to handle the pollutants.
Because the rheological properties of drilling mud affect its efficiency and effectiveness in drilling operations, it's worth looking into the rheological parameter sand characteristics of drilling mud at down-hole circumstances.

Drilling fluid with stable rheological properties is necessary when drilling at high pressures and temperatures, according to the study, which compared the rheological features of the two drilling mud kinds.

Because contaminants influenced the rheological properties of the mud samples at the end of this study, using contaminant-free drilling mud is critical in any drilling programme to ensure that the mud performs its essential tasks.

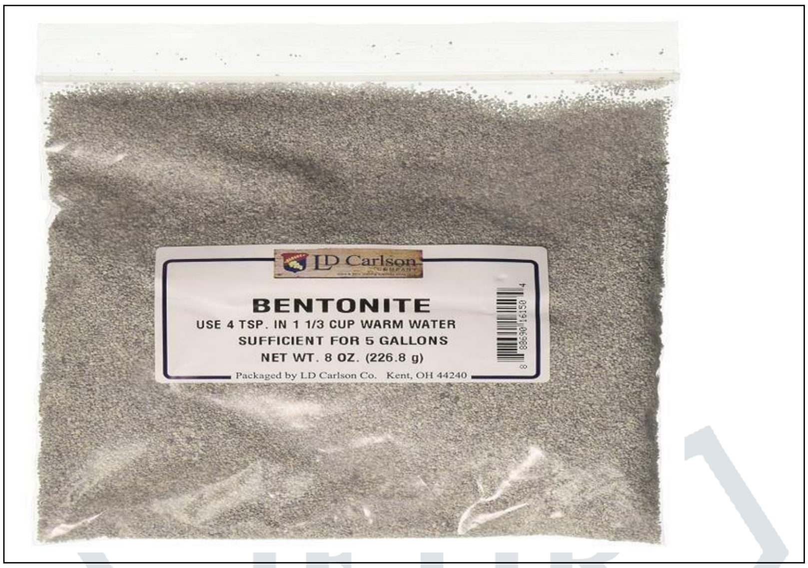
As a result, before the required drilling fluid can be designed to combat the challenges and avoid drilling problems, the mud engineer must have extensive knowledge about the formation to be drilled and the possible contaminants to be encountered ahead of time. As an end result of several pollution blanketed withinside the dust machine, the drilling dust features have grown to be unstable.

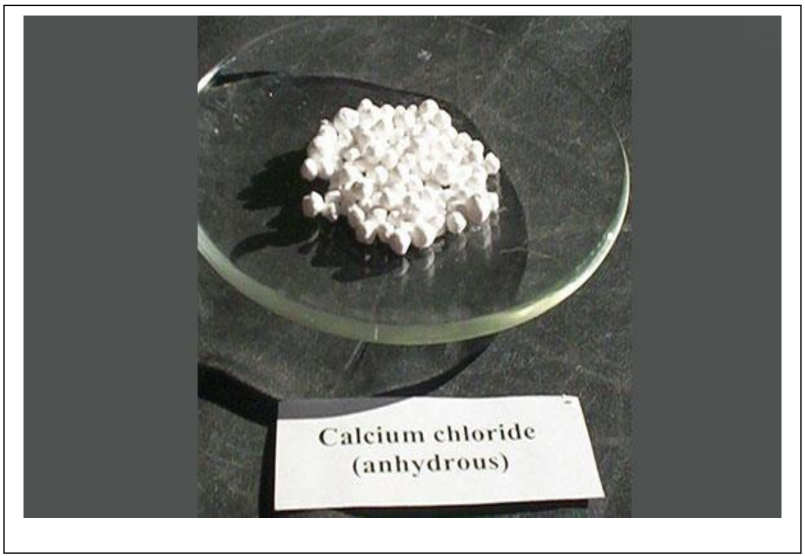
As an end result, an excessive stage of pollution in a drilling dust machine has a terrible effect at the machine's performance. Mud is polluted in preferred whilst any fabric enters the dust machine that alters the drilling dust's traits in a detrimental way.

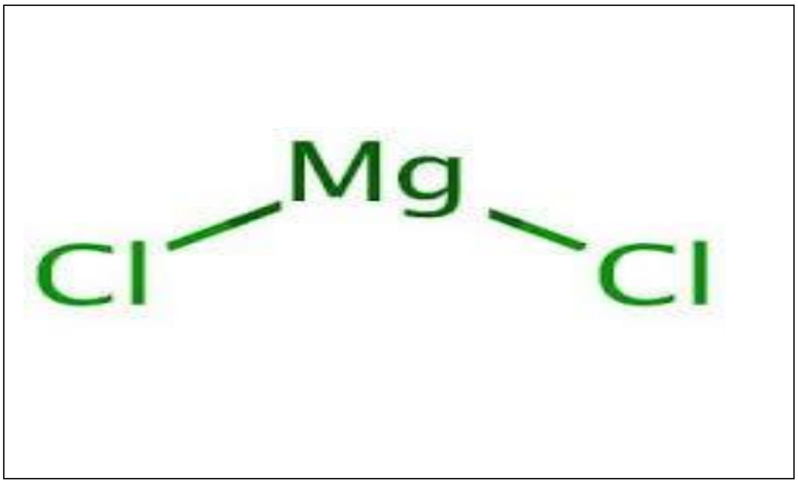
Solids, cement, sodium chloride, calcium or magnesium, salts, carbonates and bicarbonates, and anhydrite-gypsum are not unusual place contaminants encountered at some point of drilling operations, whether or not from the drilling or from the water. The maximum usually encountered salt at some point of drilling operations is sodium chloride (NaCl). When this salt comes into contact with the drilling fluid, it creates a chemical reaction.

Materials and MethodsMaterials Used

In this research work, three different types of salts were utilized in the formulation of the water-based drilling mud in this study to see how they affected the mud system's rheological qualities. Potassium chloride, calcium chloride, and magnesium chloride are the three types of salts that Halliburton Ghana provided. Potassium chloride salt had a purity of 99 percent, calcium chloride had a purity of 94- 97 percent, and magnesium chloride salt had a purity of 98 percent. Schlumberger Liberia also supplied the commercial bentonite used in the mud preparation as a viscofier, and its physicochemical qualities matched the API standard bentonite for drilling, as stated in Table. In the mud preparation, tap water was used as the combined water. The quantityis shown in the table.






Mg
Cl
Cl

Materials	**Quantity**
Bentonite	400g(25.5perset-up)
Freshwater	6000ml(400mlper set-up)
Kcl	14 g (0.2, 0.4, 0.7, 1.0 and 1.4% conc.)
Cacl	14 g (0.2, 0.4, 0.7, 1.0 and 1.4% conc.)
Macl2,*(98%purity)*	14 g (0.2, 0.4, 0.7, 1.0 and 1.4% conc.)

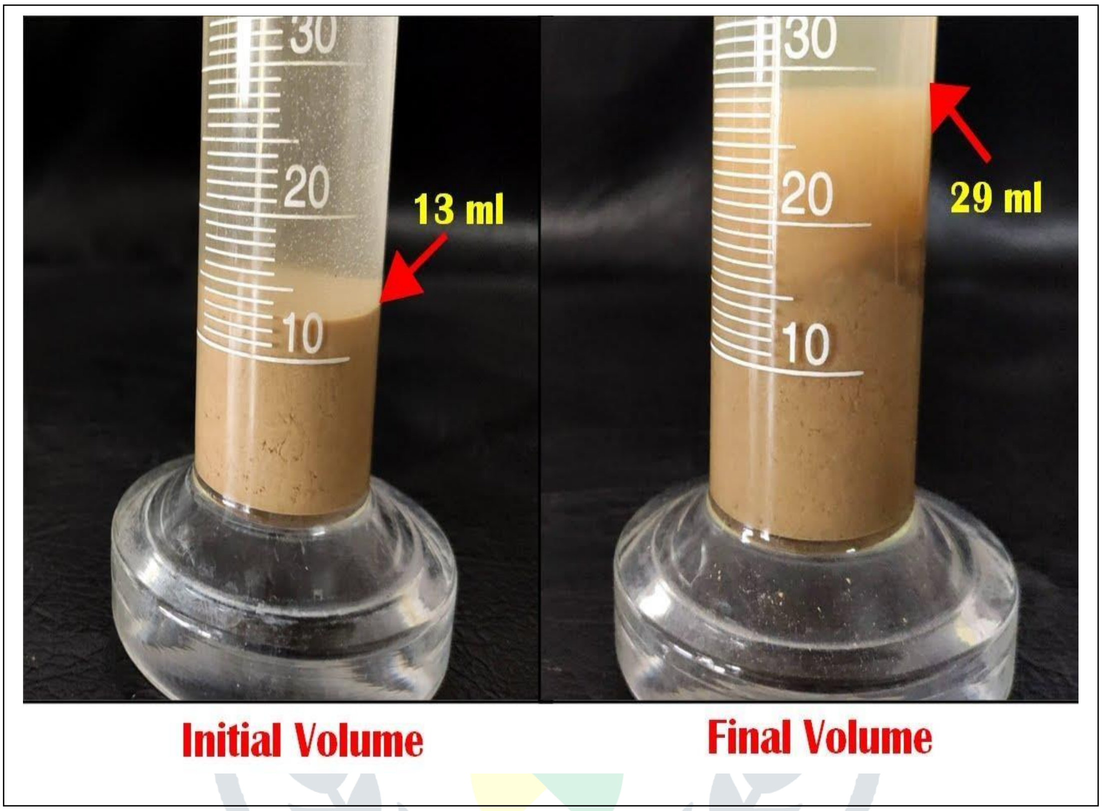
Product	**Form**	**Absolute volume L/kg(gal/lb)**	**Molecular weight(g/mol)**	**Specific gravity**	**Flash Poin (deg)[deg F]**
Sodium Bentonite	Light Tan to Gray Powder	0.376 (0.045)	421.8	2.85	> 93 [> 200]

Mineral Composition(%)					
Na_2O	**Al_2**	**Fe_2**	**MgO**	**CaO**	**SiO_2**

Experimental procedure

On an electronic balance, 360 g of Bentonite were weighed using a petri dish. A measuring cylinder was used to measure the entire amount of fresh water, which was 5,600 ml. According to API requirements for creating drilling fluid, each set-up utilized 22.5 g of bentonite and 350 ml of fresh water. Half of the fresh water (2,800 ml) was poured into a mixing cup first, followed by the weighted bentonite. For a while, the handheld mixer was used to swirl the mixture in the container. To guarantee homogeneity, the remaining water was added and mixed for 5 minutes with the handheld mixer. For the bentonite, the mixture has to sit for at least 16 hours.

After the bentonite was swelled, several amounts of monovalent and divalent salts (KCl, CaCl2, and MgCl2) were weighed and added to the bentonite (0.2 percent, 0.4 percent, 2.5 percent, 3.5 percent, and 1.4 percent). Sixteen samples were created, one of which was a control sample with no salt added. The remaining fifteen samples, five for each salt, were contaminated with the various salts. For the salt to react properly 0with the muck, the samples have been left for kind of hours.



Each mud sample had a volume of 350 ml during the laboratory experiment. The dial readings of the various samples were taken using a Fann Viscometer Model 3500 at 600, 300, 200,100, 60, 30, and 3 rpm, as recommended by API. The plastic viscosity, obvious viscosity and yield factor values have been calculated the usage of Equation 1, 2 and three respectively

Plastic Viscosity (μ_p) in mPa.s

$$\mu_p = \theta_{600} - \theta_{300} \quad (1)$$

Yield Point (YP) in (lb/100ft^2)

$$YP = \theta_{300} - \mu_P \quad (2)$$

Apparent Viscosity (μ_a) in mPa.s

$$\mu_a = \frac{\theta_{300}}{2} \quad (3)$$

The results analysis was based on a comparison study utilizing a sample mud control and the level of specification of the American Petroleum Institute (API) for drilling fluids, as well as research work already done on validated results, to verify the validity of the experiments performed. API 13A specification criteria for rheological parameters for the use of bentonite excavation distance in mud preparation gives a detailed explanation of the findings of rheological laboratory tests conducted on mud samples, including rpm values. Tests are also carried out at a temperature of around 25 ° C, although it is not guaranteed that the temperature will remain constant at that degree throughout the test, therefore, as a result, this ambiguity may have an impact on a condition. The findings were obtained. Bentonite samples and salts are weighed using an electronic balance that can calculate the exact amount of material used in the mud's creation to the closest marker.

As an external event such as wind turbulence was not considered a contributing component to the study, it is believed that the measured sample's uncertainty is zero. However, certain numbers were modified to the nearest two decimal places during the calculation of each concentrated salt used.
Human errors, on the other hand, can be included into the outcomes by studying the materials.

Furthermore, the rheometer used to capture dial reads was thought to be accurate because repeated readings on certain dialling readings yielded the same result. API Standard uncertainty of test data in the range of ± 0.01

API Standard Numerical Value Requirement for Drilling Grade Bentonite

PROPERTIES	
O700RPM	40Minimum
O400RPM	33Minimum
PLASTIC VISCOSITY	6-8Minimum

	RHEOLOGICALP ROPERTIES	
	APPARENTVISCO SITY	12-15Minim um
	YIELDPOINT	3*PVor50 Maximumm

Results from the lab experiment

PARAMETERS	**WATERBASEDDRILLINGFLUIDSAMPLES (25°C)**														
	MUD	**MUD+KCl salt**					**MUD+$CaCl_2$ salt**					**MUD+$MgCl_2$ salt**			
	%Concentration of Salt														
	0.0	**0.2**	**0.4**	**0.7**	**1.0**	**1.4**	**0.2**	**0.4**	**0.7**	**1.0**	**1.4**	**0.2**	**0.4**	**0.7**	**1.0**	**1.4**
Ɵ600 **RPM**	25	28	26	24	23	21	14	10	9	9	8	14	10	10	9	9
Ɵ300 **RPM**	17	20	19	17	16	15	10	7	6	6	5	9	7	7	6	6
Ɵ6RP**M**	11	12	13	11	10	9	5	3	2	2	2	5	2	1	1	1
Ɵ3RP**M**	10	11	9	9	8	8	4	3	2	2	1	4	2	1	1	1
PV (mPa. s)	7	8	7	7	7	6	4	3	3	3	3	5	3	3	3	3
AV(mPa.s)	12	14	13	12	11.5	10.5	7	5	4.5	4.5	4	7	5	5	4.5	4.5
YP(lb/ $100ft^2$)	10	12	12	10	9	9	6	4	3	3	2	4	4	4	3	3

Effects on salt Concentration on Plastic Viscosity Plastic Viscosity:

The viscosity of the drilling mud when extended to an infinite shear rate using the Bingham model is known as plastic viscosity, or PV. When the PV is low, the mud will drill quickly due to the low viscosity of the mud exiting the bit. High PV is caused by a viscous base fluid and the presence of abundant colloidal particles. The solid concentration of the mud can be lowered to reduce PV by diluting it.

PV is determined by measuring the shear rate at 600, 300, 200, 100, 6, and 3rounds per minute with a viscometer (rpm). By subtracting the 600 rpm reading from the 300 rpm reading, the PV value is obtained.

The resistance offered by a fluid to flow freely is known as plastic viscosity (PV). Friction between the liquid undergoing deformation under shear stress and the solids and liquids contained in the drilling mud causes this resistance. PV is a Bingham plastic model parameter that represents the slope of the shear stress/shear rate line above the yield point.

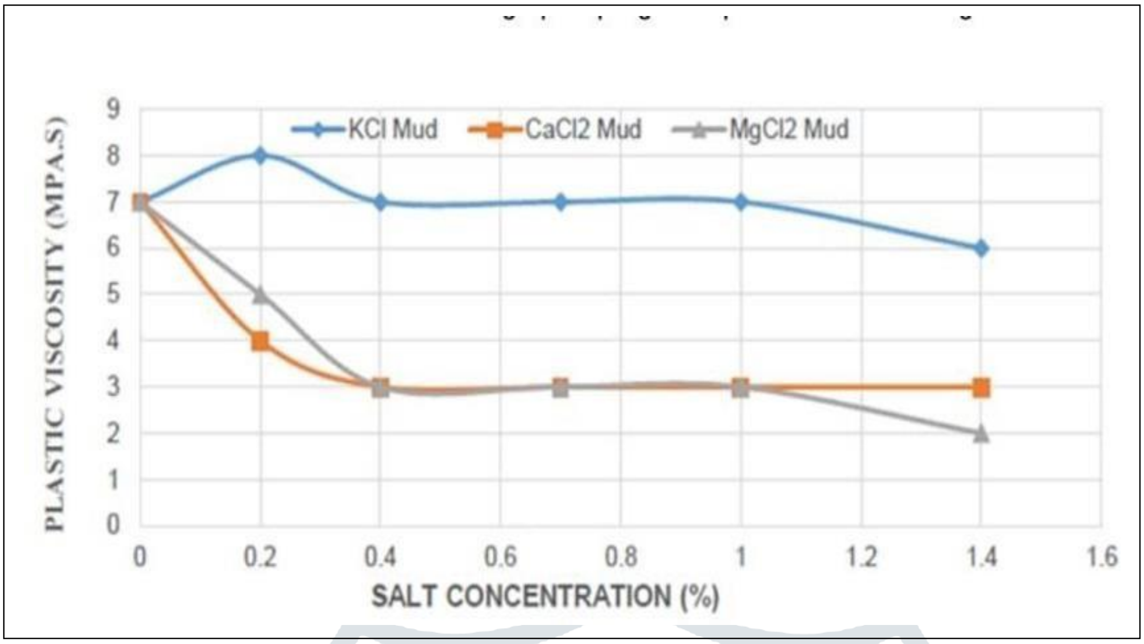
PV is a significant rheological property that impacts drilling fluid parameters.

Although several academics have looked into the impact of salt contamination on drilling fluid performance, few have looked into the impact of magnesium salt contaminants on drilling fluid parameters. The current research looks at how different quantities of magnesium salt impurities affect the efficiency of two drilling fluid samples. The experiment was carried out at both ambient and higher temperatures in order to see how thermal temperature affected drilling mud behaviour.

Various "mud chemicals" can be used to improve the viscosity of a mud system. These are largely bentonite kinds, but they also include attapulgite clays, asbestos, and gums (Guar or Xanthan).

These gums are found in polymer viscosities such as XC polymer. The majority of polymers produce a shear thinning mud. This is advantageous because it allows for the preservation of viscosity while lowering circulating pressures.
This value is derived from the viscometer as well. As previously stated, the yield point (YP) is a measurement of the electrochemical attractive forces inside the mud under flowing conditions. Positive and negative charges on or on the surface of the particle produce these forces.

With varied salt concentrations, the influence of plastic viscosity against each salt as the varied salt concentrations increase, the plastic viscosity decreases. According to API requirements for drilling fluid, the minimum plastic viscosity required for efficient drilling is 7 mPa.s. The plastic viscosity of mud contaminated with various salts decreased from the range of 8 to 6 mPa.s, while that of mud contaminated with Calcium Chloride (CaCl2) and Magnesium Chloride (MgCl2) salts both decreased from 7 to 3 mPa.s for salt concentrations of 0.2 percent, 0.4 percent, 0.7 percent, 1.0 percent, and 1.4 percent. . Although low viscosity of the mud exiting the bit shows that the mudis capable of drilling quickly, the plastic viscosity must be maintained in the range of 6 - 8 mPa.s for a good drilling operation. Because heavy pumping is required to break the gel, low PV means low Equivalent Circulating Density (ECD) exerted at the bottom, but high PV causes an increase in ECD



Effect on salt Concentration on Yield Point

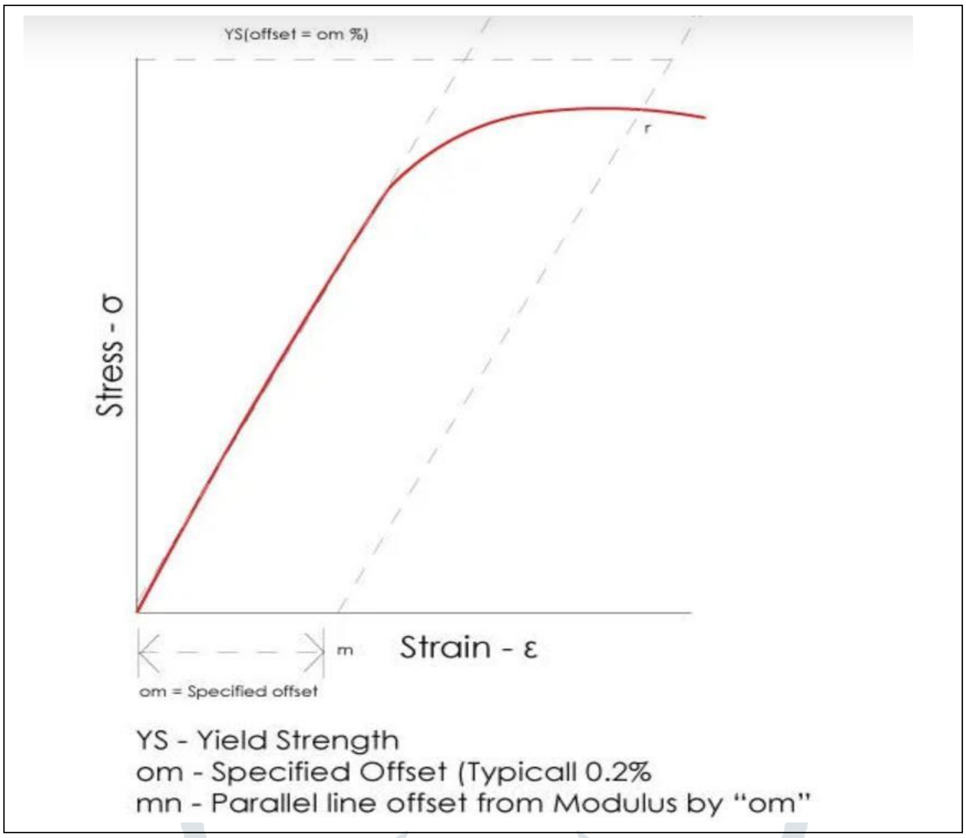
Yield Point:

A material's yield point is a mechanical property that is routinely assessed during materials testing. When a material goes from elastic behaviour (where removing the applied load returns the material to its original shape) to plastic behaviour (where deformation is permanent), it is said to have reached its yield point. The elastic area of a stress/strain curve is typically shown as the portion of the curve with a constant slope.

Depending on the type of material and the test being conducted, yield can be quantified in a variety of ways (tension, compression, etc). The most essential yield outcomes are yield strength and yield strain, as these values are frequently used to determine whether a material is suitable for a given application.

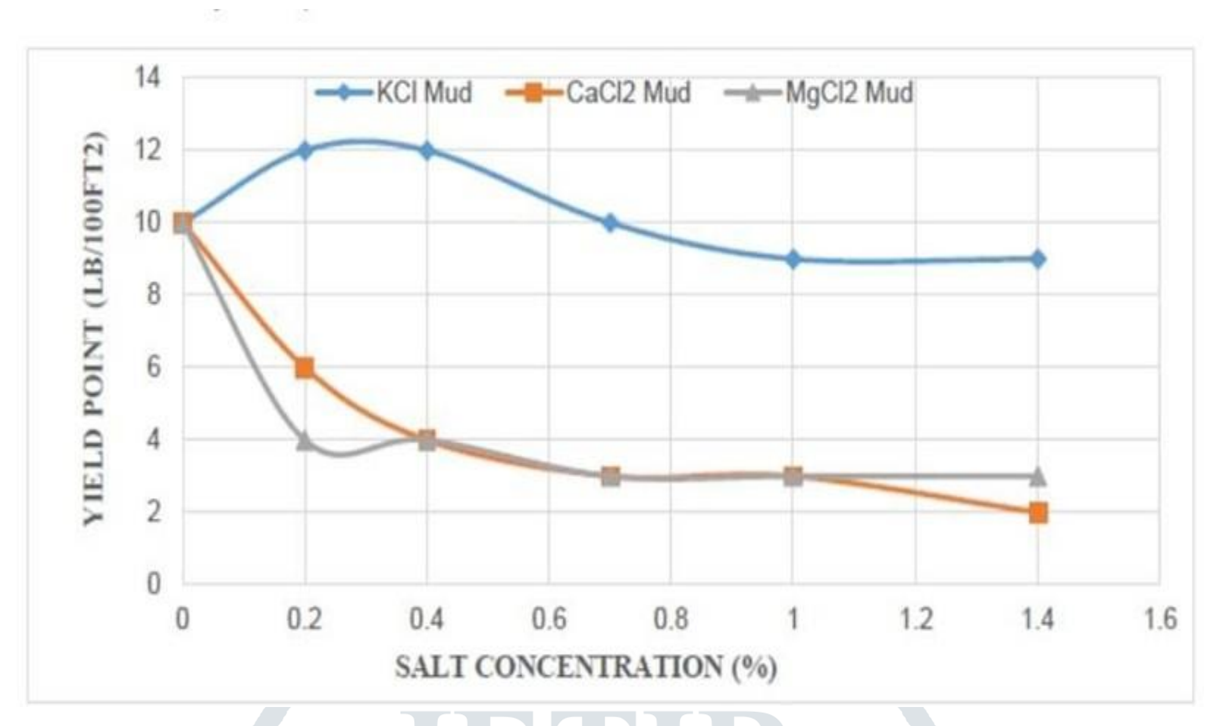
Yield strength is especially essential since it is used to determine whether or not a material achieves a specified Factor of Safety (FoS). For example, if an engineer is looking for a material to utilise in elevator cables, a FoS of at least 10 is required. This ensures that the cable can take ten times the maximum applied stress.

The offset yield method is used to calculate yield in metals, in which a line is drawn parallel to the modulus and offset by a specified amount.



The effect of the yield point (YP) against each salt at varied salt concentrations; and it shows that when the different salt concentrations grow, the yield points of the mud samples drop. For optimal drilling, the yield point of a drilling mud should be three times the plastic viscosity or not exceed the value of 50, according to API standards. The yield point of the mud containing KCl salt reduced from 12 lb/100ft2 to 9 lb/100ft2 compared to the control mud, which had a yield point of 10 lb/100ft2, practically meeting the API norm.CaCl and MgCl salts reduced mud yield points from 10 lb/100ft2 to 2 lb/100ft2, and 10 lb/100ft2 to 3 lb/100ft2, respectively. The yield point of mud containing CaCl and MgCl declined as salt concentrations increased, whereas the yield point of mud containing KCl salt stabilized and dropped as salt concentration grew.

Because potassium ions have a lesser cation replacement power than sodium ions, they are inhibitive. Because the yield point indicates a drilling mud's ability to transport cuttings to the surface, a decrease in its numerical value renders the mud inefficient as a cutting transporter. Furthermore, it is critical to maintain a high enough YP/PV ratio in the drilling fluid (maximum of 3) to ensure effective cutting conveyance

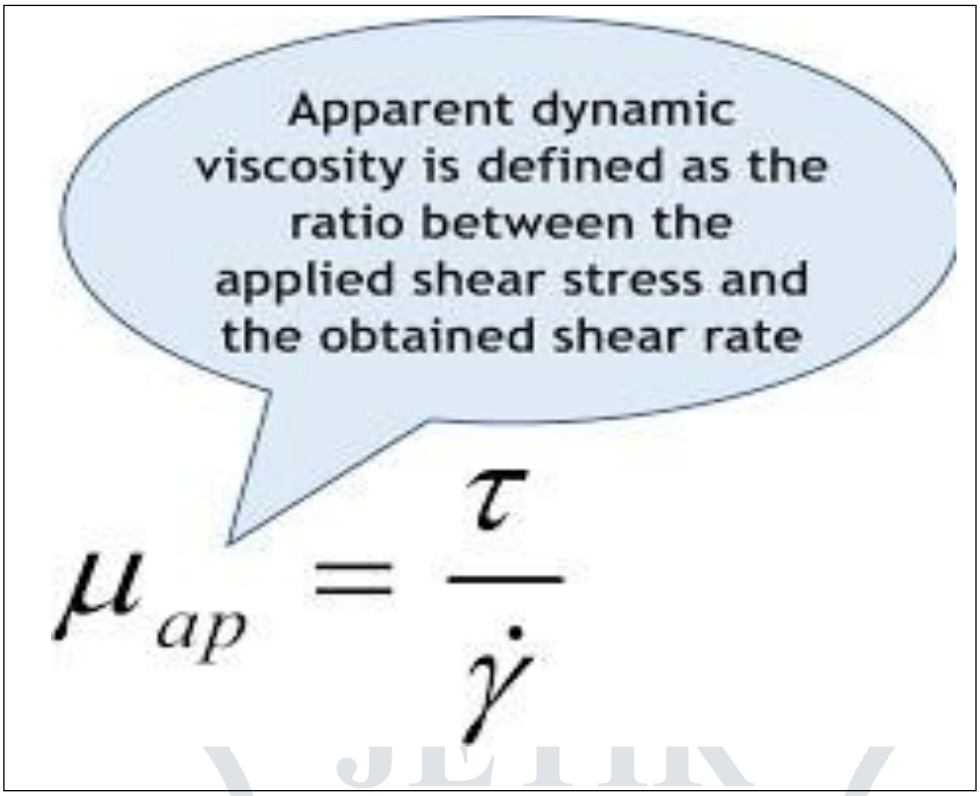


Effect on salt Concentration on Apparent Viscosity Apparent Viscosity:

The shear stress given to a fluid divided by the shear rate gives the apparent viscosity. The apparent viscosity of a Newtonian fluid is constant and equal to the fluid's Newtonian viscosity, while for non-Newtonian fluids, the apparent viscosity is dependent on the shear rate. The SI-derived unit for apparent viscosity is Pas (Pascal-second), however the centipoise is more commonly used in practise.

The apparent viscosity of a fluid is determined by a single viscosity measurement at a steady speed in a conventional viscometer. Measurement of apparent viscosity without knowledge of the shear rate is of limited utility in non-Newtonian fluids: the measurement cannot be compared to other observations if the speed and geometry of the two devices are not comparable. Without the shear rate or information about the instrument and parameters (for example, speed and spindle type for a rotational viscometer), an apparent viscosity is meaningless.

Multiple measurements of apparent viscosity at various, well-defined shear rates can provide useful information on a fluid's non-Newtonian behaviour, allowing it to be predicted.



The effect of apparent viscosity (µa) against each salt concentration, where an increase in the various salt concentrations resulted in a drop in the apparent viscosities of the contaminated mud samples The control mud, which had a viscosity of 12 mPa.s and was also used as a benchmark, met the API criteria for drilling grade bentonite mud, which states that the apparent viscosity

should be between 12 and 15 mPa.s.At concentrations of 0.2 percent, 0.4 percent, 0.7 percent, 1.0 percent, and 1.4 percent, the apparent viscosities reported decreased from 14 mPa.s to 10.5 mPa.s for mud samples with KCl salt, 12 mPa.s to 4 mPa.s for mud samples with CaCl2 salt, and 12 mPa.s to 4.5 mPa.s for mud samples with MgCl2 The apparent viscosity is the viscosity measured at 600 rpm, This reflects the plastic viscosity as well as the yield point. This illustrates that lowering both of them lowers the apparent viscosity. This value aids the mud engineer in developing and maintaining the drilling fluid's characteristics to the appropriate specifications.

In comparison to other ions, potassium ions are distinctive in nature. When added to drilling fluid, they have little or no effect due to their inhibitive characteristic. This is due to the fact that potassium ions fit considerably tighter into the lattices of clay structure, decreasing its capacity to hydrate. The ion exchange hypothesis does not completely describe how potassium interacts with clay. Sodium has a lower cation exchange replacement power than calcium and magnesium. The degree of hydration is considerably reduced and the tendency to disperse is prevented when bentonite is added to water containing more than one hundred ppm of each of these ions. As a result, there is little viscosity development and a significant amount of fluid loss.

Various researchers have already undertaken and validated studies on the influence of salt on the properties of water- based mud, and their conclusions are in agreement with the findings of this research in the sense that their work portrayed the same trend as this research work as shown in through. Increases in salt concentrations resulted in a deterioration in the rheological properties of the mud samples, according to their findings [20, 18, 23]. The results also showed that even at the lowest concentration of salt, 0.2 percent, there was a deterioration in rheological properties; however, the effect was more severe with mud contaminated with divalent salts (CaCl2 and MgCl2) than with mud polluted with monovalent salts (CaCl2 and MgCl2 and KCl).

The overall findings suggested that cation could help to retain clay mineral particles together by acting as a link. Multivalent cations, according to Weber (1970), have the ability to link layers together more securely than monovalent cations, resulting in clay particle aggregation. The exception to the norm is potassium, a monovalent cation. The hydration, dispersion, and flocculation behavior of clay particles are all affected by the ionic concentration of water. The degree of hydration and dispersion decreases as the salt level rises, forcing the exchange cations closer to the clay platelet's surface.

The water layer bonded by the clay surface and the exchange cations becomes thinner as a result of this. The viscosity will be reduced as a result. Because the water barrier is thinner, platelets can get closer to one another, increasing their potential to flocculate.

Conclusion:

- The various salts contamination influenced the rheological properties of the water-based mud, which in turn affected the efficiency of the mud samples, according to this study.

- According to this study, varied salt contamination changed the rheological properties of the water-based mud, which in turn influenced the effectiveness of the mud samples.

- The effects of the salts on the mud samples were stronger in the calcium and magnesium salt-contaminated mud samples than in the potassium chloride-contaminated mud samples

Because contaminants influenced the rheological properties of the mud samples at the conclusion of this study, drilling mud that is free of contaminants is critical in any drilling programme in order for the mud to perform its essential tasks.

As a result, before the required drilling fluid can be designed to combat the obstacles and avoid drilling problems, the mud engineer must have extensive information of the formation to be drilled and the possible contaminants to be found. This will save time and money.

As the amounts of pollutants grew, so did the thickness of the mud.

The pH of the mud increased as the concentration of sodium carbonate contamination grew, but reduced when the concentration of sodium bicarbonate increased. The pH of the created mud system was nearly restored using treatment chemicals.

Plastic viscosity declined progressively as contamination and treatment agent concentrations rose, but increased somewhat as sodium hydroxide concentrations increased.

As the concentration of pollutants rose, the yield point climbed dramatically. However, as the mud got contaminated with large levels of sodium carbonate and sodium bicarbonate, the yield point gradually declined.
At 10 seconds, gel strength acts differently than at 10 minutes. It steadily increased when sodium carbonate and calcium sulphate concentrations increased, but it reduced when concentrations reached 5 g.

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