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University of Misan

College of Engineering

Department of Petroleum Engineering

Expermental stady to evaluate the offect of kcl-Brine on the Rheological properties of cmc l-v mud (carboxy mathely celleleuse)

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بِسمِ اللهِ الرحّمنِ الرَّحيمِ

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صدق الله العلي العظيم

سورة الضحى , الآية ٥

SUPERVISOR CERTIFICATION

I certify that the preparation of this project entitled

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CERTIFICATE OF EXAMINERS

We certify, as an examining committee, that we have read this project report entitled

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DEDICATION

أهدي بحث تخرجي بكل فخر واعتزاز إلى الكهف الحصين وغياث المضطر المستكين وملاذ المؤمنين بقية الله في أرض صاحب العصر والزمان الامام المهدي المنتظر (عجل الله تعالى فرجه الشريف)، سائلين الله عز وجل أن يجعل عملنا هذا في ميزان حسناتنا

ABSTRACT

This project presents the results of an experimental investigation into the effects of salinity and pH on the rheological and filtration properties of drilling mud. Results are given from tests conducted on a water-based mud containing CMC polymer and kcl . The addition of KCl to drilling fluids improves the stability of rheological properties, reduces unwanted changes in viscosity and fluidity limit and contributes to improving the overall performance of the fluid under different drilling conditions.

The addition of potassium chloride (KCl) significantly affects the rheological properties of drilling fluids, affecting how the fluid flows and interacts with the surrounding formations. KCl can reduce viscosity in some cases, especially when using water-based drilling fluids. At high concentrations, it can result in a slight increase in viscosity due to increased ionic interaction strength between the fluid components.

KCl improves the fluid's response to shear stress, making the fluid more tolerant and controlling the cuttings.

KCl enhances the fluid limit, helping to keep the cuttings suspended in the fluid and prevent downhole deposits.

KCl improves the fluid's stability at high temperatures, reducing changes in rheological properties during drilling at great depths.

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Chapter One: Introduction

Chapter One: Introduction

1.1 Drilling Mud:

"Drilling mud, an essential component of drilling operations in the petroleum industry, is a specialized fluid that serves multiple crucial functions during the drilling process. Fundamentally, drilling mud consists of two main components: the solid phase and the liquid phase. The solid phase comprises various additives such as weighting agents, viscosifiers, fluid loss control agents, and other specialized chemicals, which are suspended or dispersed within the liquid phase. The liquid phase, which forms the bulk of the drilling mud, typically consists of water, oil, or synthetic fluid, serving as a carrier for the solid additives.

1.2 Drilling Mud Functions:

Drilling fluids, also known as drilling mud, play a crucial role in petroleum engineering drilling operations. Here are some key aspects of their importance:

1. Cooling and Lubrication: Drilling generates a significant amount of heat due to friction between the drill bit and the formation being drilled. Drilling fluids help dissipate this heat and lubricate the drill bit, reducing wear and tear and prolonging its lifespan.
2. Pressure Control: Drilling fluids exert hydrostatic pressure on the walls of the wellbore, which helps to balance the pressure of the formation being drilled. This prevents blowouts and other dangerous situations by ensuring that the pressure in the well remains within safe limits.
3. Cuttings Transport: As drilling progresses, rock cuttings are produced. The drilling fluid carries these cuttings up to the surface, where they can be removed from the well. Without proper transport of cuttings, they can accumulate around the drill bit, impeding progress and potentially causing damage.
4. Formation Stability: Drilling fluids help stabilize the formation being drilled by preventing the collapse of the wellbore walls. They form a thin layer on the walls, providing support and preventing the formation from caving in.

5. Formation Evaluation: Drilling fluids can carry rock cuttings and other formation materials to the surface, allowing geologists and engineers to analyze the properties of the formations being drilled. This information is crucial for making decisions about the well, such as whether to continue drilling or to adjust drilling parameters.
6. drilling or to adjust drilling parameters.

7. Well Control: In addition to preventing blowouts, drilling fluids also help control gas influxes and other unexpected pressures that may occur during drilling. They can be weighted or formulated to counterbalance these pressures and maintain stability in the well.

1.3 Types of Drilling Mud:

1.3.1 Water-Based Mud (WBM):

• **Composition**: Water-based muds use water as the continuous phase and may contain additives such as clays (e.g., bentonite), polymers, and salts.

• **Advantages:** Environmentally friendly, cost-effective, easily disposed of, and suitable for a wide range of formations.

• **Limitations:** Susceptible to hydration and swelling in certain formations, limited temperature stability, and potential formation damage.

1.3.2 Oil-Based Mud (OBM):

• **Composition:** Oil-based muds use oil, such as diesel or mineral oil, as the continuous phase, along with additives such as emulsifiers, wetting agents, and rheology modifiers.

• **Advantages:** Higher temperature stability, better lubrication, wellbore stability, reduced formation damage, and improved hole cleaning in certain formations.

• **Limitations:** More expensive than water-based muds, potential environmental concerns with oil disposal, and complex waste management requirements.

1.3.3 Synthetic-Based Mud (SBM):

• **Composition:** Synthetic-based muds use synthetic fluids as the continuous phase, such as esters or olefins, along with additives similar to those used in oil-based muds.

• **Advantages:** Combines the benefits of both water-based and oil-based muds, offering improved performance in high-temperature environments, reduced environmental impact, and better hole cleaning.

• **Limitations:** Higher cost compared to water-based muds, limited availability of synthetic fluids, and potential compatibility issues with certain formations and additives

1.4 Drilling Fluid Composition

Drilling fluids consist of several main components, which vary depending on the type of fluid and its purpose, including:

1. Base Fluid: It can be water, oil, or synthetic fluid.

2. Solids: such as barite to increase density, and bentonite to improve viscosity.

3. Additives: such as stabilizers, emulsifiers, and corrosion inhibitors to modify the properties of the fluid.

1.5 Choosing the appropriate drilling fluid

Choosing the appropriate drilling fluid depends on several factors, including:

• Type of geological formation: Some formations interact with water, which requires the use of oil or synthetic fluids.

• Depth and temperature: The greater the depth and temperature, the greater the need for fluids with stable properties.

• Cost and environmental impact: Performance must be balanced against cost and compliance with environmental standards.

1.6 Factors affecting performance:

One of the factors affecting the performance of drilling fluid is the rheology of the fluid. Change the viscosity of the drilling fluid. Change the density of the drilling fluid. Drilling fluids containing nanoparticles are particularly suitable for high pressure and high-temperature situations. Nanoparticles can enhance the effectiveness of fracturing fluids by improving their cleanliness, stability and resistance to friction. In oil and gas drilling operations, carboxymethyl cellulose (CMC), polyanionic low-viscosity cellulose (PAC-LV) and starch are commonly used as fluid loss control additives to reduce filtration loss. The drilling fluid recipe using nanoparticles was developed to increase the efficiency of drilling operations to maximize access to new and mature oil reserves and suitable for different drilling conditions. The solution to severe drilling problems such as pipe sticking, loss of circulation, formation damage, well corrosion, thermal instability of drilling fluids and insufficient gel properties of drilling fluids lies in controlling and improving the rheology of drilling fluid. The inefficiency of drilling fluid in performing certain functions is mainly due to the deficiency of a certain rheological property. The performance of waterbased bentonite drilling mud from clay compounds was investigated in terms of its rheological behavior in drilling systems at different pressures and temperatures. It was found that temperature has a detrimental effect on the rheological properties. The behavior was investigated using a water-based nano-bentonite drilling fluid. The fluid retained all the required rheological properties at high temperatures and pressures, thus enhancing its applicability in deep wells, where high temperatures and pressures were very common.

Chapter Two: Literature Review

Chapter Two: Literature Review

Introduction:

Drilling operations in the oil and gas industry are vital processes that require high precision and efficiency, playing a pivotal role in extracting natural resources from beneath the Earth's surface. These operations necessitate the use of specialized materials known as drilling mud, which is an essential element in ensuring the success of drilling activities. The role of drilling mud includes cooling drilling tools, facilitating the transport of cuttings, stabilizing wellbore walls, and preventing fluid loss to surrounding geological formations.

The rheological properties of drilling mud are influenced by several factors, including the chemical composition of the mud, temperature, pressure, and the presence of salts. Salts are common additives in drilling mud formulations, playing a crucial role in enhancing the physical and chemical properties of the mud. Among these salts, potassium chloride (KCl) is one of the most widely used additives due to its ability to improve viscosity and flexibility, contributing to greater stability during drilling operations.

Carboxymethyl cellulose (CMC) is a widely used additive in drilling mud formulations, known for its ability to increase the viscosity of the mud, thereby improving drilling performance. However, the effect of salts such as potassium chloride on the rheological properties of low-viscosity CMC-based drilling mud remains a subject of research and study.

Investigating the impact of potassium chloride on the rheological properties of drilling mud involves analyzing how viscosity, elasticity, and flow behavior change under various conditions. For instance, the addition of potassium chloride can enhance the mud's resistance to separation, reducing the risk of complications during drilling. Different concentrations of potassium chloride can also affect the stability of the mud, necessitating a thorough study to understand the relationship between chemical composition and rheological properties.

Furthermore, understanding the effect of salts on the rheological properties of drilling mud can contribute to the development of new strategies to enhance drilling operations. By optimizing mud formulations, costs can be reduced, and efficiency increased, leading to better outcomes in diverse geological environments. Therefore, research in this area is essential for developing new techniques that ensure the success of drilling operations and meet the growing demands of the industry.

Understanding the effect of potassium chloride on the rheological properties of low-viscosity CMC-based drilling mud is a crucial step toward improving the performance of drilling operations, opening new avenues for research and development in this vital field.

2.1 Low viscosity CMC (CMC-LV) and Potassium chloride salt KCL in drilling mud

2.1.1 Low viscosity CMC (CMC-LV)

is a type of chemical substance added to drilling mud. Its primary function is to reduce fluid loss from the mud into the rock formations during drilling. It is characterized by not making the mud too viscous, which makes it suitable for some drilling operations where high viscosity mud is not preferred. It also helps to stabilize the properties of the mud and prevent problems such as the swelling of clay-rich formations. In short, it is a material for regulating fluid loss in drilling mud while maintaining a low viscosity."

2.1.2 Potassium chloride salt KCL

"Potassium chloride is considered an important additive in drilling mud, especially for sensitive shale formations. Its primary benefit lies in stabilizing these formations and preventing their swelling and collapse through the interaction of potassium ions with clay minerals. It also contributes to preventing the migration of these minerals and maintaining reservoir permeability, thus improving drilling efficiency and reducing costs.
On the other hand, potassium chloride may cause in addition to the potential for corrosion of drilling equipment and unwanted reactions with other materials in the mud. Its cost and availability should also be considered. Therefore, its use requires careful management and a comprehensive understanding of its benefits and drawbacks to make informed decisions in drilling operations."

2.2 Several studies explore the effect of potassium chloride on the biological properties of drilling mud and some other salts.

2.2.1 paper 1 the Effect of KCl on Rheological Properties of Shale Contaminated Water-Based MUD (WBM)(Global Journal of Researches in Engineering" in 2012)

This research paper investigates the impact of potassium chloride (KCl) on the rheological properties of water-based mud (WBM) contaminated with shale, addressing the significant issue of wellbore instability encountered during drilling operations. The study highlights the challenges posed by conventional WBMs when drilling through water-sensitive shale formations, which often lead to instability due to swelling and other adverse reactions.

The authors emphasize the resurgence of interest in WBMs, particularly potassium-based muds, as a viable alternative to oil-based muds (OBMs), which are limited by high costs and environmental concerns. The research employs a FANN viscometer to evaluate the rheological properties of the WBM at various concentrations of KCl (0.2%, 0.4%, 1.0%, 2.0%, and 4.0%). The results demonstrate a significant reduction in rheological values with increasing KCl concentration, indicating its effectiveness in inhibiting shale swelling.

Quantitative findings reveal that the rheological values at 600 RPM decreased by 0%, 36%, 60%, 94%, and 181% for the respective KCl concentrations compared to the control sample without KCl. This reduction underscores the potential of KCl to enhance the stability of drilling fluids and mitigate non-productive time associated with hole instability.

The study advocates for the proper design of drilling fluids using KCl to improve operational efficiency and safety when drilling through shale zones. The findings contribute valuable insights into the development of more effective water-based muds for drilling applications, emphasizing the importance of selecting appropriate additives to combat shale instability.

Focus of the Study:
The research primarily investigates the impact of potassium chloride (KCl) on the rheological properties of water-based mud (WBM) that has been contaminated with shale. It addresses the challenges of wellbore instability caused by problematic shales during drilling operations and explores the potential of KCl as an inhibitive agent to mitigate these issues.

Key Findings :
Reduction in Rheological Values: The introduction of potassium chloride (KCl) significantly reduced the rheological properties of water-based mud (WBM) contaminated with shale, with reductions of up to 181% at higher KCl concentrations.
Inhibition of Shale Swelling: KCl effectively inhibited the swelling tendencies of shale, improving the stability of the drilling fluid.
Operational Efficiency: Proper use of KCl in WBMs can reduce non-productive time associated with wellbore instability, enhancing overall drilling performance in shale formations.

2.2.2 paper 2 The Effect of Potassium Chloride on the Rheological Properties of Cellulose Mixtures in Drilling Fluids"

(Uduba et al. (2023). Experimental study on KCl's influence on CMC and PAC-R rheological properties. The Journal of Engineering and Exact Sciences, 9(3). DOI: 10.18540/jcecvl9iss3pp15211-01.)

This study addresses the effect of potassium chloride (KCl) salt on the rheological properties of a mixture of carboxymethyl cellulose (CMC) and polyanionic cellulose - regular (PAC - R) under increasing temperature conditions. Drilling fluids are a mixture of water, clay, weighting materials, and some chemicals used to stabilize wellbore pressure. The properties of these fluids affect drilling operations, as the cost of drilling fluids represents a significant challenge. The study aims to determine the effect of salinity on the rheological properties of the CMC and PAC - R mixture. The results showed that increasing salinity leads to a decrease in the effectiveness of the polymer, negatively impacting the rheological properties. It was also observed that plastic viscosity decreases with increasing temperature, while the yield point increases. Additionally, the thixotropic property (gel strength) increases with temperature but decreases with the introduction of salt. The results indicate that the ability to suspend cuttings for both KCl and CMC mixtures is unique.

Focus of the Study:
- Investigating the effect of potassium chloride salinity on the rheological properties of the CMC and PAC - R mixture.
- Analyzing how temperature affects the rheological properties of the drilling mixture.
- Evaluating the effectiveness of the polymers used in drilling fluids under different salinity conditions.

Key findings:
- Rheology: The study of the behavior of materials during flow and deformation.
- Viscosity: The resistance of a fluid to flow, an important property in drilling fluids.
- Salinity: The concentration of salts in the fluid, which affects the effectiveness of polymers.
- Thixotropic Properties: The ability of a fluid to change its viscosity with varying shear rates.
- Yield Point: The minimum pressure required to initiate the flow of the fluid.

2.2.3 paper 3 Interference of Sodium Chloride on Shale Stabilization with Potassium Chloride in Drilling Fluid
(Journal of Petroleum Science and Technology, Volume 10, 2020,)

A recent study investigated the challenges associated with drilling in shale formations, which are frequently cited as a primary cause of wellbore instability and significant cost overruns in the oil drilling industry. The environmental limitations of traditional oil-based drilling fluids have prompted a shift towards the adoption of water-based alternatives.

The research primarily focused on the effectiveness of potassium chloride (KCl) as a shale inhibitor, alongside an evaluation of the impact of sodium chloride (NaCl) when incorporated into KCl-based drilling fluids. To this end, the researchers prepared KCl fluids across a concentration range of 1 to 15 wt% and conducted a series of tests, including linear swelling, capillary suction time (CST), and dispersion experiments, with the aim of determining the efficacy of these fluids in preventing shale swelling.

The key findings of the study revealed that KCl significantly reduces shale swelling, with the optimal concentration range identified as 3 to 15 wt%. However, the presence of NaCl was observed to interfere with the effectiveness of KCl, particularly at higher concentrations, potentially leading to increased swelling and a reduction in potassium yield. The study underscored the critical role of cation exchange, whereby K+ ions displace Na+ and Ca2+ ions within the clay structure, and elucidated how elevated NaCl concentrations disrupt this mechanism.

Results from the CST tests indicated that the use of KCl alone enhances shale stabilization, while the addition of NaCl alters the fluid properties, impacting the rate of water absorption and shale dispersion. Based on these findings, the research concluded that for young and active shale formations, the exclusive use of KCl is advisable for achieving optimal outcomes, whereas a combination of low concentrations of NaCl and KCl may offer benefits in the case of older shale formations.

the study emphasized the necessity of meticulous management of salt concentrations in drilling fluids to ensure effective shale inhibition and the maintenance of wellbore stability throughout drilling operations.

Focus of the Study:
The study focuses on the effectiveness of potassium chloride (KCl) as a shale inhibitor in drilling fluids and examines how the presence of sodium chloride (NaCl) affects KCl's performance in stabilizing shale formations during drilling operations.

Key Findings:

- KCl Effectiveness: KCl significantly reduces shale swelling, with optimal concentrations between 3 to 15 wt%.
- NaCl Interference: Higher concentrations of NaCl negatively impact KCl's efficiency, leading to increased swelling and reduced potassium yield.
- Cation Exchange: The presence of NaCl disrupts the cation exchange process essential for shale stabilization.
- CST Results: KCl alone improves shale stabilization, while NaCl alters fluid properties, affecting water absorption and shale dispersion.

2.2.4 paper 4 Effect of Salinity (KCl) on Rheological Properties and Rate of Penetration of Treated Bentonite and Ca^{2+} Based Polymer Drilling Mud (International Journal of Research and Scientific Innovatio)

This study examines the effect of salinity, specifically through the addition of potassium chloride (KCl), on the rheological properties and rate of penetration (ROP) of treated bentonite mud and Ca^{2+} based polymer drilling mud. Laboratory-prepared treated bentonite and field-acquired Ca^{2+} based polymer mud were subjected to varying salinity levels ranging from 0% to 15%, with measurements taken under both low pressure/low temperature (LP/LT) and high pressure/high temperature (HP/HT) conditions. Key rheological properties, including plastic viscosity, yield point, and apparent viscosity, were evaluated alongside fluid loss and density. The results indicated that increasing KCl concentration generally led to higher mud weight and gel strength, while plastic viscosity, yield point, and apparent viscosity decreased for Ca^{2+} polymer mud. In treated bentonite mud, a decrease in these properties was observed from 0% to 2% salinity, followed by an increase from 5% to 10%. Additionally, fluid loss to formation increased with salinity, negatively impacting the quality of the filter cake formed. A correlation was established where ROP increased as plastic viscosity decreased. The findings suggest that high concentrations of KCl can destabilize water-based muds and increase fluid loss, emphasizing the need for careful management of KCl concentrations in drilling mud formulations. This research contributes valuable insights into optimizing drilling operations in the petroleum industry by understanding the effects of salinity on drilling fluid performance.

Focus of study:
The document focuses on the impact of salinity, specifically potassium chloride (KCl), on the rheological properties and rate of penetration (ROP) of two types of drilling mud: treated bentonite mud and Ca^{2+} based polymer mud. It evaluates key properties such as plastic viscosity, yield point, and fluid loss, aiming to provide insights for optimizing drilling fluid performance in the petroleum industry.

The key findings :
1. Increased Salinity Effects: Higher KCl concentrations lead to increased mud weight and gel strength.

2. Rheological Changes: For Ca^{2+} polymer mud, plastic viscosity, yield point, and apparent viscosity decrease with increased salinity.

3. Treated Bentonite Behavior: Treated bentonite mud shows a decrease in viscosity properties up to 2% salinity, then an increase from 5% to 10%.

4. Fluid Loss Increase: Salinity increases fluid loss to formation, affecting filter cake quality.

5. ROP Correlation: Rate of penetration improves as plastic viscosity decreases.

These findings highlight the importance of managing salinity in drilling mud formulations to optimize drilling performance.

2.2.5 paper 5 The Effect of Inorganic Salt on the Structure of Filter Cake of Water-Based Drilling Fluid(Y. Rugang, J. Guancheng, Y. Longyun, L. Wei, D. Tianqing (1 China University of Petroleum, 2 China Oilfield Services Ltd.))

The research addresses the effect of inorganic salts on the structure of the filter cake formed from water-based drilling fluids. The filter cake is a vital component in drilling operations, playing an important role in stabilizing the wellbore and preventing fluid leakage into surrounding geological formations. This work aims to provide a comprehensive review of the microstructure, elemental composition, particle size distribution, and polymer concentration in different layers of the filter cake.
The results indicate that high levels of electrolyte contamination contribute to the flocculation of drilling fluids, leading to a weakening of the gel strength and its ability to suspend larger particles. As a result, it becomes easier for larger particles to settle in fluids

contaminated with electrolytes. High-temperature and high-pressure fluid loss tests were used to study the impact of inorganic salts on the properties of the filter cake.

The findings show that the filter cake formed by large particles has increased porosity and permeability. It was also observed that the particle size in the bottom layer of the filter cake is larger than that in the middle and top layers. This suggests that flocculation affects the distribution of particles within the filter cake.

Furthermore, the salt tolerance of water-based drilling fluids can be improved by providing a homogeneous distribution of deformable colloidal particles. Scanning electron microscopy (SEM) was employed to analyze the microstructure, along with particle size distribution (PSD) analysis.

Inorganic salts promote the flocculation of particles rather than enhancing their hydration and dispersion, leading to an increase in particle size and filter cake permeability. This results in increased fluid loss, negatively impacting the performance of drilling fluids.

Therefore, it is essential to add effective additives to improve the salt resistance of drilling fluids. New additives such as ADAA were utilized, resulting in a significant reduction in fluid loss.

The results demonstrate that a deep understanding of the impact of inorganic salts on filter cake properties is crucial for enhancing the performance of drilling fluids in harsh environments. By improving the distribution of deformable colloidal particles, the resistance of the filter cake can be enhanced, and fluid loss can be minimized, contributing to better outcomes in drilling operations.

Focus of study :
This document focuses on the effect of inorganic salts on the filter cake in drilling fluids and the impact of electrolyte contamination on particle flocculation and gel strength weakening.
Key findings:
- Filter cake, inorganic salts, electrolyte contamination, gel strength, microstructure, particle size distribution, effective additives.

2.2.6 paper 6 Influence of Salt Contamination on the Rheological and Filtration Properties of Bentonite-Based Mud (IOP Conference Series: Earth and Environmental Science,)

This study addresses the impact of salt contamination on the rheological properties of bentonite-based mud, a type of clay widely used in the fields of oil, geotechnical, and civil engineering. Bentonite-based mud is a fundamental material in drilling operations, playing a vital role in lubricating the drill bit, maintaining wellbore stability, and lifting drilled cuttings to the surface.

The increasing need to explore oil in deeper and more complex formations is driven by the growing global demand for hydrocarbons. In this context, understanding the effects of contaminants, such as salts, on the quality of bentonite-based mud becomes essential. Contamination of the mud with salts can negatively affect its properties, leading to issues in drilling operations.

Experiments were conducted on samples of mud with varying concentrations of salts, where the rheological properties of the mud were measured using specialized laboratory equipment. Eight samples of bentonite-based mud were prepared, using 5% bentonite powder and fresh water. The mud was prepared by mixing water and bentonite using a mixer, and a sample without salt addition was classified as "base mud." Subsequently, two types of salts (NaCl and CaCl2) were added at different concentrations, and the rheological properties of the mud were measured using a multi-speed viscometer and API filter press according to the standards of the American Petroleum Institute (API).

The results indicated that salt contamination adversely affects the properties of the mud. As the salt concentration increased, a significant reduction in rheological parameters was observed, such as apparent viscosity (AV), plastic viscosity (PV), yield point (YP), and gel strength (GS). For instance, experiments showed that adding 2% NaCl resulted in an 81% decrease in apparent viscosity and a 67% decrease in plastic viscosity. Filtration tests also revealed that bentonite-based mud experienced significant water loss to the formation with increasing salt concentration.

The reduced rheological properties of the mud lead to inefficiencies in suspending and lifting drilled cuttings, potentially causing issues such as loss of circulation, formation damage, wellbore instability, and decreased drilling efficiency. Additionally, increasing salt concentrations lead to diminished properties of the mud, resulting in poor performance in drilling operations.

This study highlights the importance of understanding the effects of salt contamination on the properties of bentonite-based mud. By analyzing the impacts of different salts, improvements can be made to the formulations of mud used in drilling operations, contributing to enhanced operational efficiency and reduced problems associated with mud contamination.

Focus of study: this study focuses on the impact of salt contamination on the rheological and filtration properties of bentonite-based mud.
Key findings Impact of Salt Contamination, Rheological Parameter Reduction, Fluid Loss Increase, Specific Concentration Effects, Operational Implications, Need for Monitoring.

Key findings: Impact of Salt Contamination, Rheological Parameter Reduction, Fluid Loss Increase, Specific Concentration Effects, Operational Implications, Need for Monitoring.

2.3 Theoretical background

2.3.1 Drilling Fluid Chemical Composition:

The chemical composition of drilling fluid encompasses a wide range of additives and compounds, each serving specific functions to optimize drilling performance, ensure wellbore stability, and meet environmental and safety standards. Here's a breakdown of the key chemical components commonly found in drilling fluids:

1. Water-Based Fluids (WBFs):

- Water: The primary component of water-based drilling fluids, serving as the base fluid.
- Clay: Clay minerals such as bentonite are often added as viscosifiers to increase fluid viscosity and suspend drill cuttings.
- Polymers: Synthetic polymers like polyacrylamide or xanthan gum may be added to enhance fluid viscosity and stability.
- Biocides: Chemicals like glutaraldehyde or chlorine-based compounds are included to prevent microbial growth in the fluid.
- Defoamers: Antifoaming agents help control foam formation in the drilling fluid, improving drilling efficiency

2. Oil-Based Fluids (OBFs):

• Base Oil: Hydrocarbon-based oils, such as diesel, mineral oil, or synthetic oils, serve as the base fluid.

• Emulsifiers: Surfactants and emulsifiers are added to stabilize the oil-water emulsion and prevent phase separation.

• Weighting Agents: Compounds like barite or calcium carbonate increase fluid density to control formation pressure.

• Lubricants: Lubricating additives reduce friction between the drill string and wellbore, improving drilling efficiency.

• Corrosion Inhibitors: Compounds like amines or phosphonates are added to protect metal equipment from corrosion.

3. Synthetic-Based Fluids (SBFs):

• Synthetic Base Fluid: Synthetic fluids, such as esters, glycols, or linear alpha olefins, serve as the base fluid.

• Viscosifiers and Rheology Modifiers: Similar to WBFs and OBFs, polymers and additives are used to control fluid viscosity and rheological properties.

• Emulsion Stabilizers: Surfactants and emulsifiers ensure stable emulsion formation between the base fluid and other additives.

• Filter Control Agents: Compounds like sized calcium carbonate or synthetic polymers help control filtration properties and prevent fluid loss into the formation

2.3.2 Types of Polymers Used in Drilling Fluids:

1. Xanthan Gum:

Xanthan gum is a natural polysaccharide produced by fermentation of carbohydrates by the bacterium Xanthomonas campestris. Widely used in water-based drilling fluids, xanthan gum serves as a viscosifier and rheology modifier. It imparts pseudoplastic rheological behavior to the fluid, meaning its viscosity decreases under shear stress, facilitating fluid circulation while maintaining viscosity when static.

2. Polyacrylamide (PAM):

Polyacrylamide is a synthetic polymer derived from acrylamide monomers. Used in water-based drilling fluids to increase fluid viscosity, improve shale inhibition, and control fluid loss. Polyacrylamide forms a protective barrier around clay particles in shale formations, preventing hydration and reducing wellbore instability.

3. Partially Hydrolyzed Polyacrylamide (PHPA):

PHPA is a modified form of polyacrylamide with hydrolyzed segments. Particularly effective in inhibiting shale formations prone to swelling and dispersion during drilling operations. PHPA enhances shale inhibition by encapsulating clay particles and minimizing wellbore instability, reducing the risk of stuck pipe incidents.

4. Hydroxyethyl Cellulose (HEC):

Hydroxyethyl cellulose is a water-soluble polymer derived from cellulose. Used in water-based drilling fluids to provide viscosity, fluid loss control, and thermal stability. HEC exhibits good thermal stability and can withstand high temperatures encountered during drilling, making it suitable for various drilling environments.

5. Polyethylene Glycol (PEG):

Polyethylene glycol is a synthetic polymer composed of repeating ethylene glycol units. Employed in water-based and oil-based drilling fluids to improve lubricity and reduce friction between the drill string and wellbore. PEG enhances drilling efficiency by reducing torque and drag, preventing sticking of the drill string, and improving overall drilling performance.

6. Carboxymethyl Cellulose (CMC):

Carboxymethyl cellulose is a water-soluble cellulose derivative modified with carboxymethyl groups. Used in water-based drilling fluids as a viscosifier,

fluid loss control agent, and shale inhibitor. CMC helps maintain fluid viscosity, prevents fluid loss into permeable formations, and inhibits swelling of clay minerals in shale formations.

7. Styrene Butadiene Rubber (SBR):

SBR is a synthetic rubber polymer composed of styrene and butadiene monomers. Utilized in drilling fluids to improve fluid rheology, enhance suspension of drill cuttings, and increase fluid stability. SBR imparts excellent shear stability and suspension properties to drilling fluids, ensuring efficient removal of drill cuttings and maintaining wellbore integrity.

2.3.3 The Chemical Composition :

2.3.3.1 Bentonite:

1.Main Components:

• Montmorillonite: Bentonite primarily consists of montmorillonite, a type of swelling clay mineral belonging to the smectite group.

• Aluminum Silicates: Montmorillonite is composed of stacked layers of aluminum silicate sheets, with an octahedral layer sandwiched between two tetrahedral layers.

•Hydrated Sodium Calcium Aluminum Magnesium Silicate Hydroxide: This mouthful of a chemical name describes the combination of elements found in bentonite, including sodium

(Na), calcium (Ca), aluminum (Al), magnesium (Mg), silicon (Si), oxygen (O), and hydrogen (H).

2.Chemical Formula: The chemical formula for montmorillonite, the primary constituent of bentonite, can be expressed as

$(Na,Ca)_{0.33}(Al,Mg)_2(Si_4O_{10})(OH)_2 \cdot nH_2O$. And the bentonite as : $Al_2O_3.4(SiO_2)$.

This formula represents the repeating unit structure of montmorillonite, where the cations (Na^{+1}, Ca^{+2}, Al^{+3}, Mg^{+2}) occupy the interlayer spaces between the silicate layers.

2.3.3.2 Xanthan gum (XC-Polymer)

Xanthan gum is a high-molecular-weight polysaccharide, produced by the fermentation of carbohydrates with the bacterium Xanthomonas campestris. It is widely used in various industries, including food, pharmaceuticals, cosmetics, and drilling fluids, due to its unique rheological properties and water-solubility.

1. Chemical Structure:

Xanthan gum is composed of repeating units of pentasaccharide side chains, consisting of D-glucose, D-mannose, and D-glucuronic acid. The repeating pentasaccharide unit is comprised of a backbone of alternating D-glucose and D-mannose residues, with side chains of D-glucuronic acid and D-mannose attached to the glucose residues. Acetyl and pyruvyl groups are also present, attached to some of the mannose residues, contributing to the overall structure and properties of xanthan gum

2. Chemical Formula : The chemical formula for xanthan gum can be represented as $(C_{35}H_{49}O_{29})$

2.3.3.3 Carboxymethyl Cellulose (CMC)

Carboxymethyl cellulose (CMC), also known as cellulose gum or sodium carboxymethyl cellulose (NaCMC), is a water-soluble polymer derived from cellulose, a natural polysaccharide found in plant cell walls. CMC is widely used in various industries, including food, pharmaceuticals, cosmetics, and drilling fluids, due to its unique rheological properties and water-solubility.

1.Chemical Structure: Carboxymethyl cellulose is a cellulose derivative in which some of the hydroxyl groups of the cellulose polymer chains are substituted with carboxymethyl groups. It has a linear structure.

2.Chemical Formula: The chemical formula for carboxymethyl cellulose can be represented as $C_6H_7O_2(OH)_3$-$n(OCH_2COONa)n$,where n represents the degree of substitution (number of carboxymethyl groups per glucose unit).

2.3.4 Key Parameters:

1- **Rheology**: Rheology is the science of studying the flow and deformation behavior of materials, particularly fluids and soft solids, under stress or strain. It encompasses the viscosity, elasticity, shear stress, shear rate, and other flow properties of fluids, as well as their response to external forces.

2- **Viscosity:** Viscosity is a measure of a fluid's resistance to flow. It quantifies how easily a fluid deforms or flows under an applied force. Fluids with high viscosity flow more slowly, while those with low viscosity flow more easily.

3- **Shear Stress and Shear Rate:** Shear stress is the force per unit area applied parallel to the direction of flow, while shear rate is the rate of change of deformation with respect to distance. The relationship between shear stress and shear rate characterizes a fluid's rheological behavior.

4- **Viscoelasticity:** Some fluids exhibit both viscous (flowing) and elastic (deformable) properties. Viscoelastic fluids can store and recover energy, exhibiting behaviors such as creep, stress relaxation, and hysteresis.

2.3.5 Classification of Fluids:

Fluids can be classified into different rheological categories based on their flow behavior:

1- **Newtonian Fluids:** These fluids have a constant viscosity regardless of the applied shear stress or shear rate. Examples include water, most oils, and some gases.

2- **Non-Newtonian Fluids:** Non-Newtonian fluids exhibit variable viscosity depending on the applied stress or shear rate. They can be further categorized into:

3- **Shear-Thinning or Pseudoplastic:** Viscosity decreases with increasing shear rate. Examples include ketchup, toothpaste, and xanthan gum solutions.

4- **Shear-Thickening or Dilatant:** Viscosity increases with increasing shear rate. Examples include cornstarch suspensions and certain clay suspensions.

5- **Thixotropic:** Viscosity decreases over time under constant stress. Examples include certain paints, inks, and drilling fluids.

6- **Rheopectic:** Viscosity increases over time under constant stress. Examples include certain greases and lubricants

2.3.6 Polymers Functions in Drilling Fluids:

1.Improved Fluid Rheology:

Polymers modify the viscosity and rheological properties of drilling fluids, allowing for better control over fluid flow and circulation. By adjusting fluid rheology, polymers ensure that drilling fluids can effectively carry drill cuttings to the surface while maintaining wellbore stability

2.Enhanced Suspension of Drill Cuttings:

Polymers aid in suspending and transporting drill cuttings generated during drilling operations. By preventing settling and accumulation of drill cuttings in the wellbore, polymers facilitate efficient drilling and reduce the risk of equipment damage or blockages.

3. Effective Shale Inhibition:

Clay minerals present in shale formations can pose significant challenges during drilling by swelling and destabilizing the wellbore. Polymers, such as polyacrylamide (PAM) and partially hydrolyzed polyacrylamide (PHPA), encapsulate clay particles and inhibit shale hydration, minimizing wellbore instability and reducing the risk of stuck pipe incidents.

4. Fluid Loss Control:

Polymers act as fluid loss control agents, reducing the loss of drilling fluid into permeable formations. By forming a protective barrier on the wellbore walls, polymers minimize fluid invasion into the formation, maintain wellbore integrity, and prevent formation damage.

5. Temperature and Salinity Stability:

Some polymers exhibit excellent thermal stability and can withstand high temperatures encountered during drilling operations. Additionally, certain polymers, like hydroxyethyl cellulose (HEC), are compatible with saltwater-based drilling fluids, making them suitable for use in high-salinity environments.

6. Environmental Compatibility:

Many polymers used in drilling fluids are biodegradable and environmentally friendly, minimizing their impact on the surrounding ecosystem. By choosing environmentally compatible polymers, drilling operations can reduce their environmental footprint and adhere to regulatory standards.

7. Versatility and Compatibility:

Polymers are versatile additives that can be tailored to meet specific drilling challenges and conditions. They are compatible with a wide range of other additives used in drilling fluids, allowing for customization and optimization of fluid formulations based on operational requirements. Bentonite is a naturally occurring clay mineral renowned for its unique chemical composition and versatile applications in various industries, including drilling fluids. Its chemical composition plays a crucial role in determining its properties and funct

2.3.7Rheological Properties and Measurement Methods for Each

.1Viscosity

-Definition :

- A measure of a fluid's resistance to flow. It indicates how difficult it is for a fluid to flow under the influence of force.

-Measurement Methods:

- Cone-Plate Rheometer:

- Measures viscosity at both low and high shear rates. A cone is used with a plate to determine viscosity accurately.

- Coaxial Cylinder Rheometer:

- Measures viscosity in fluids with non-Newtonian properties. It consists of an inner and outer cylinder.

- Dynamic Viscosity Test:

- Measures viscosity at specific shear rates using devices like the Brookfield viscometer.

.2Yield Stress

-Definition :

- The minimum stress required to initiate flow in a material. It serves as an indicator of how solid a material is before it begins to flow.

-Measurement Methods:

- Yield Stress Measurement Using Rheometer:
- The stress required to initiate flow is measured using a specialized rheometer that can assess yield stress.
- Static Shear Test:
- A constant stress is applied to the sample until flow begins, and the stress at this point is measured.

.3Consistency

-Definition :

- A measure of how thick or thin a fluid is. It is usually expressed in units like Pa.s.

-Measurement Methods:

- Viscosity Test Using Rheometer:
- Consistency is measured by analyzing data obtained from viscosity measurements at different shear rates.
- Kinematic Viscosity Test:
- Measures the time it takes for a fluid to flow through a tube, which helps in calculating consistency.

.4Flow Index

-Definition :

- Indicates how viscosity changes with varying shear rates. It reflects the behavior of the material under different pressure conditions.

-Measurement Methods:

- Data Analysis from Rheometer:
- The flow index is calculated by analyzing the flow curves obtained from viscosity measurements at different shear rates.
- Dynamic Flow Test:

- Measures how viscosity changes with varying shear rates using specialized measurement devices.

.5Non-Newtonian Behavior

-Definition :

- Refers to the behavior of fluids that do not follow Newton's law of viscosity, where viscosity changes with varying shear rates.

-Measurement Methods:

- Rheometer Tests:

- Used to measure non-Newtonian behavior by analyzing data from viscosity measurements at different shear rates.

- Flow Tests:

- Include measuring how viscosity changes with varying shear rates, helping to determine the type of non-Newtonian behavior (such as shear-thinning or shear-thickening).

Chapter Three: Methodology

Chapter Three: Methodology

3.1 Materials Used

For the experiment we have used:

1- Fresh water

2- Bentonite

3-CMC polymer

4- kcl

-A number of materials can be added to improve the physical and chemical properties of drilling mud, such as:

(Kaolin: to improve the cohesion and resistance of clay

Gelatin: Reduce fluid loss

$CaCl_2$: Improve hydraulic stability)

3.2 Divices Used:

1- Viscometer: The Fan Model 35 Viscometer is widely known as the "Standard of the Industry" for drilling fluid viscosity measurements. The Model 35 Viscometer is a versatile instrument for research or production use. In the six-speed models, test speeds of 600, 300, 200, 100, 6 and 3 rpm are available via synchronous motor driving through precision gearing. Any test speed can be selected without stopping rotation. The shear stress is displayed continuously on the calibrated scale, so that time-dependent viscosity characteristics can be observed as a function of time. The Model znn-d6 . Shear stress and gel is read directly from a calibrated scale. Plastic viscosity and yield point of a fluid can be determined easily by making two simple subtractions from the observed data

Figure1 (Viscometer)

2- Electronic Weighing Scale: Electronic Weighing Scale is a device used to measure mass or weight

Figure 2 (Electronic Weighing Scale)

3-Mixers – Hamilton Beach: Hamilton Beach Mixers, Single and Three-Speed Models, are recommended for use in general purpose mixing of drilling fluids in preparation for laboratory tests of mud materials. These mixers can also be used to mix cement for field or laboratory testing.

Figure 3 (Mixers – Hamilton Beach)

to evaluate the filtration properties of a drilling fluid. This instrument consists of a pressure cell, frame, pressure source, filter medium, and a graduated cylinder. It conforms to API specifications, and is suitable for both field and lab use.

Figure 4 (Filter Press)

Laboratory tools:

- Test tubes: to test different properties on small samples.

Figure 5 (Test tubes)

- Measuring bucket: to measure large quantities of clay and water

Figure6 (Measuring bucket)

-Density meter: to determine the density of clay

Figure7 (Density meter)

-PH measurement:

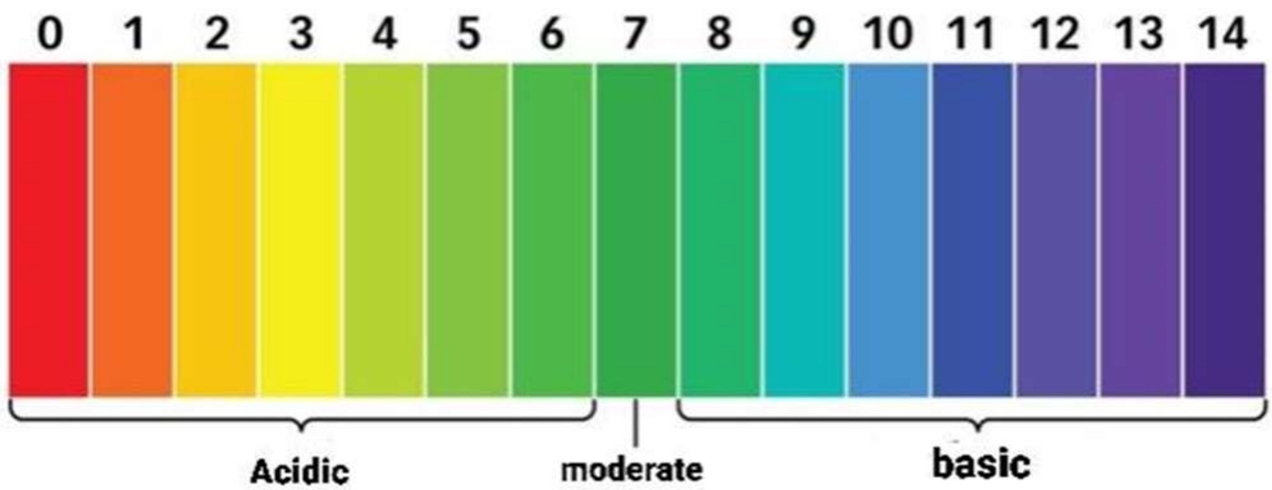

Figure 8 (PH measurement)

Properties	Measurement
ϴ300	The highest reading speed is at 300 in the viscometer
ϴ600	The highest reading speed is at 600 in the viscometer
Gel strength	For a period of 10 minutes we keep the sample undisturbed (at speed 3) and observing the maximum deflection before the gel breaks.
Filtration	As API (mL)
Plastic Viscosity (Py)	ϴ600- ϴ300 (Sr)
Apparent Viscosity (AV)	$\frac{\Theta 600}{2}$ (cp)
Yield Point (YP)	ϴ300 - pv(Ib/seqft)
Ph	Water Quality Tester
Salinity	Water Quality Tester (ppm)

Table 1 (Properties and its measurements)

3.3 EXPERIMENTAL METHODS:

The drilling muds used in this study are Ca2+ based polymer mud collected from the field and a laboratory prepared treated bentonite mud. The water base mud was prepared in accordance with American National Standards Institute/American Petroleum Institute (ANSI/API) specifications. The standard bentonite drilling mud is described in the API 13A page 15. The standard temperature is 27 °C and 22.5 g/350 cm^3 distilled water. Normally the bentonite is 3-8 by mass. It consists of 90 percent montmorillonite and 10 percent other minerals, mostly feldspar. The montmorillonite is a crystalline, three phase hydrosilicate. It absorbs five times its own mass and swells about 15 times. In the study, the water base mud was prepared using bentonite and distilled water, Caustic Soda, Lime, Polythin, Polypac, Polydrill, Duo-vis and Barites being the additives and salt was added in time steps to increase its salinity. The Hamilton beach multi-mixture was used in mixing the mud. The mud was prepared by weighing 285 grams of the bentonite using a triple beam balance. The measured sample was transferred into cup containing 4 litres of distilled water to allow for its mixing. 16 grams of polydrill was then added to ensure fluid loss control at HPHT, 3 grams of Duo-Vis for rheology, 11.4 grams of Polypac -R for general fluid loss control. 12 grams of Polythin as a thinner, 11 grams of caustic soda to increase and maintain pH and alkalinity, 5.7 grams of lime for pH buffer and 411 grams of barites to achieve the desired weight. The mixture was vigorously agitated with the multimixer for 10-15 minutes to produce a homogeneous mixture after each additive was added. The mud sample was then aged for 24 hours to allow for adequate hydration after which the properties under investigation was measured

The Salinity of both lab and field mud was increased by adding KCL in steps after each measurement. The salts were added from (0-15)% in 5% step increase. However, a further (1 and 2) % salinity increase test was conducted using the treated bentonite mud to confirm a trend which was observed during the test.

3.4 Rheological Measurements:

The theological properties of the fluid samples used in this study were measured using Fann 35A Viscometer

determines the rheological properties although sometimes come computations are needed (Anon., 2018). The properties of interest in this study includes gel strength, plastic viscosity, yield point and apparent viscosity and were computed using Equations

Plastic viscosity PV = $\Theta600 - \Theta300$

Where:

$\Theta600$: 600 rpm dial reading

$\Theta300$: 300 rpm dial reading

Yield Point YP= $\Theta300$ – pv

Apparent viscosity = $\Theta600 / 2$

3.5 . Filtration and Mud Cake Measurements:

Fluid loss is the measurement of filtrate passing from a drilling mud into a porous permeable formation. A good drilling mud should form a thin filter cake on the sides of the wellbore to prevent excessive fluids loss into the formation. Low fluid loss is a characteristic of good drilling fluids and vital to the integrity of the wellbore (Broni-Bediako et al., 2019). Filtration is done by measuring the amount of filtrate that will pass through filter paper in 30 minutes under given pressure and temperature condition using a standard size cell. Filtration of the mud was determined at high pressure and high temperature dynamic conditions for the Ca^{2+} base mud using the OFITE HPHT dynamic filter press and at low pressure and low temperature static conditions for both mud using

Baroid multiple unit filter press. After each measurement, the thickness of the cake formed was measured.

The dynamic HTHP filtration was determined using Equation

Chapter Four:

Results and Discussion

Chapter Four:Results and Discussion

4.1 Results

4.1.1 Tables

Drilling fluid preparation materials	
bentonight	30 gm
water	350 ml
ligno	2 gm
costic	0.375 gm
cmc(l.v)	2 gm

Table 2 (Drilling fluid preparation materials)

CMC

bentonight

ligno

costic

Add (gm)	Ø300	Ø600	P.V	A.V	Y.P	0Gel	PH
0	41	53	12	26.5	29	28	9.85
1.93	54	65	11	32.5	43	45	9.72
3.86	91	95	4	47.5	87	76	9.59
5.79	148	155	7	77.5	141	83	9.46
7.72	165	176	11	88	154	94	9.33
9.65	181	196	15	98	166	105	9.25

Table 3 (Salt concentration with the ermometric specifications of salt KCL)

Add (gm)	Ø300	Ø600	P.V	A.V	Y.P	Gel	PH	FILT after 7 min (ml)
0	41	53	12	26.5	29	28	9.85	5.2
1.93	54	65	11	32.5	43	45	9.72	
3.86	91	95	4	47.5	87	76	9.59	
5.79	148	155	7	77.5	141	83	9.46	
7.72	165	176	11	88	154	94	9.33	6.2
9.65	181	196	15	98	166	105	9.25	

Table 4 (Salt concentration with the ermometric specifications of salt KCL)

4.1.2 (Effect of KCl salt concentration on drilling mud properties)

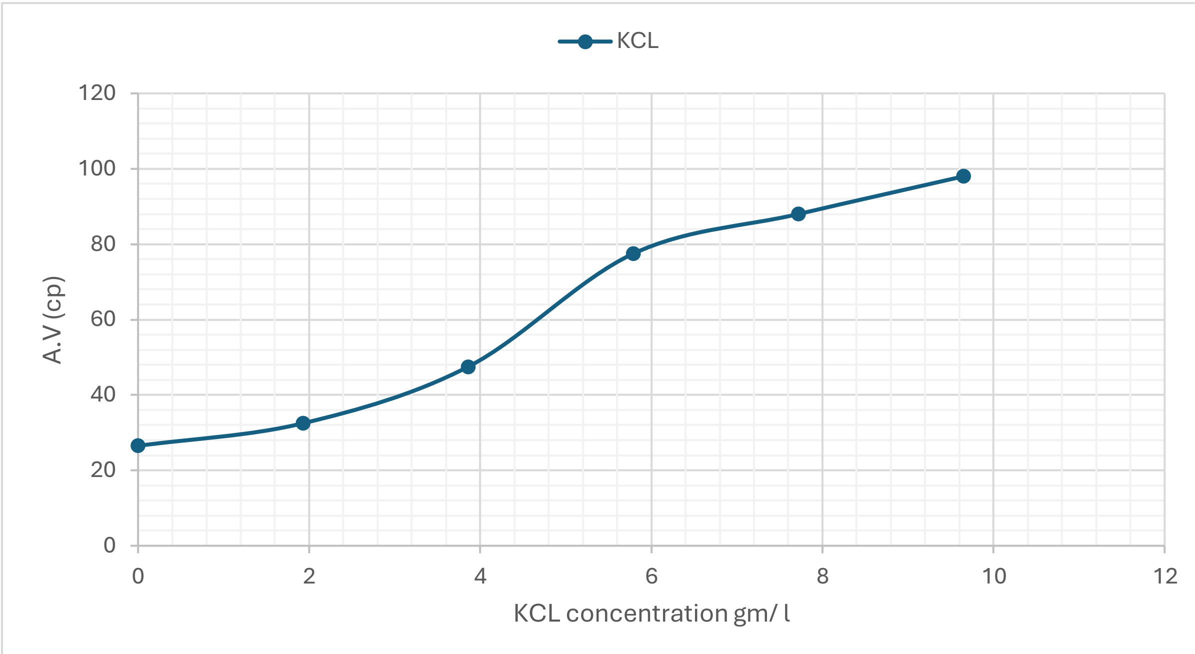

Figure 9 (Apparent viscosity versus various salt

This graph shows that the apparent viscosity of the solution increases with increasing KCl concentration. At a concentration of 0 g/L, the viscosity was approximately 25 cp.

As the KCl concentration increased, the viscosity gradually and significantly increased until it reached approximately 98 cp at a concentration of 10 g/L.

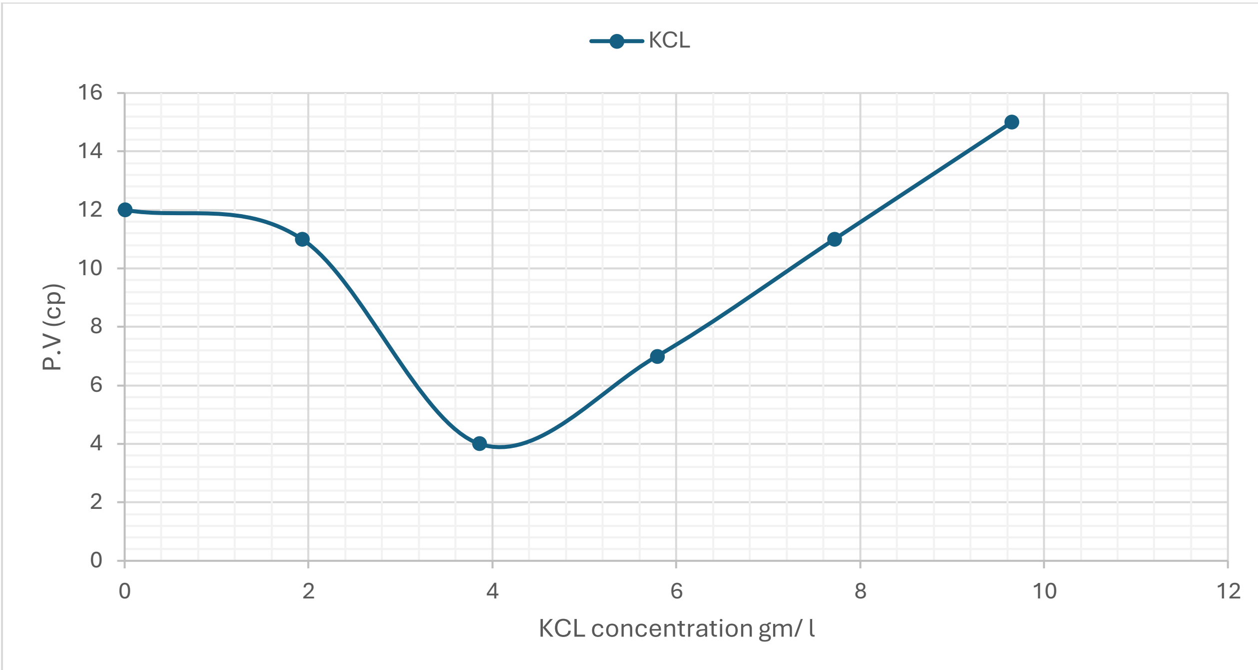

Figure 10 (Plastic viscosity versus various salt concentrations)

This graph shows a nonlinear behavior, with the plastic viscosity initially decreasing as the KCl concentration increases and then rising again: At a concentration of 0 g/L, the viscosity was approximately 12 cp. It decreased to a minimum value of approximately 4 cp at a concentration of 4 g/L. Thereafter, it gradually increased to approximately 15 cp at 10 g/L.

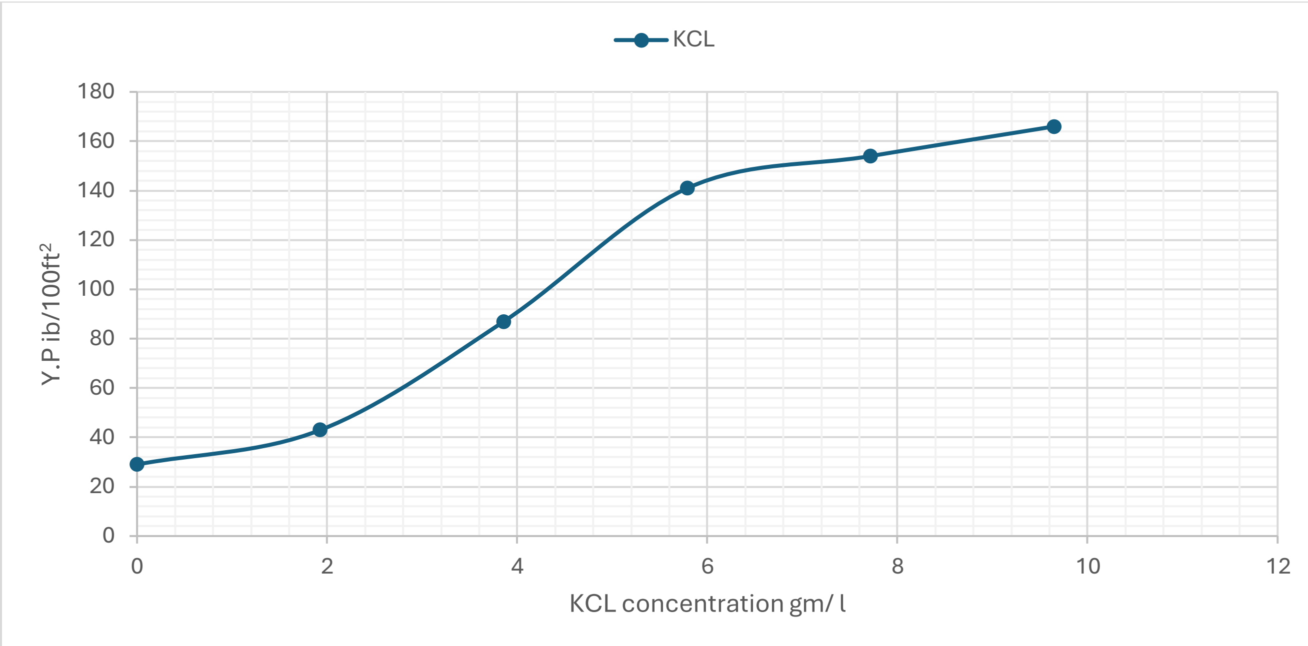

Figure 11 (Yield point versus various salt concentrations)

The graph shows how the flow point changes with KCl concentration. At 0 g/L, the flow point was approximately 30 lb/100 ft². The flow point began to rise as the KCl concentration increased: It reached approximately 160 lb/100 ft² at 9.5 g/L.

The increase was particularly pronounced between 3 and 6 g/L, and then began to stabilize relatively.

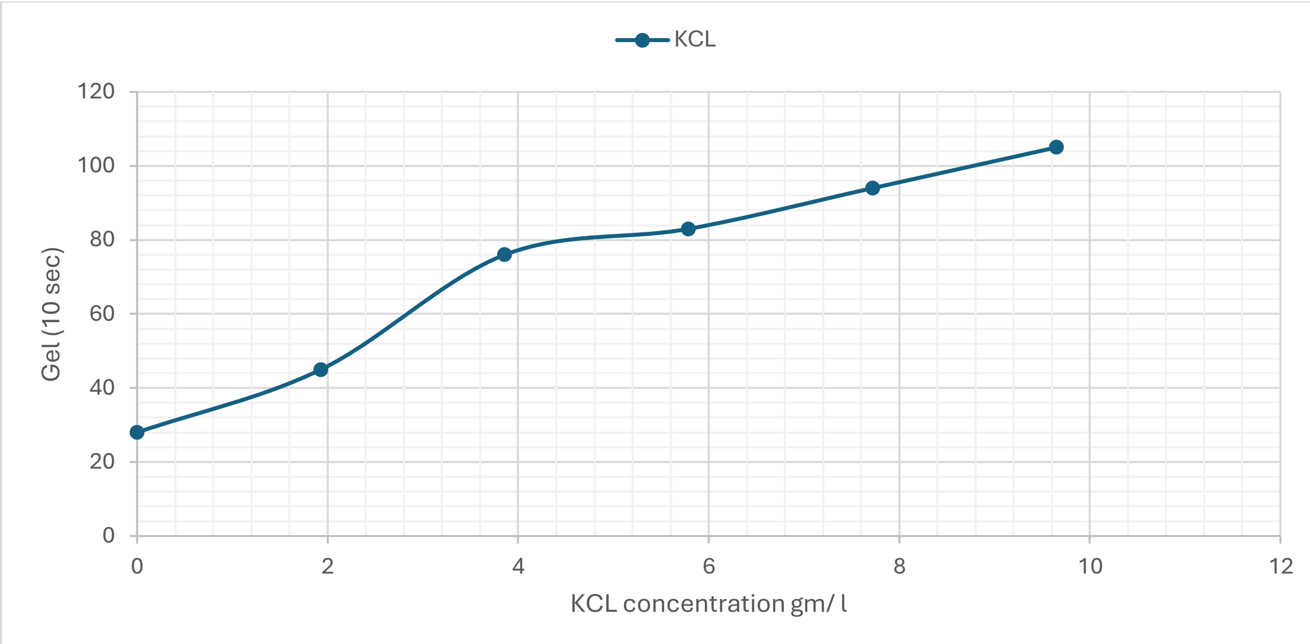

Figure 12 (Gel strength 10 sec versus various salt concentrations)

The graph shows the development of gel strength during the first 10 seconds of cessation (i.e., the ability of the liquid to hold together immediately after cessation). At a concentration of 0 g/L, the value was approximately 28 It gradually increased to approximately 105 at a concentration of 10 g/L. The increase was rapid between 2 and 4 g/L and then continued at a lesser rate.

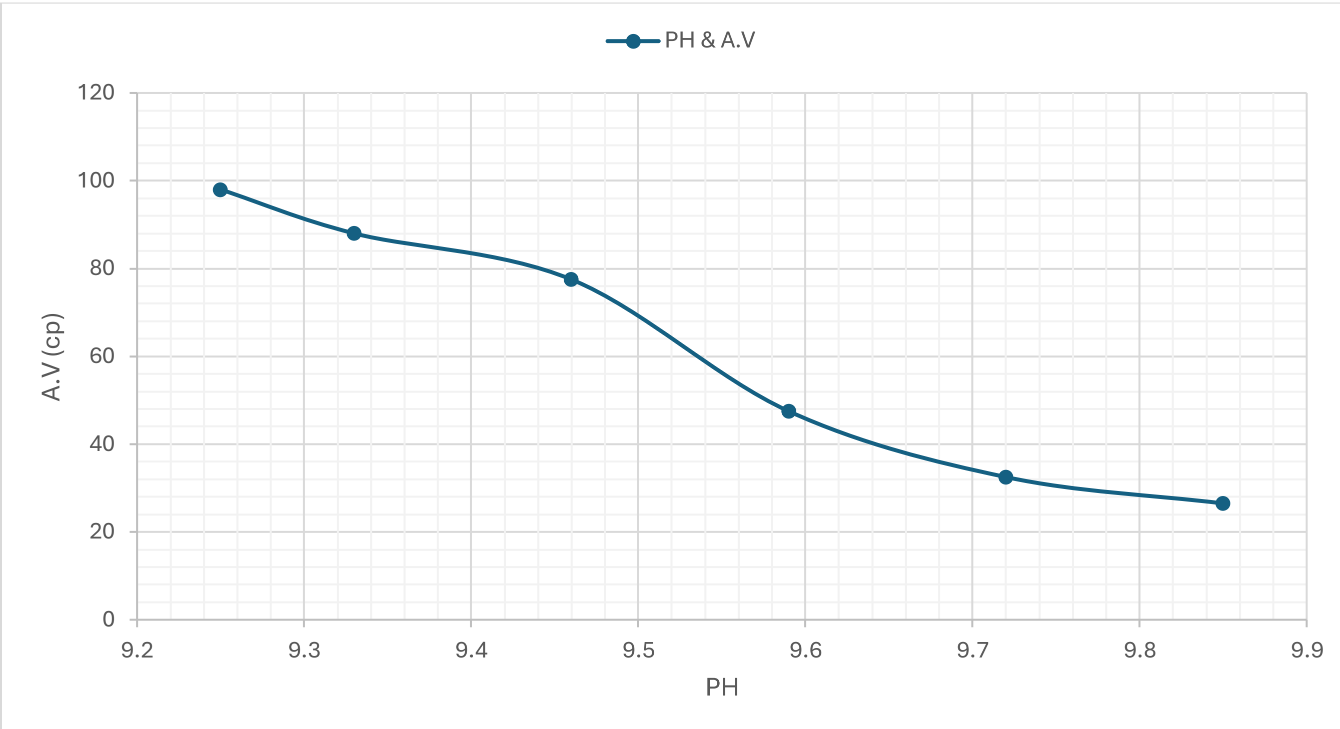

Figure 13 (Apparent viscosity versus various pH)

At pH = 9.2, the viscosity was approximately 100 cp. As the pH value increased, the viscosity decreased almost continuously. At pH = 9.9, the viscosity decreased to approximately 27 cp.

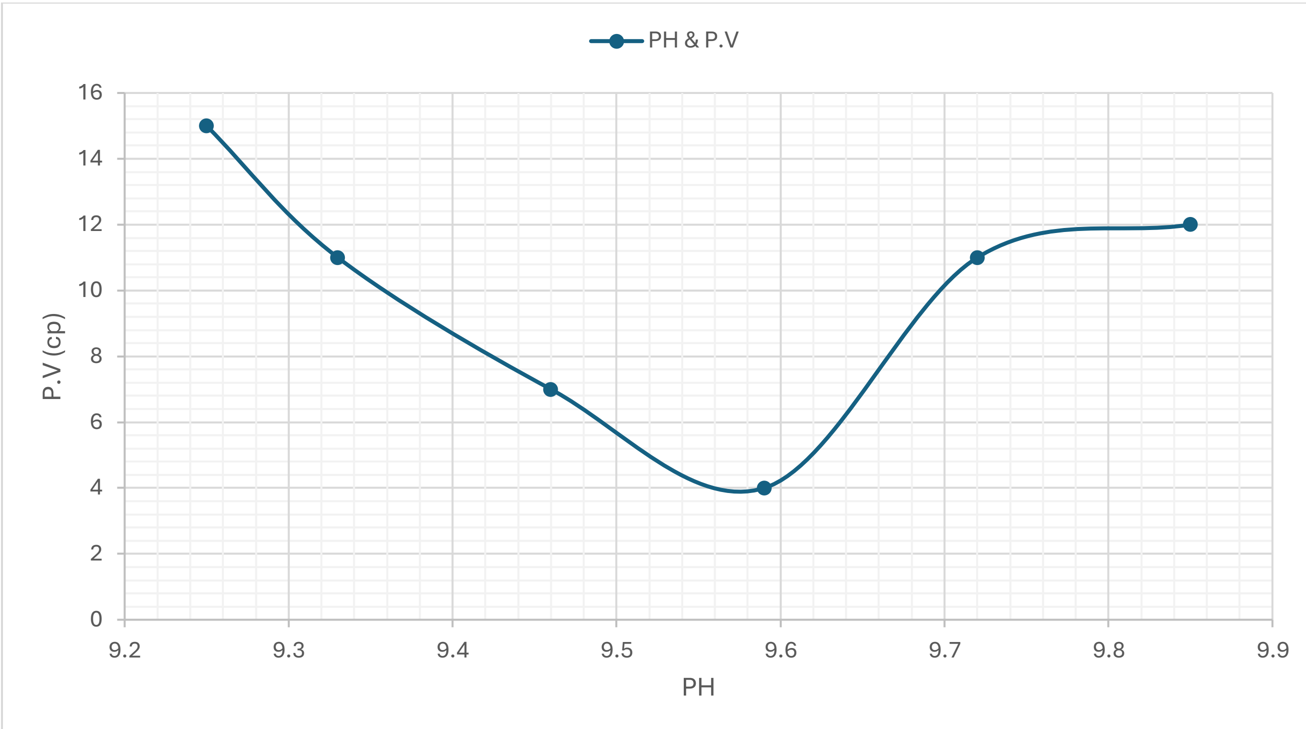

Figure14 (Plastic viscosity versus various pH)

At pH = 9.2, the plastic viscosity was relatively high (~15 cp). It began to decrease until it reached its lowest value at pH = 9.6 (about 4 cp). It then began to increase again, reaching about 12 cp at pH = 9.9.

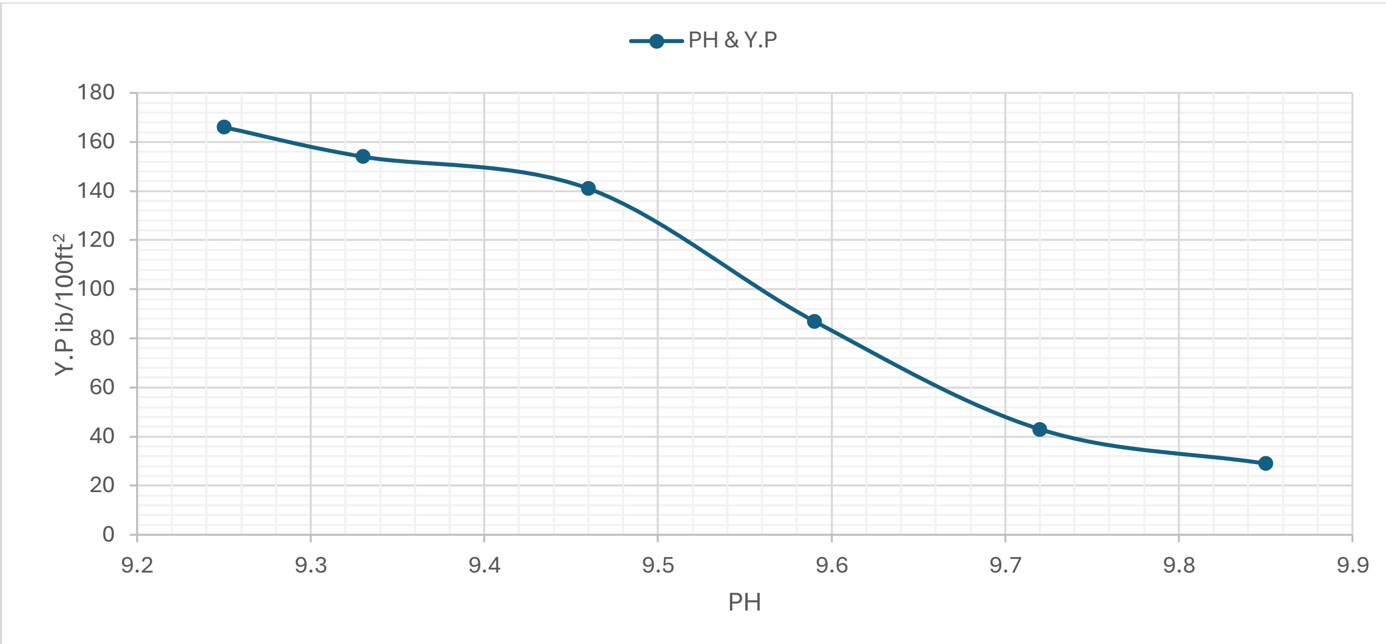

Figure 15 (Yield point versus various pH)

High pH leads to the disintegration of the clay's network structure, reducing the cohesion of the particles and thus decreasing the fluid's resistance to flow (i.e., lowering the yield point).

This indicates that increased alkalinity reduces the structural viscosity properties of the clay, negatively impacting its ability to transport rock cuttings from the well.

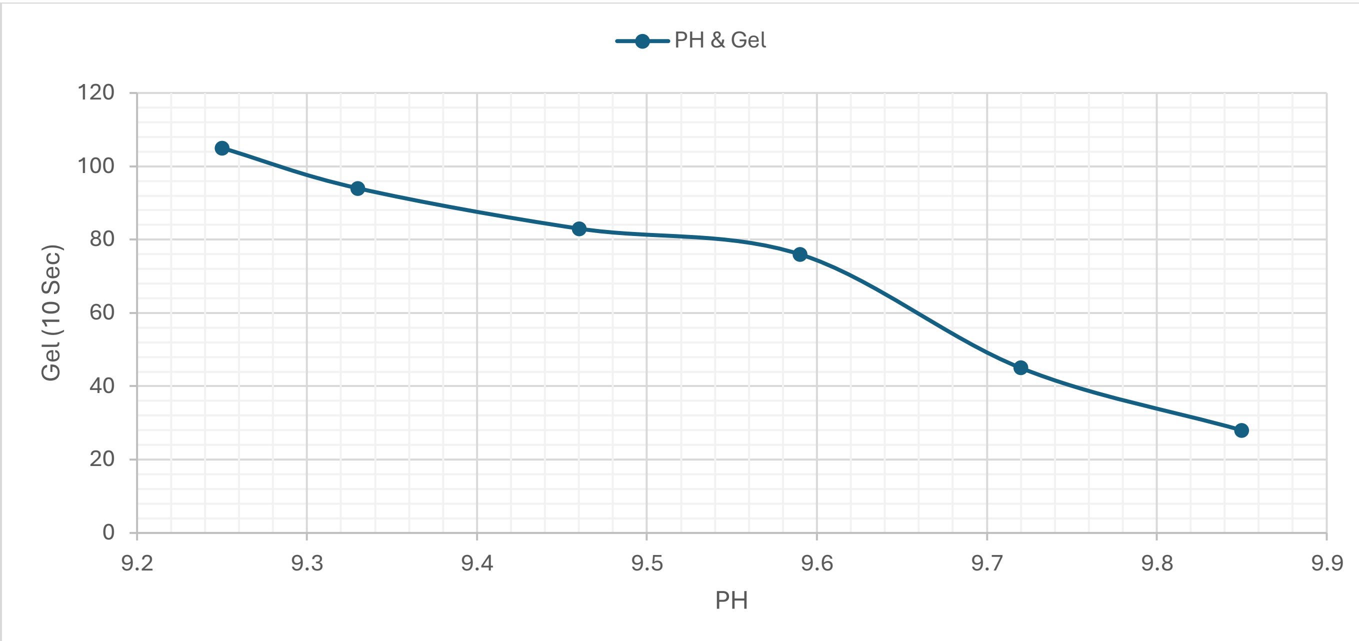

Figure 16 (Gel strength 10 sec versus various pH)

It is used to measure the ability of mud to consolidate after pumping stops. This property is important for preventing rock cuttings from settling in the well.

High pH reduces the interaction of the bonded molecules in the mud, weakening the gelatinous structure.

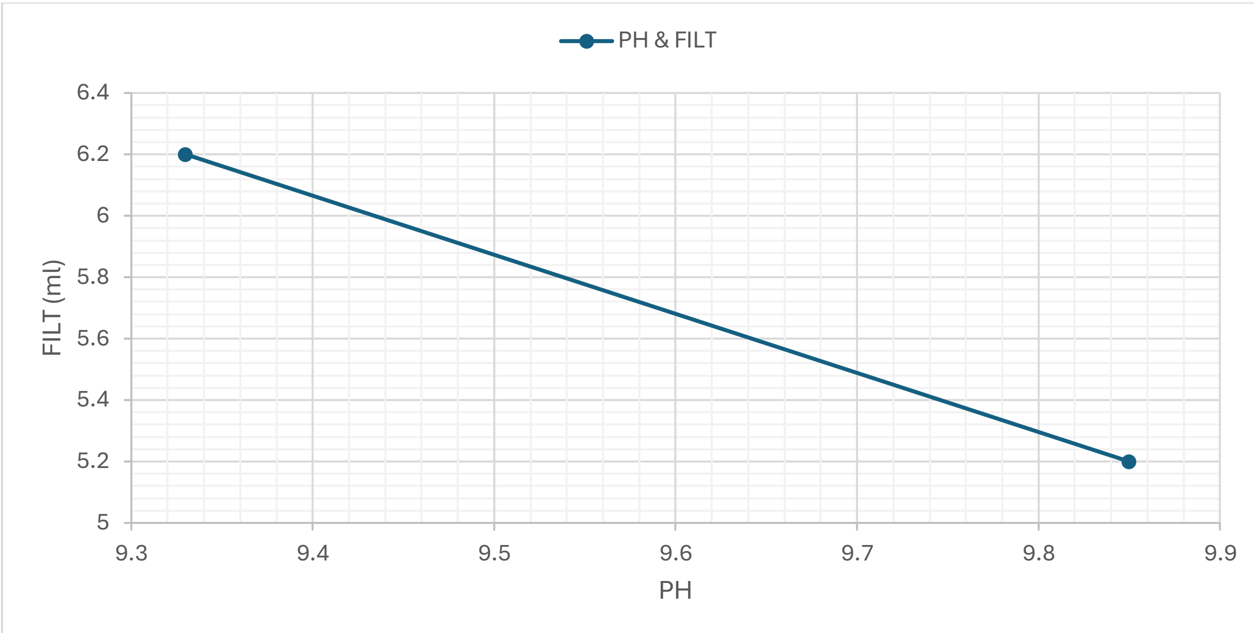

Figure 17 (Filtration versus PH)

This alkalinity leads to increased dispersion of clay particles, which allows them to better adhere and form a thin, effective layer on the filter paper.

This limits fluid loss during the filtration process, which explains the decrease in filtrate volume with higher pH.

Conclusion:

Increasing pH is beneficial in reducing filtrate loss, which is important for maintaining well wall stability.

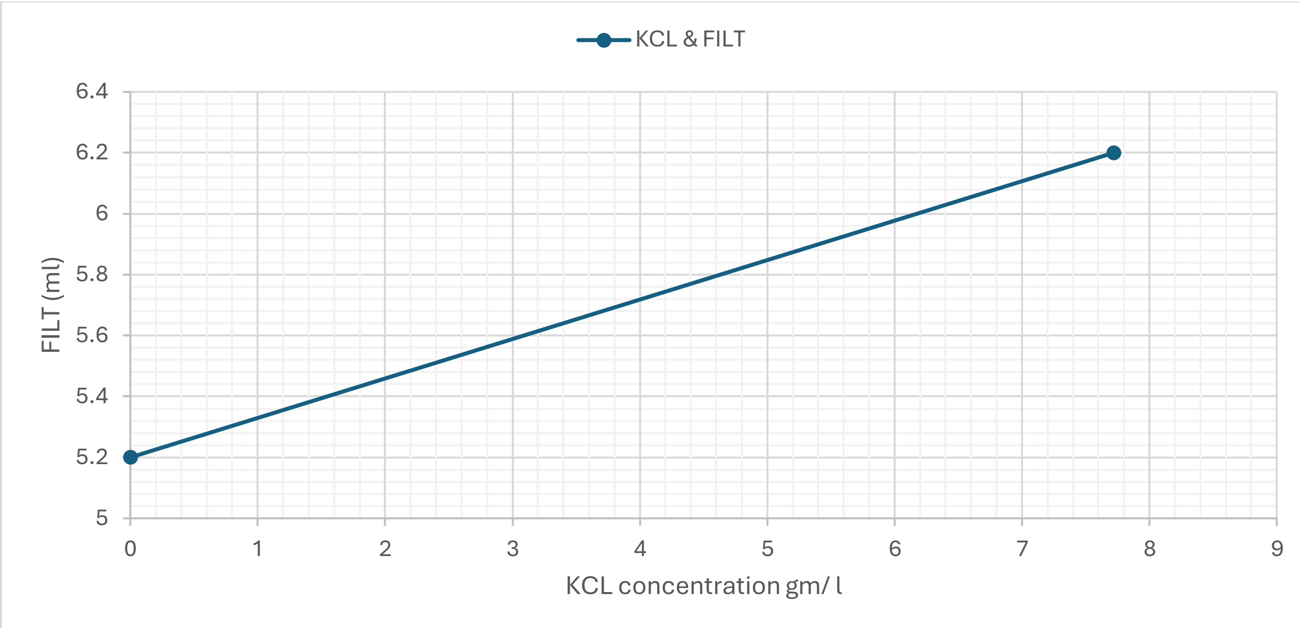

Figure 18 (Filtration versus various salt concentrations)

KCl is used as a clay stabilizer and prevents clay impurities from swelling.

However, it also causes particles to converge and coagulate.

This reduces the ability to form a thin film on the filter paper, thus increasing the amount of filtered liquid.

4.2 Discussion

4.2.1 Effects of kcl Concentration on Drilling Mud Properties:

1. Upper left graph (PV) figure 10 Horizontal axis: KCl concentration (g/L)

Vertical axis: PV We note that PV decreases significantly at a concentration of 4 g/L. After this concentration, the value begins to rise again as the KCl concentration increases.

2. Lower left graph (Yield Point) figure 11 Horizontal axis: KCl concentration Vertical axis: YP (lb/100 ft^2) There is a clear, gradual increase in YP as KCl concentration increases until it reaches a near-steady state at 8-10 g/L.

3. Upper right graph (FILT) figure 18 Horizontal axis: KCl concentration

Vertical axis: FLT (ml) probably means filtration or fluid loss. There is a roughly linear relationship; filtration increases as KCl concentration increases.

4. Bottom right graph (AV) Figure 9 Horizontal axis: KCl concentration

Vertical axis: AV (possibly Apparent Viscosity) A clear increase in apparent viscosity with increasing KCl.

5. Bottom middle graph (GEL) Figure 12 Horizontal axis: KCl concentration

Vertical axis: Gel strength (possibly at 10 seconds) Gel strength gradually increases with increasing concentration.

4.2.2 The effect of pH on Drilling Mud Properties:

1. Figure 15 Yield Point (YP) vs. pH Note: YP decreases with increasing pH from ~170 to ~60 lb/100 ft^2.

Analysis:

YP represents the strength of the clay to hold solids. Increasing pH affects the charge and dispersion of clay particles (especially sodium bentonite), resulting in reduced cohesion and reduced suspending capacity. This decrease indicates a loss of structural network within the clay.

2. Figure 13 Apparent Viscosity (AV) vs. pH Note: AV gradually decreases from ~100 cP to ~30 cP.

Analysis:

AV is affected by the quantity and distribution of suspended particles. As pH increases, excessive dispersion of particles occurs and a decrease in aggregation occurs, reducing resistance to flow. Result: A less viscous fluid that flows more easily, but may be impaired in lifting and cleaning operations.

3. Figure 16 Gel Strength vs. pH Observation: A marked decrease in gel strength from ~110 to ~30.

Analysis:

Gel strength is important to prevent solid precipitation when pumping stops. High pH deteriorates the tertiary structure of bentonite and reduces its ability to form a gelatinous network.This can lead to settling and corrosion problems.

4. Figure 17 Filtrate Loss (FLT) vs. pH Observation: A gradual decrease from ~6.4 to ~5.1 ml.

Analysis:

This indicates an improvement in fluid loss reduction. This may result from improved fine solids distribution or an increased ability of bentonite to form a less permeable filter at high pH.

A positive effect in terms of formation protection.

5. Figure 14 Plastic Viscosity (PV) vs. pHObservation: A decrease, then an increase (U-shape).

From ~15 cP to ~4, then an increase to ~10 cP.

Analysis:

PV represents the resistance of the fluid to particle flow under shear. The decrease indicates reduced interparticle overlap at the onset of dispersion, but the subsequent increase may be due to secondary aggregation, the effect of salt accumulation, or a qualitative change in the interaction of the clay materials.

Chapter Five: Conclusion

Chapter Five: Conclusion

5.1 Conclusion

From the study, the following conclusions have been drawn:

a. KCl may cause some water base muds to be unstable at higher concentrations.

b. The use of KCl in mud formulation will increase the amount of fluid loss to formation.

c. The addition of KCl to a drilling mud will have an influence on ROP because it will alter the plastic viscosity of the mud.

d. Drilling mud with or without KCl assumed the Herschel Bulkley (yield Power law) model

Based on this study, it is obtained that the pH and rheological properties of drilling mud are affected by each of the Sodium Chloride, Cement and Silica Sand contamination. It is found that Sodium Chloride contamination decreases the plastic viscosity, apparent viscosity, yield point and gel strength for the formulated mud samples

which affects their efficiencies. Also, NaCl salt contamination affects the mud pH, and mud weight. As the concentration of NaCl salt increases the mud weight and pH decreases gradually. It is seen that Cement contamination increases the mud pH and rheological properties as well as the mud weight and temperature which can alter its performance during drilling operations. It is also found that the increase in the concentration of Silica Sand led to an increase in apparent viscosity, yield point, gel strength, and mud weight, but decreases the plastic viscosity and has negligible effect on the pH of the used drilling

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I have formatted them in a consistent style, including all author names, publication year, title, journal name (where applicable), volume and issue numbers, and page numbers.

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