Republic of Iraq

Ministry of Higher Education and Scientific Research

University of Misan

College of Engineering

Department of Petroleum Engineering

EFFECTS OF SALINITY AND PH ON CMC POLYMER AND XC POLYMER PERFORMANCE

A graduation project submitted to the **Department of Petroleum Engineering**, in partial fulfillment for the requirements for the award of the degree of Bachelor of **Petroleum Engineering**

By Students :-

Ahmed Riyad Abdulameer

Jafar Mohammed Salim

Karrar Saad Mohsin

Mohammad Ridah Habeeb Naeem

Supervisor :-

Asst. Lect. Montadher A. Jabbar

بِسَمِ اللهِ الرّحمنِ الرَّحِيمِ

{يَرْفَعِ اللَّهُ الَّذِينَ آمَنُوا مِنْكُمْ وَالَّذِينَ أُوتُوا الْعِلْمَ دَرَجَاتٍ وَاللَّهُ بِمَا تَعْمَلُونَ خَبِيرٌ}

صدق الله العلي العظيم

سورة المجادلة, الآية 11

SUPERVISOR CERTIFICATION

I certify that the preparation of this project entitled

(**EFFECTS OF SALINITY AND PH ON CMC POLYMER AND XC POLYMER PERFORMANCE**)

Prepared by

Ahmed Riyad Abdulameer

Jafar Mohammed Salim

Karrar Saad Mohsin

Mohammad Ridah Habeeb Naeem

Was under my supervision at General Petroleum Engineering Branch, Petroleum Engineering Department, University of Misan in partial fulfilment of the requirements for the degree of Bachelor of Science in Petroleum Engineering.

Signature:

Supervisor Name:

Date:2024/5/5

CERTIFICATE OF EXAMINERS

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

(EFFECTS OF SALINITY AND PH ON CMC POLYMER AND XC POLYMER PERFORMANCE)

Examined the students

Ahmed Riyad Abdulameer

Jafar Mohammed Salim

Karrar Saad Mohsin

Mohammad Ridah Habeeb Naeem

In its contents and found the project meets the standard for the degree of

Bachelor of Science in Petroleum Engineering.

Signature:	Signature:
Name:	Name:
Date:	Date:

Signature:	Signature:
Name;	Name;
Date :	Date:

DEDICATION

I dedicate this final project to all those who have supported me on this challenging and rewarding journey.

First and foremost, I dedicate this project to my family. Your unwavering love, encouragement, and belief in my abilities have been my pillars of strength throughout this endeavor. Thank you for always being there for me, cheering me on, and providing a safe haven where I could focus and pursue my dreams.

To my friends, thank you for your constant support and understanding. Your words of encouragement, late-night study sessions, and shared laughter have made this journey memorable and enjoyable. Your presence has reminded me of the importance and the power of a strong support system.

To our extraordinary supervisor **Asst. Lect. Montadher A. Jabbar,** In deep appreciation for your invaluable guidance and mentorship throughout this project. Your constant support and willingness to answer endless questions were instrumental in overcoming challenges and achieving this milestone

ACKNOWLEDGEMENT

Praise be to **ALLAH** who enabled us to complete this work under his benediction.

Cordial thanks and deepest gratitude to our supervisor (Asst. Lect. Montadher A. Jabbar) for being assistance and for the continuous encouragement and suggestions from him which helped us to successfully complete this project.
We would like to express our thanks to our university for their encouragements and anyone helped us.
Finally, sincere gratitude and appreciation and love to our families for their encouragements and supports and for all things they have given us.

ABSTRACT

The rheological and filtration properties of drilling mud under down-hole conditions may be very different from those measured at ambient pressures and temperatures at the surface. This project presents the results of an experimental investigation into the salinity and pH effects on drilling mud rheological and filtration properties. Results are given from tests on water base mud containing CMC polymer and XC polymer. Drilling fluid was containing (8.6)Kg/bbl bentonite. this study were fresh water . It was found that pH of drilling mud should be kept at range of (9-10) because increasing pH of drilling mud will increase its rheological properties. The salinity effects show that as the salinity of drilling mud are increased the effectiveness of polymers in drilling mud will decreased. Moreover, they have a negative effect on filtration properties of drilling mud.

Table of Contents

List of Figures

List of Tables

Chapter One: Introduction

Chapter one: Introduction

---

1. 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. 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.

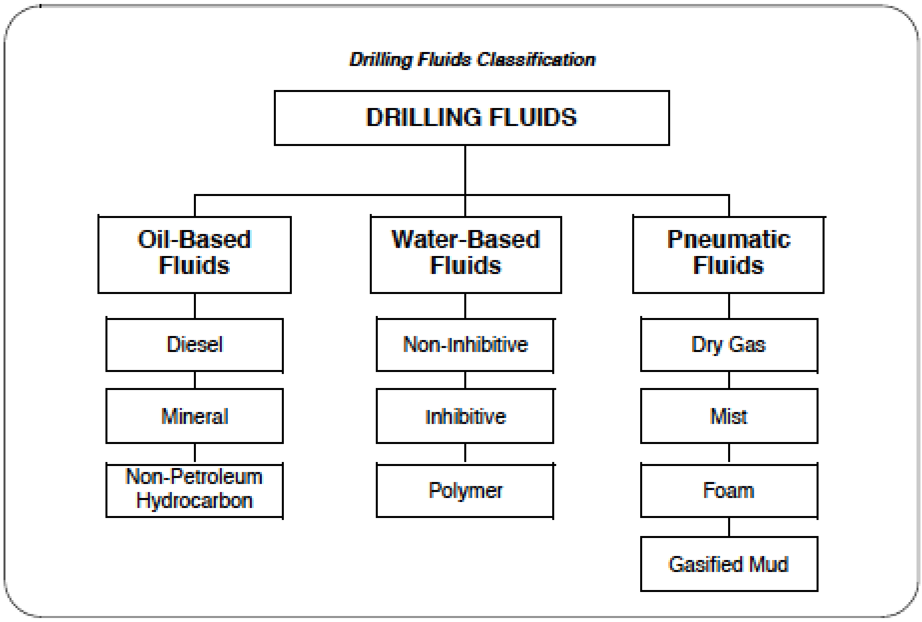

Figure 1 **(**Drilling fluids classification**)**

1.4 Mud Testing and Analysis:

1.4.1 Rheological Tests:

• **Purpose:** Measure the flow properties of the drilling mud, including viscosity, yield point, and gel strength.

• **Methods:** Common tests include the Marsh funnel viscosity test, viscometer measurements, and gel strength measurements using a rotational viscometer.

• **Importance:** Rheological properties influence the ability of the drilling mud to suspend cuttings, maintain wellbore stability, and circulate effectively.

1.4.2 Mud Weight and Density Measurements:

• **Purpose:** Determine the density of the drilling mud, which affects wellbore pressure control and formation stability.

• **Methods:** Measurements are typically performed using a mud balance or mud density meter.

• **Importance:** Proper mud weight control is crucial for preventing well kicks, maintaining wellbore integrity, and optimizing drilling performance.

1.4.3 Filtration Control Tests:

• **Purpose:** Evaluate the ability of the drilling mud to control fluid loss into the formation, which affects wellbore stability and formation damage.

• **Methods:** Tests such as the API filtration test measure the rate of fluid loss under standardized conditions.

• **Importance:** Effective filtration control helps maintain wellbore integrity, prevent formation damage, and optimize drilling fluid performance.

1.5 AIM OF PROJECT

Aim Of This Project Is To Study The Effects Of Salinity And PH On CMC Polymer And XC Polymer Performance.

Chapter Two: Literature Review

Chapter Two: Literature Review

Drilling mud plays a vital role in ensuring the success and safety of drilling operations. It serves multiple functions, including maintaining wellbore stability, cooling and lubricating the drill bit, and transporting drill cuttings to the surface. The performance of drilling mud relies heavily on the properties of the additives incorporated into its formulation. Among these additives, XC and CMC polymers stand out for their ability to enhance mud rheology (flow behavior) and filtration control. This literature review delves into the influence of two crucial environmental factors, salinity and pH, on the performance of XC and CMC polymers within drilling mud formulations. Understanding how these factors impact polymer behavior is essential for optimizing drilling mud design and ensuring efficient and safe drilling operations. The review will first provide a brief overview of XC and CMC polymers, highlighting their roles in drilling muds. Subsequently, it will explore the existing research on the impact of salinity and pH on these polymers, focusing on their effects on viscosity, filtration control, and overall rheological properties. Finally, the review will identify any remaining knowledge gaps specific to drilling mud applications and propose areas for further investigation.

2.1 XC and CMC Polymers in Drilling Mud

2.1.1 XC Polymers: In drilling muds, various XC polymers are commonly used to enhance rheological properties and control fluid loss. One such polymer is xanthan gum. Other common XC polymers used in drilling muds include guar gum and hydroxyethyl cellulose (HEC), both of which also offer thickening and fluid loss control properties essential for maintaining wellbore stability and effective hole cleaning

2.1.2 CMC Polymers: Carboxymethyl cellulose (CMC) is a water-soluble polymer derived from cellulose, which is a naturally occurring polymer found in plant cell walls. CMC is produced by reacting cellulose with chloroacetic acid or its sodium salt, resulting in the substitution of carboxymethyl groups onto the cellulose backbone. This chemical modification imparts water solubility to the cellulose molecule, making CMC readily dispersible in water-based fluids such as drilling muds.

in drilling fluids, CMC plays several crucial roles:

1. Enhancing viscosity
2. Filtrate volume control
3. Formation of a filter cake

Overall, CMC's unique structure and water solubility make it a valuable additive in drilling mud formulations, providing viscosity control, fluid loss prevention, and the formation of a protective filter cake critical for successful drilling operations.

2.2 Several studies explore the detrimental effect of salinity and PH on the performance of XC and CMC polymers in drilling muds:

2.2.1 Paper 1: Effects of Salinity, pH and Temperature on CMC Polymer and XC Polymer Performance (Alaskari & Teymoori, 2007)

The rheological and filtration properties of drilling mud under down-hole conditions may be very different from those measured at ambient pressures and temperatures at the surface. This paper presents the results of an experimental investigation into the temperature and salinity and pH effects on drilling mud rheological and filtration properties. Results are given from tests on water base mud containing CMC polymer and XC polymer. Drilling fluid was investigated at three different temperatures (21.1°C, 48.9°C, 80°C) containing 8.165Kg/bbl bentonite. The drilling mud salinities in this study were fresh water (Ahwaz water: ppm: 400, Hardness: 120), 2000 ppm, 4000 ppm, 8000 ppm and 40000 ppm. It was found that pH of drilling mud should be kept at range of 8-10, because increasing pH of drilling mud will increase its rheological properties. The salinity and temperature effects show that as the salinity and temperature of drilling mud are increased the effectiveness of polymers in drilling mud will decreased. Moreover, they have a negative effect on filtration properties of drilling mud. In suspensions of sodium montmorillonite that are well dispersed and have low gel strength, both plastic viscosity and yield point decrease with increasing temperature.

Focus: This study examines how three factors - salinity, pH, and temperature - influence the performance of CMC and XC polymers commonly used in drilling mud formulations.

Key Findings: Increased salinity and temperature might hinder the polymers' ability to thicken the drilling mud effectively. The study also suggests a potentially optimal pH range for maximizing the mud's rheological properties.

2.2.2 Paper 2: The Effect of Salts and Hematite on Drilling Muds in Shale Formations (Kuma et al., 2020)

A common issue encountered by drilling engineers during drilling operation in oil and gas industries is that simple water-based muds are not suitable for deeper depth and certain

clay-swelling formations. Another option as to increasing the density of the drilling mud which brings about an increase in filtration loss, additives may be added to improve the fluid properties. This paper aims on determining the effectiveness of common salts, sodium chloride (NaCl) and potassium chloride (KCl), and hematite on the rheological properties of optimized carboxymethyl cellulose (CMC)–bentonite and partially hydrolyzed polyacrylamide (PHPA)–bentonite muds. Both CMC and PHPA polymer act as fluid loss-reducing agents and viscosifers for normal bentonite water-based mud. The mud is further enhanced to counter certain swelling formations such as shale through the addition of NaCl and KCl. These salts inhibit the shale formation from swelling through its ions by entering the lattice of the drilling mud or formation instead of the water ions. Hematite, on the other hand, basically functions to increase mud density and acts as a substitute for barite. The effect of hematite on drilling fluid was studied because it gives higher degree of rheological parameters and increases density as compared to barite. So, an optimized concentration of additives was determined for both CMC–bentonite and PHP.A bentonite mud systems, respectively. Three grams of KCl and 3 g hematite were used for CMC–bentonite mud, while 3 g KCl and 1 g hematite were added

into PHPA–bentonite mud. Both these muds have shown swelling reduction as compared to those without the use of additives. Moreover, they exhibited Herschel–*Bulkley* fluid behavior according to the power law model where their ‘n’ value was less than 1, while their yield points were more than zero. Since shale sloughing is a major problem faced during drilling operation, it leads to major complications in drilling. So, finally, both the formulated drilling fluids are tested to analyze their effect in shale formations by static immersion test. The shale rock was collected from *Champhai District* of *Mizoram*. Both the formulated muds exhibited great results as swelling in shale rock was reduced for both muds and optimum rheological values were maintained.

Focus: This research explores the effectiveness of two drilling mud types (CMC)bentonite and (PHPA-bentonite) when encountering salts and hematite, both prevalent in shale formations.

Key Findings: The study reveals that simple water-based muds are inadequate for drilling in shale formations with swelling clays. Additionally, the presence of salts and hematite can negatively affect the performance of both mud types, although the severity depends on the specific mud, salt concentration, and hematite content.

2.2.3 Paper 3: The Effect of Salinity on Rheological Properties of Water-Based Mud (HPHT) (Amani & Al-Jubouri, 2012) .

The significance of exploring deep and ultra-deep wells is increasing rapidly to meet the escalating global demands on oil and gas. Drilling at such depth introduces a wide range of difficult challenges. One of these challenges is the negative impact on the drilling fluids rheological properties when exposed to high pressure high temperature (HPHT) conditions and/or becoming contaminated with salts, which are common in deep drilling or in offshore operations. The drilling engineer must have a good estimate for the values of rheological

characteristics of a drilling fluid, such as viscosity, yield point and gel strength, and that is extremely important for a successful drilling operation. In this research work, experiments were conducted on water-based muds with different salinity content, from ambient conditions up to very elevated pressures and temperatures. In these experiments, water based drilling fluids containing different types of salt (NaCl and KCl) at different concentrations were tested by a state-of-the-art high pressure high temperature viscometer. In this paper, the effect of different electrolysis (NaCl and KCl) at elevated pressures (up to 35,000 psi) and elevated temperatures (up to 450 ºF) on the viscosity of water based mud has been investigated. Conducting this study led to the conclusion NaCl contaminated samples had higher shear stress-shear rate curves than water based mud; whereas, KCl contaminated samples had lower shear stress-shear rate curves than water based mud. Also, the study showed that Hershel-Bulkely model provides a good fit for the experimental data and well predicts the observed muds behavior.

Focus: This study by (Amani & Al-Jubouri, 2012) investigates how salinity (NaCl & KCl) affects rheological properties (viscosity, yield point, gel strength) of water based muds under HPHT conditions for deep well drilling.

Key Point: Salinity might reduce mud's effectiveness in HPHT wells, requiring adjustments to the mud formulation.

2.2.4 Paper 4: Effect of Salinity on Polymers Performance (Misbah et al., 2015)

Drilling industry is driving toward improving the performance of the drilling process in an economical and environmental attractive way. Recently, drilling development techniques faced greater challenges in terms of wellbore stability as polymers with different salt concentrations, have major effect on the drilling mud properties. The rheological behavior of several polymers used effect on common

types of mud with different salt concentrations, that change normal mud properties (plastic viscosity, yield point, gel strength, API filtration). Exposing to different concentrations require utilizing polymers additives in order to avoid high cost and nonproductive time. The present work tested the effect of three different salt concentrations on mud polymers during drilling operations.

Focus: Investigates how different salt concentrations affect key rheological properties (plastic viscosity, yield point, etc.) of drilling muds containing various polymers.

Key Point: Polymer selection and optimization are crucial for effective drilling mud performance in varying salinity conditions.

2.2.5 Paper 5: pH & Salinity Impact on Natural Polymer Muds (Gamal et al., 2019)

Drilling muds are designed to perform certain functions of drilling operation. Some of the functions are to cool and lubricate the drilling bit, transmit hydraulic power to drill bit, provide filter cake and remove drilling cuttings and maintaining wellbore stability. Various additives with specific properties are added in the mud to help prevent the challenges encountered during drilling process. The work studies the effect of pH and salt on the rheological properties of drilling mud formulation from two natural polymers (Terminaliamantaly(TM) exudate and Guar gum) with the use of Model 35 viscometer. Drilling mud formulation with these polymers was investigated at pH of (7.05, 8.15, 10.07, and 11.13) and salt concentrations of (2, 4, 6, 8 and 10g/ml). Results obtained from drilling mud with TM exudate were compared with drilling mud with guar gum. It was found that the rheological properties of drilling mud with Terminaliamantaly exudates increased for higher pH as compared to drilling mud with Guar gum. The increase in salinity reduced the effectiveness of the rheological properties of the mud such that as the salinity in drilling mud increased, the rheological properties of drilling mud with Terminaliamantaly and Guar gum decreased. The performance is attributed to flocculation, dispersion, and hydration behavior of particles in the mud.

Focus: Studies pH & salinity effects on rheology (flow behavior) of drilling muds using natural polymers (TM exudate & Guar gum).

Key Point: TM exudate mud performs better at higher pH, while salinity reduces effectiveness of both mud types. Gaps in Knowledge While the reviewed research provides valuable insights, some knowledge gaps remain specific to drilling mud applications: The studies primarily focus on the effects of salinity on CMC. More research might be needed to explore the combined effect of salinity and pH on a wider range of XC polymers used in drilling muds. The optimal pH range for different drilling mud formulations containing various combinations of XC and CMC polymers with other additives needs further investigation.

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

$(Na,Ca)_{0.33}(Al,Mg)_2(Si_4O_{10})(OH)_2 \bullet nH_2O$. And the bentonite as : $Al_2O_3.4(SiO_2).H_2O$

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 functionality.

Chapter Three: Methodology

Chapter Three: Methodology

3.1 Materials Used:

For the experiment we have used :

1. Water: Fresh Water
2. Bentonite Powder
3. CMC Polymer
4. SALT (NaCl)
5. Caustic Soda (NaOH)
6. XC-Polymer

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 35A Viscometer is powered by a 60-Hz motor; Model 35SA Viscometer by a 50-Hz motor. 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

Figure 2 **(**Viscometer**)**

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

Figure 3 **(**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 4 **(**Mixers – Hamilton Beach**)**

4- Filter Press: The OFITE Low Pressure Filter Press provides a quick, easy way 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 5 **(**Filter Press**)**

5- Water Quality Tester: is a simple, easy to use, water quality tester designed to measure both the acidity of liquids (pH), salinity and temperature using a single sensor.

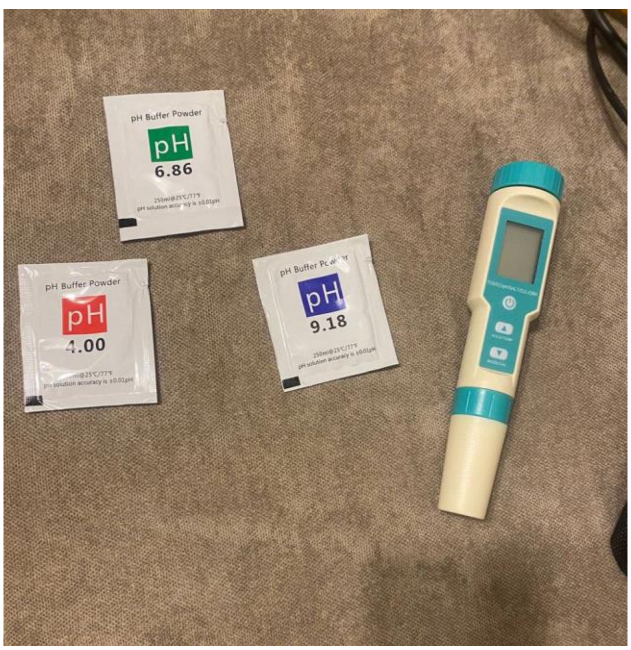

Figure 6 **(**Water Quality Tester**)**

Properties	Measurement
Θ_{300}	The highest reading speed is at 300 in the viscometer
Θ_{600}	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 (Pv)	Θ_{600}- Θ_{300} (cp)
Apparent Viscosity (AV)	$\frac{\Theta 600}{2}\,(cp)$
Yield Point (YP)	Ɵ300- pv(Ib/seqft)
Ph	Water Quality Tester
Salinity	Water Quality Tester (ppm)

Table 1 (Properties and its measurements)

3.3 PROCEDURE:

A nominal amount of water 500ml and the requisite amount of bentonite27g (taken percentage wise) was taken after weighing it on a weigh-scale. The bentonite and water were taken in the Hamilton Beach mixer for the dispersion of the bentonite clay particles by mechanical shearing provided by the mixer and for the preparation of drilling mud and the mud was fermented for two days and mixture was made in mixer before the measurements With each sample of drilling mud prepared, we use viscometer to record the readings to each sample which corresponds to the rheological properties.

3.3.1 PREPARATION OF DIFFERENT SETS OF DRILLING FLUIDS:

A. Original drilling mud consists of an adequate amount of water and a certain percentage of bentonite which is altered to record the changes in its rheological properties such as plastic viscosity, yield point, apparent viscosity and gel strength and PH.
B. drilling fluids consists of a mixture of water, bentonite, and CMC polymer. For every sample in this variant of drilling fluid, the amounts CMC was changed. CMC being meticulously measured. was taken into the mixture of bentonite and water and mix it using the mixer. get the readings of ϴ300, ϴ 600 and initial gel strength. we find PV, YP and AV.
C. drilling fluids consists of a mixture of water, bentonite, and XC polymer. For every sample in this variant of drilling fluid, the amounts of XC was changed. XC being meticulously measured with the help of a digital scale ,was taken into the mixture of bentonite and water and mix it using mixer. The prepared solution was transferred to the viscometer to get the readings of ϴ 300, ϴ600 and initial gel strength and filtration measurement.. we find the PV, YP and AV.

D. drilling fluids consists of a mixture of water, bentonite, CMC polymer, and salt (Nacl) the amounts of CMC was constant With changing the proportions of added salt, was taken the salt and water and bentonite and mix it using the mixer.

   Get the readings of ϴ300, ϴ600 and Initial Gel Strength and Filtration measurement and degree of salinity .we find out the PV, YP and AV.

E. drilling fluids consists of a mixture of water, bentonite, XC polymer, and salt (Nacl) the amounts of XC was constant With changing the proportions of added salt, was taken the salt and water and bentonite and mix it using the mixer.

Get the readings of Θ300, Θ600 and initial gel strength measurement.
we and degree of salinity. we find out the PV, YP and AV.

F. drilling fluids consists of a mixture of water, bentonite, Caustic soda (NaOH) the amounts of caustic was changing, was taken the caustc and water and bentonite and mix it using the mixer. The prepared solution was transferred to the viscometer to get the readings of Ө300, Ө600 , gel and PH .we find out the PV, YP and AV.

G. drilling fluids consists of a mixture of water, bentonite, CMC polymer, and Caustic soda (NaOH), amounts of CMC was constant With changing the proportions of added caustic, was taken the caustic and water and bentonite and mix it using the mixer. we filtration measurement.

Chapter Four:

Results and Discussion

Chapter Four: Results and Discussion

4.1 Results

4.1.1 tables

Add (gm)	add (lb/bbl)	Ø300	Ø600	Pv	Av	Yp	Gel	FILT	PH
0	0	33	39	6	20	27	38	7.2	9.7
0.25	0.175	46	56	10	28	36	43		
0.5	0.35	66	80	14	40	52	53		
1	0.7	83	110	27	55	56	64		
2	1.4	135	160	25	80	110	83		
3	2.1	172	195	23	98	149	102		
4	2.8	250	286	36	143	314	125		

Table 2 (Polymer concentration with rheological properties for XC-polymer)

Add (gm)	add (lb/bbl)	Ø300	Ø600	Pv	Av	Yp	Gel	FILT	PH
0	0	33	39	6	20	27	38	7.2	9.7
0.25	0.175	51	55	4	28	47	54	4.8	
0.5	0.35	53	65	12	33	41	53	4.4	
1	0.7	63	75	12	38	51	74	5	
2	1.4	105	123	18	62	87	98	3.2	
3	2.1	168	191	23	96	145	115	2.6	
4	2.8	182	194	12	97	170	128	2.4	

Table 3 (Polymer concentration with rheological properties for CMC-polymer)

Add(gm) Caustic Soda	**Ø300**	**Ø600**	**Pv**	**Av**	**Yp**	**Gel**	**PH**
0	33	39	6	19.5	27	38	9.74
0.25	40	43	3	21.5	37	32	9.92
0.5	47	52	5	26	42	40	10.05
0.75	53	57	4	28.5	49	57	10.22
1	71	75	4	37.5	67	90	10.36
1.25	69	75	6	37.5	63	89	10.4

Table 4 (Original Mud with pH and rheological properties)

Caustic Soda add	**CMC**	**pH**	**Filter(ml)**
0.25	1g	9.82	3.6
0.5	1g	9.94	4
0.75	1g	10.29	3.2
1	1g	10.42	3.4
1.25	1g	10.47	4

Table 5 (pH effect on filtration for CMC-polymer)

PH	CmC (g)	XC (g)	Salinity(PPM)	Salt Additives (g)	Ɵ300	Ɵ600	A.V	P.V	Y.P	Gel Strength (lb/100 sqft)	Filtration (mL)
9.19	0	1.5	750	0							
		1.5	1150	0.2	85	100	50	15	70	56	
		1.5	6150	2.7	125	145	74	20	108	115	
		1.5	11150	5.2	129	142	71	13	116	102	
		1.5	16150	7.7	90	105	53	15	75	90	
		1.5	21150	10.2	300	95	48	9	77	73	

Table 6 (salinity effect on XC-polymer)

PH	CMC(g)	XC(g)	Salinity(PPM)	Salt Additives (g)	Ɵ300	Ɵ600	A.V	P.V	Y.P	Gel Strength (lb/100 sqft)	Filtration (mL)
9.19	1.5	0	670	0							
	1.5	0	1070	0.2	67	78	39	11	56	70	2
	1.5	0	2480	0.5	96	105	53	9	87	119	2.8
	1.5	0	5480	2	153	155	78	2	151	300	4
	1.5	0	8480	3.5	149	158	79	9	140	116	4.4
	1.5	0	13480	6	153	174	87	21	132	70	8
	1.5	0	19480	9	93	96	48	3	90	25	9

Table 7 (salinity effect on CMC-polymer)

4.1.2 Effects of Polymer Concentration on Drilling Mud Properties

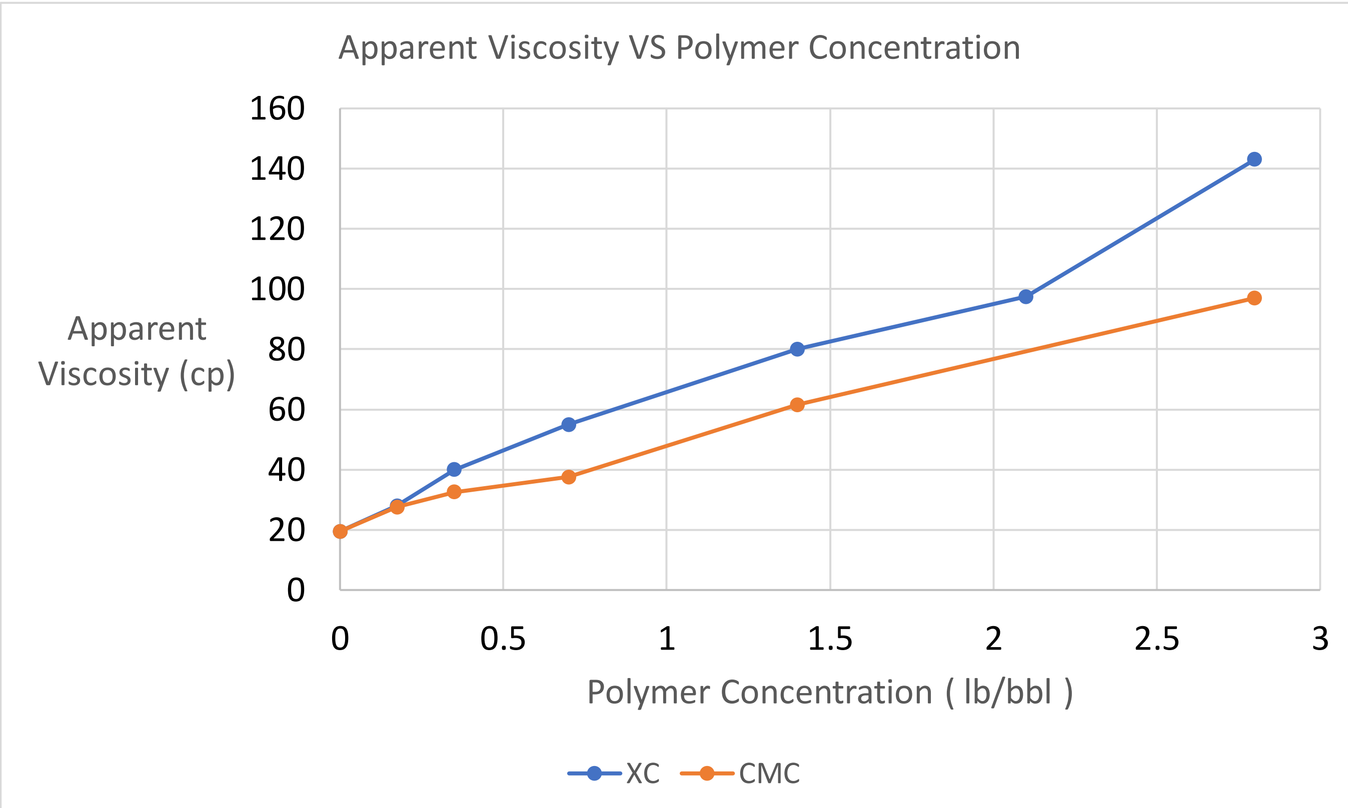

***Figure 7* (**Apparent viscosity versus various polymers concentrations.**)**

The graph depicts the apparent viscosity of a water-based mud with increasing concentrations of XC and CMC polymers. Both curves likely exhibit an upward trend, signifying a rise in viscosity with increasing polymer content. The XC curve might be steeper, suggesting a more pronounced viscosity increase compared to CMC at similar concentrations.

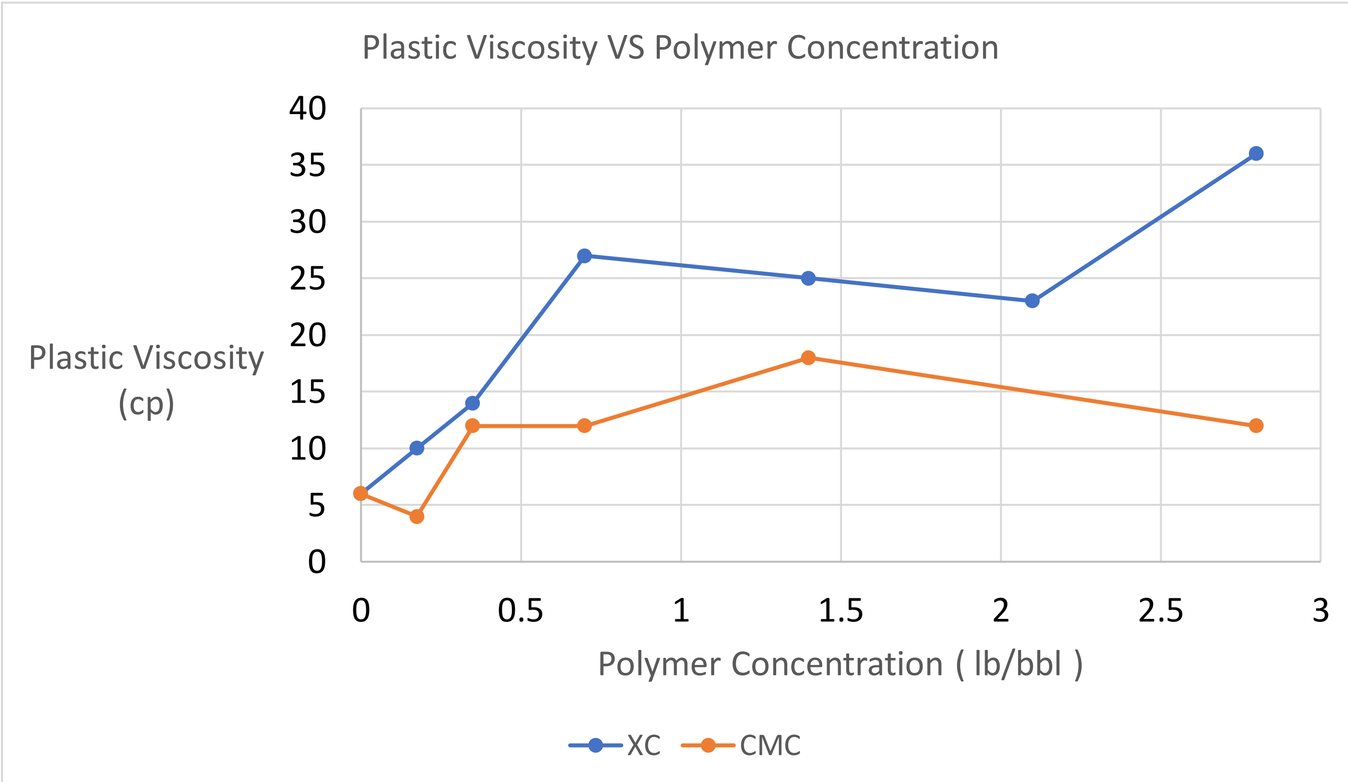

Figure 8 **(**Plastic viscosity versus various polymers concentrations**)**

The graph shows the plastic viscosity (PV) of a water-based bentonite mud with increasing concentrations of XC and CMC polymers. The curves for both XC and CMC likely exhibit an upward trend, indicating a rise in PV as their concentration increases. The rate of increase may differ between the two polymers, resulting in curves with potentially varying slopes.

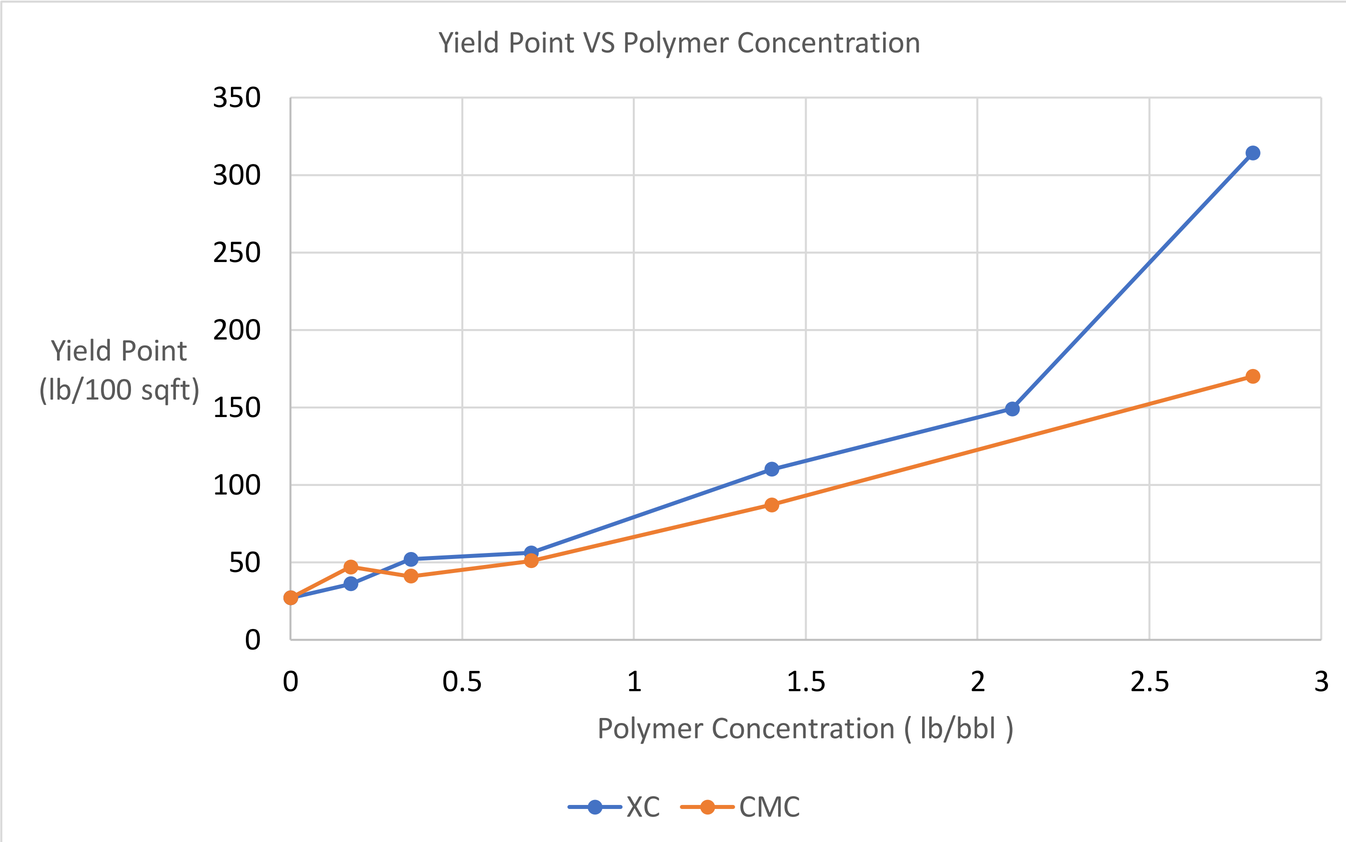

Figure 9 **(**Yield point versus various polymers concentrations**)**

The graph shows the yield point, a measure of mud stiffness, versus polymer concentration for a water-based mud containing xanthan gum (XC) and carboxymethylcellulose (CMC) polymers. The yield point increases for both XC and CMC as their concentration increases. The curve for XC appears to be steeper than the curve for CMC, indicating that XC may cause a more rapid increase in yield point compared to CMC at the same concentration.

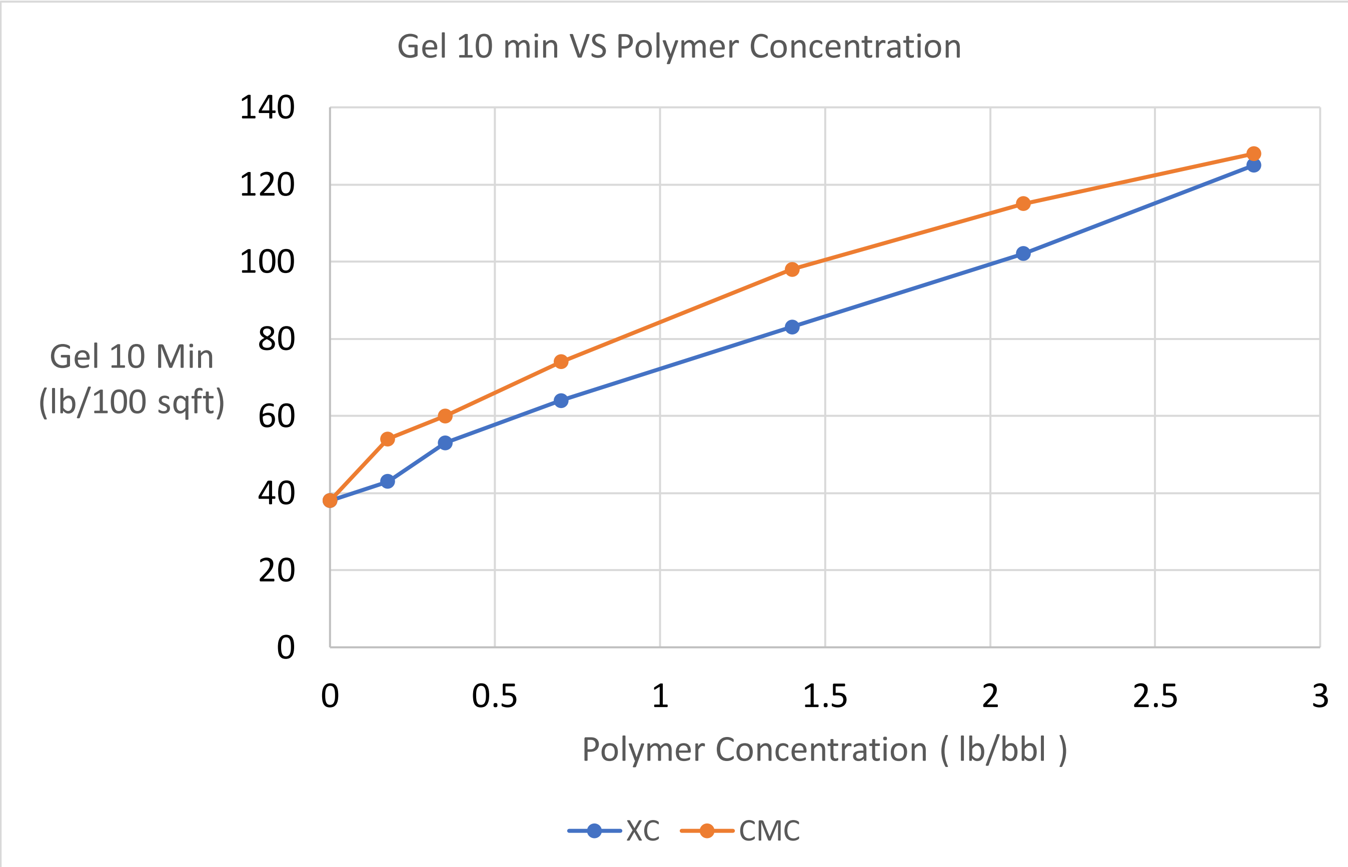

Figure 10 **(**Gel strength 10 min versus various polymers concentrations**)**

The graph shows the effect of increasing XC and CMC concentrations on the gel strength of a bentonite-based mud. Both XC and CMC curves likely exhibit an upward trajectory, signifying a rise in gel strength with increasing polymer content. The curves may differ in steepness, suggesting a potential variation in how effectively each polymer strengthens the gel.

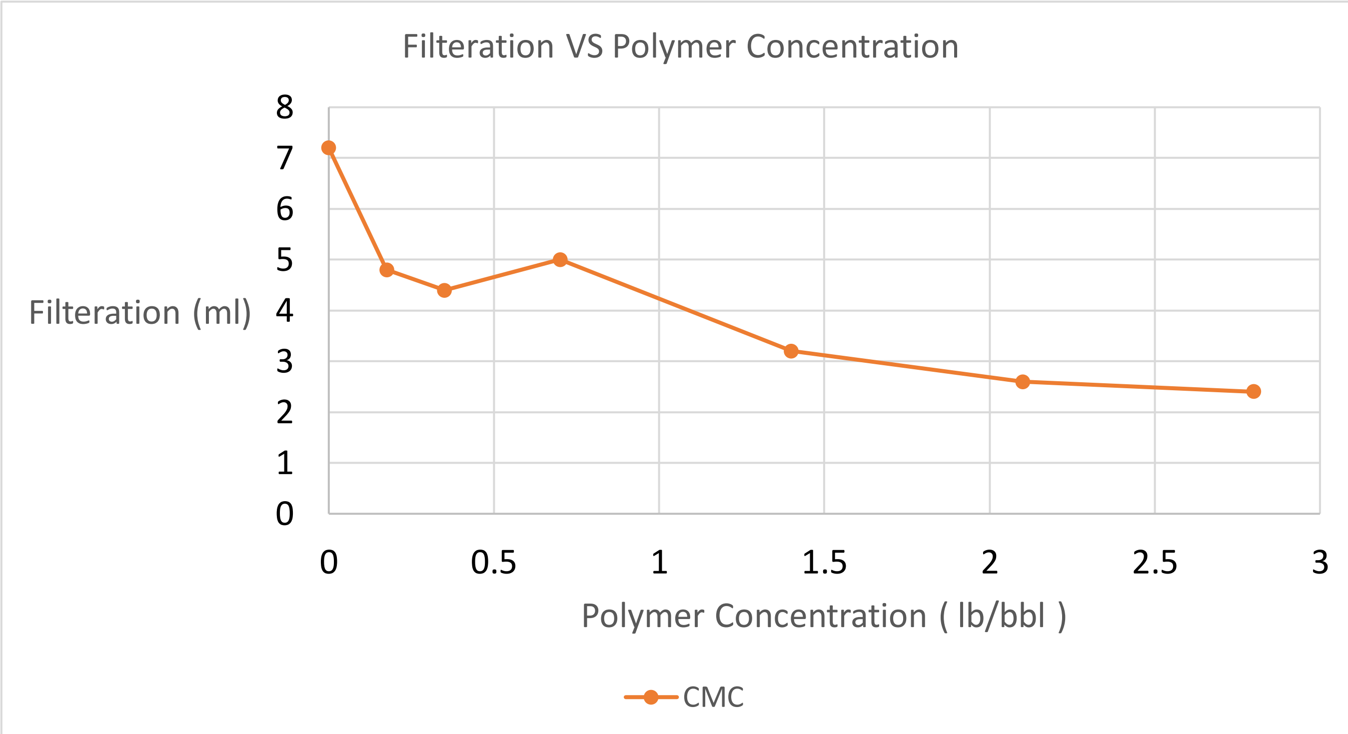

Figure 11 **(**Filtration versus various polymers concentrations**)**

The graph illustrates the effect of increasing CMC concentration on filtration rate in a bentonite-based mud. The downward-sloping curve suggests that filtration rate decreases as CMC concentration increases. This indicates that CMC effectively reduces fluid loss from the mud.

4.1.3 The effect of Salinity on Drilling Mud Properties

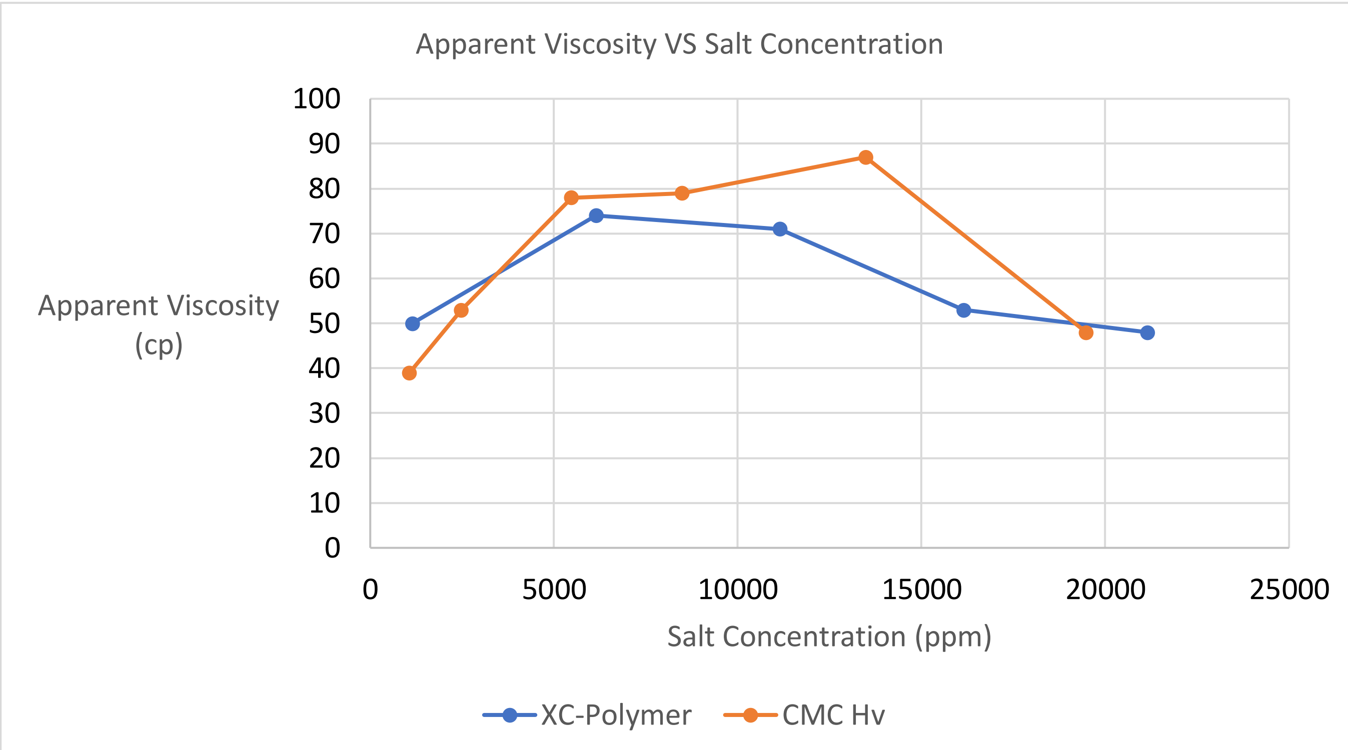

Figure 12

(Apparent viscosity versus various salinity for two muds containing CMC Hv and XC-polymer.**)**

The graph shows the effect of increasing salt concentration on the Apparent viscosity of two muds (a water-based bentonite mud) containing XC and CMC HV polymers. At the beginning Both curves trend upwards. But at high salinities the Apparent viscosity values start to decrease indicating that the apparent viscosity decreases for both polymers as the salt concentration rises especially at high salinities.

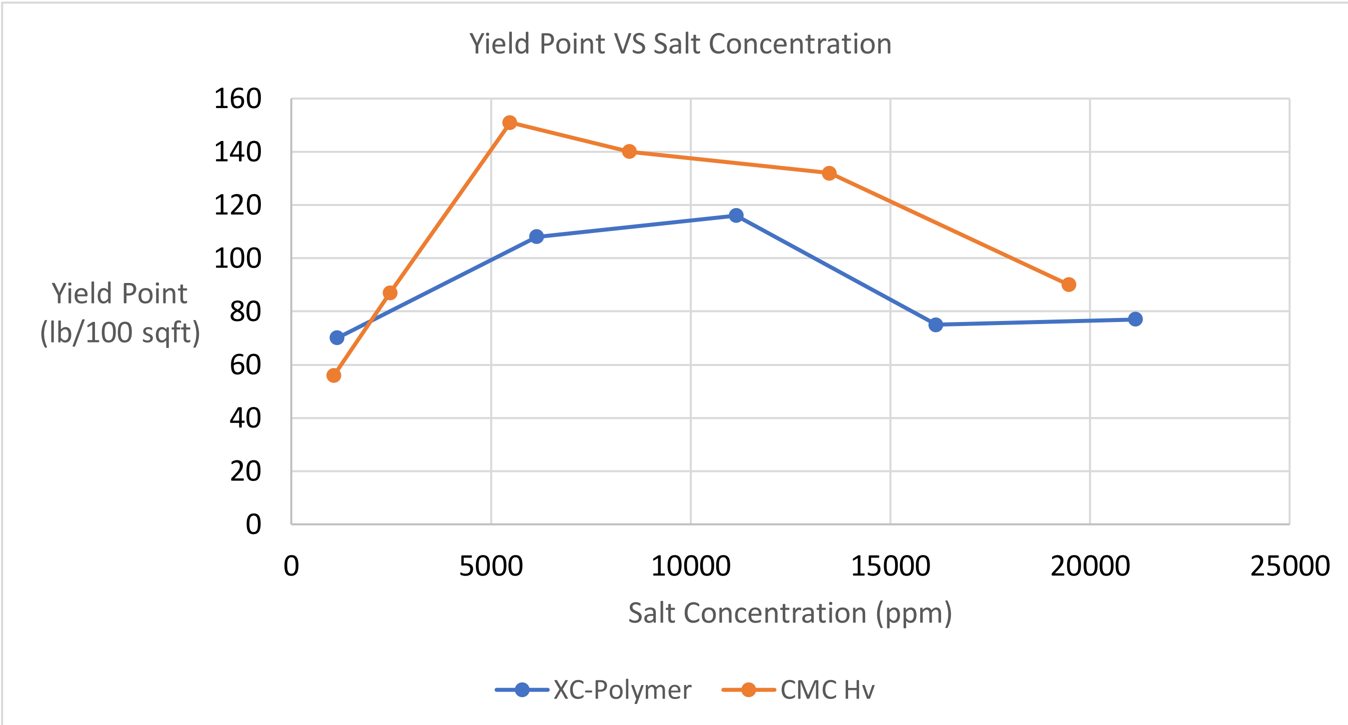

Figure 13

(Yield point versus various salinity for two muds containing CMC Hv and XC-polymer.**)**

The graph illustrates the effect of increasing salt concentration on the yield point of two muds (a water-based bentonite mud) containing XC and CMC HV polymers. At the beginning Both curves trend upwards. But at high salinities the yield point values start to decrease indicating that the yield point decreases for both polymers as the salt concentration rises.

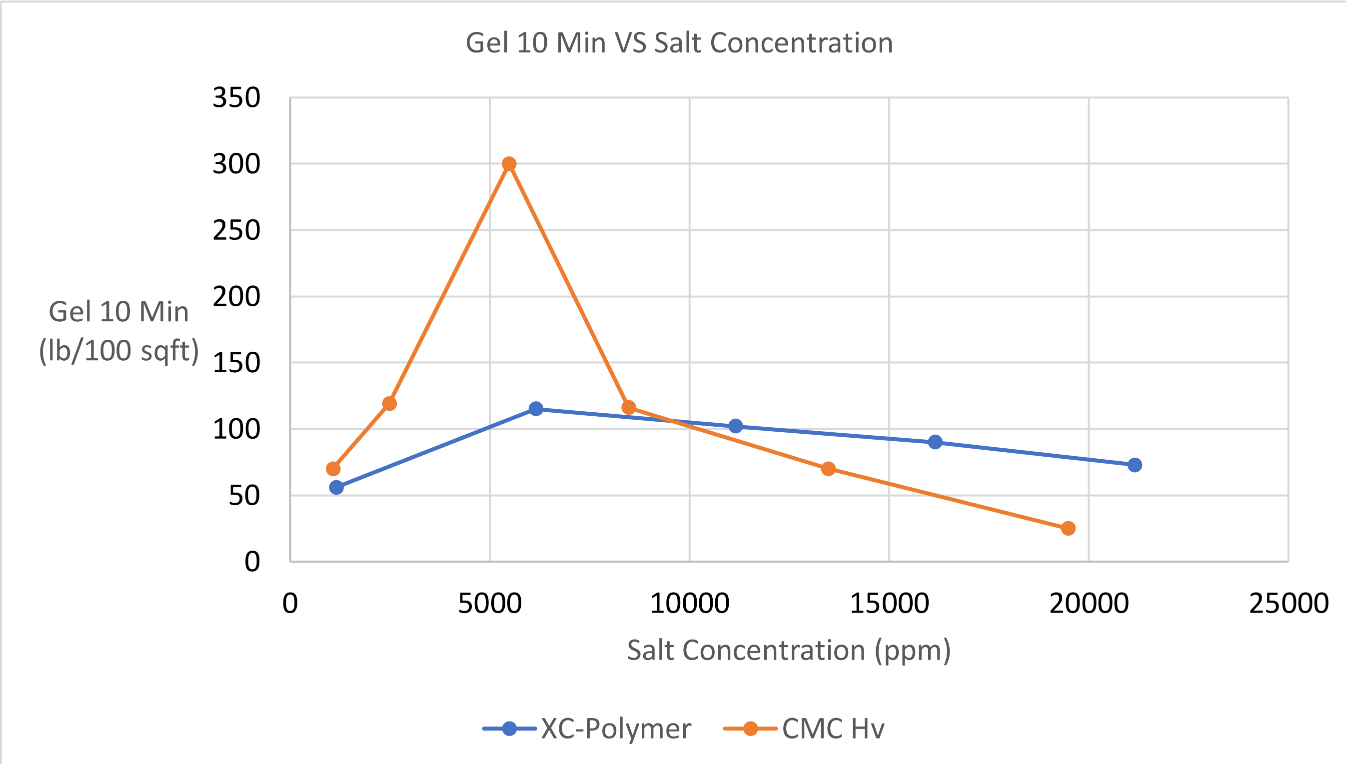

Figure 14

(Gel strength 10min versus salinity for two muds containing CMC Hv and XC-polymer.**)**

The graph shows the effect of increasing salt concentration on the Apparent viscosity of two muds (a water-based bentonite mud) containing XC and CMC HV polymers. The same result we got for the above properties at the beginning Both curves trend upwards. But at high salinities the Gel strength values start to decrease indicating that the Gel strength decreases for both polymers as the salt concentration rises especially at high salinities.

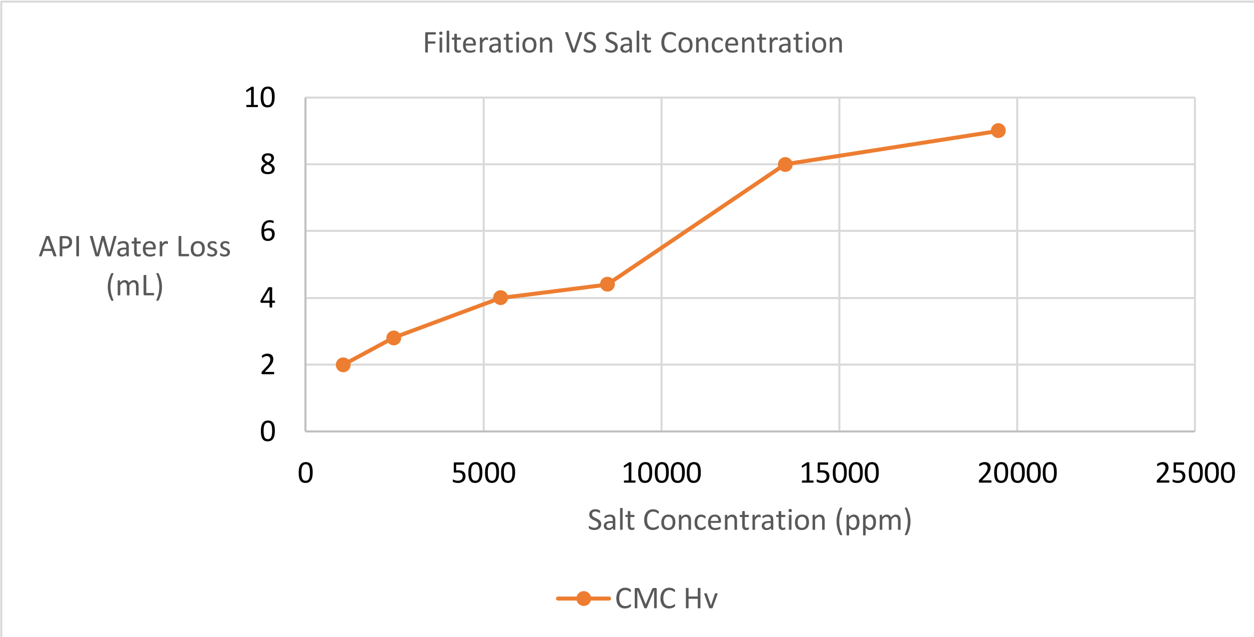

Figure 15 **(**Filtration versus various salinity for CMC Hv polymers**)**

The graph illustrates the effect of increasing salt concentration on the filtration rate of a water-based bentonite mud containing CMC polymer. The upward trend in the curve suggests that filtrate volume increases as salt concentration increases.

This indicates that the CMC polymer become less effective at retaining fluid within the mud as salt concentration rises.

4.1.4 Effect of pH on Drilling Mud Properties

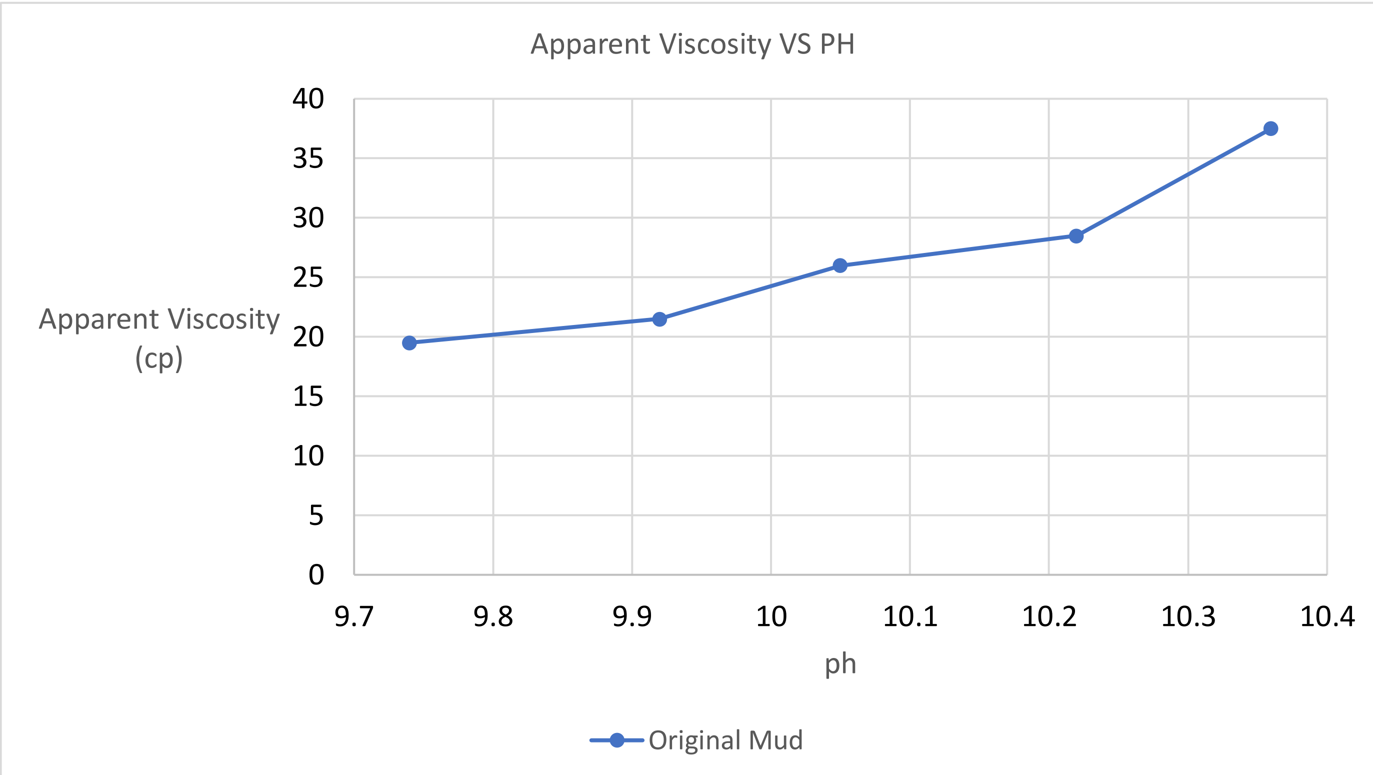

Figure 16 **(**Apparent viscosity versus various pH**)**

The graph shows the influence of increasing pH on a bentonite water-based mud's apparent viscosity. The upward trend in the curve suggests that apparent viscosity increases as the pH level rises.

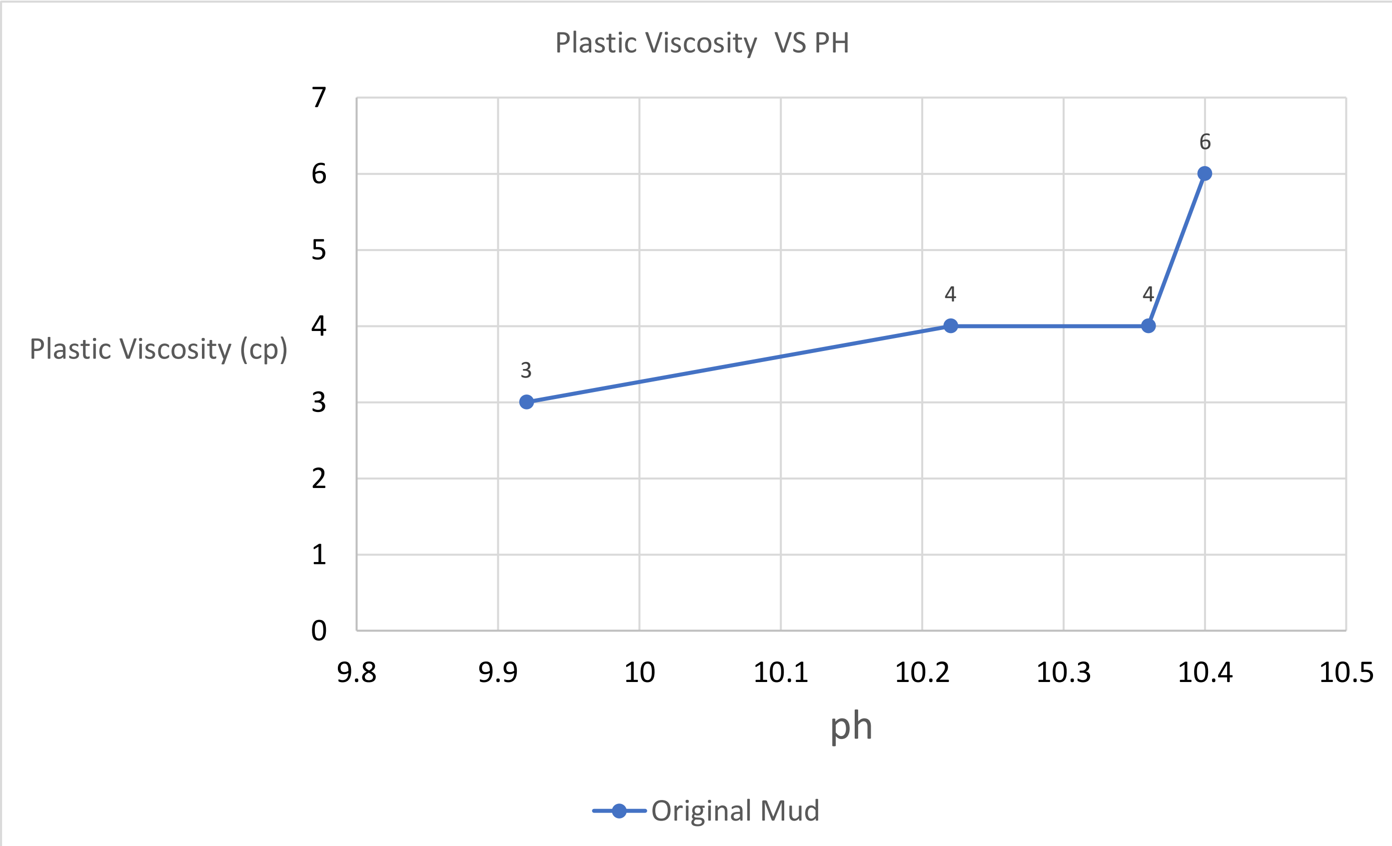

Figure 17 **(**Plastic viscosity versus various pH**)**

The graph shows the effect of increasing pH on the plastic viscosity of a bentonite water-based mud. The curve shows a slight upward trend, suggesting a minor increase in plastic viscosity with increasing pH. This may be due to increased expansion and interaction of bentonite particles at higher pH levels.

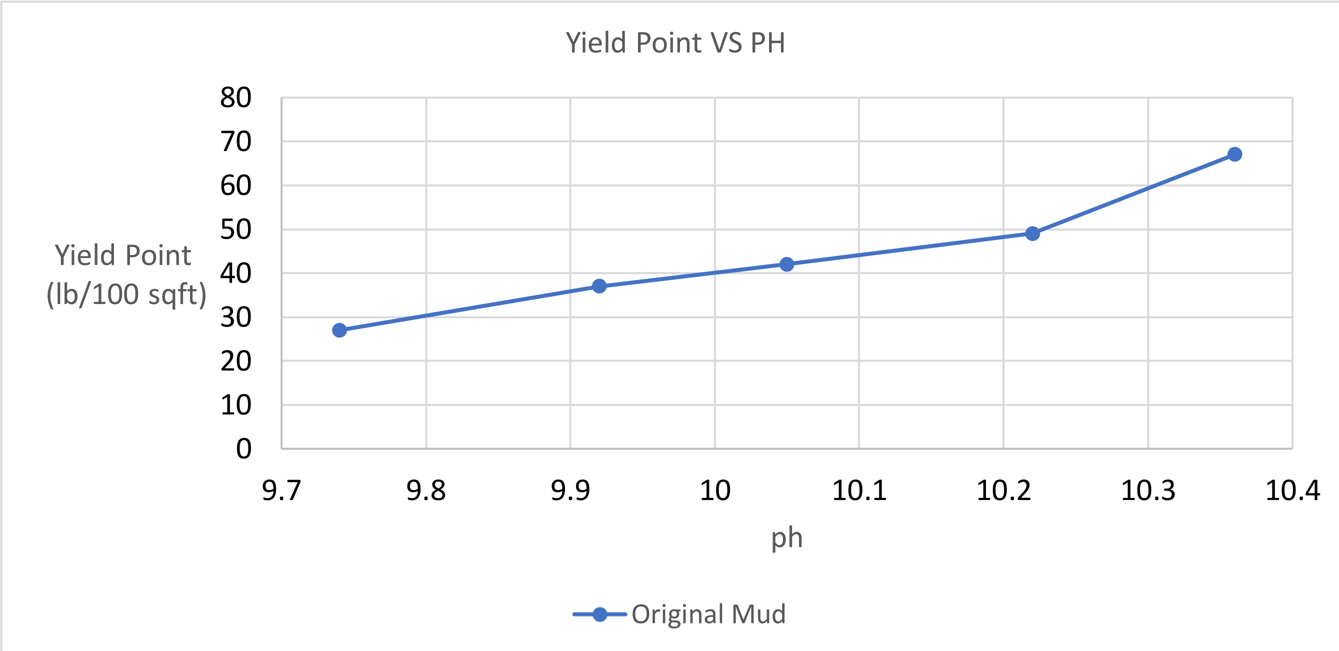

Figure 18 **(**Yield point versus various pH**)**

The graph depicts the yield point of a bentonite water-based mud with increasing pH. The curve exhibits an upward trend, signifying a rise in yield point as the pH level increases.

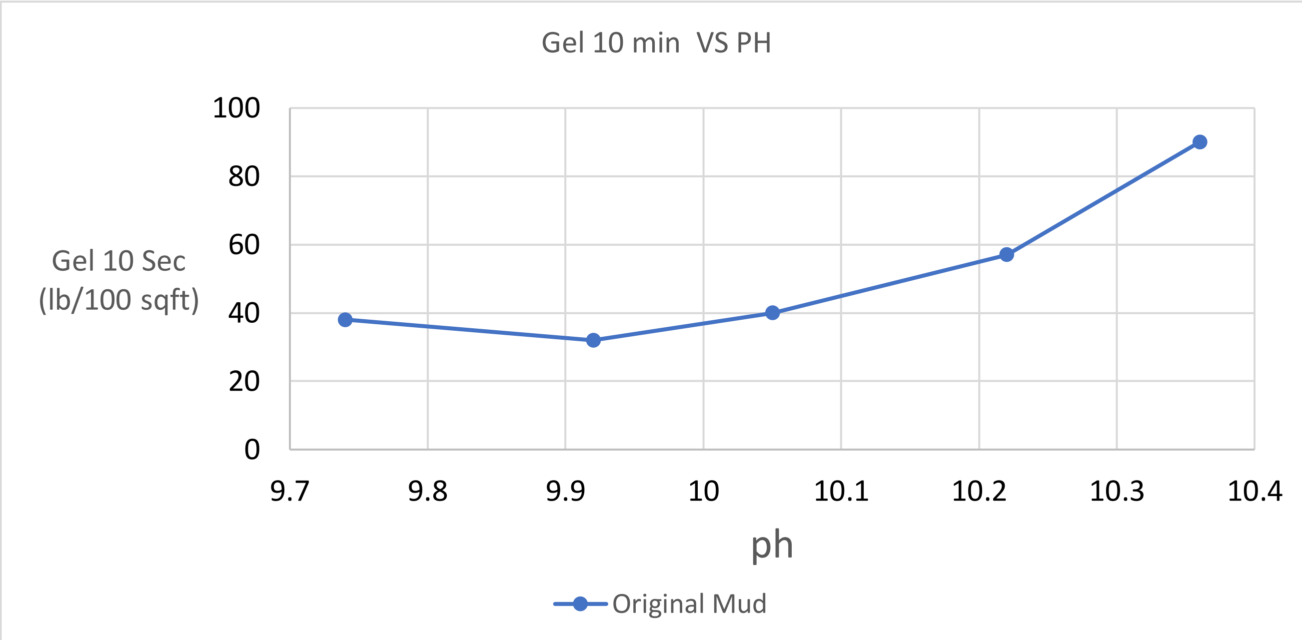

Figure 19 **(**Gel strength 10 min versus various pH**)**

The graph shows the effect of increasing pH on the (10 min – gel strength) of a bentonite water-based mud. The curve shows an upward reaching approximately 90 Ib/100 seqft, indicating a minor rise in gel strength with increasing pH

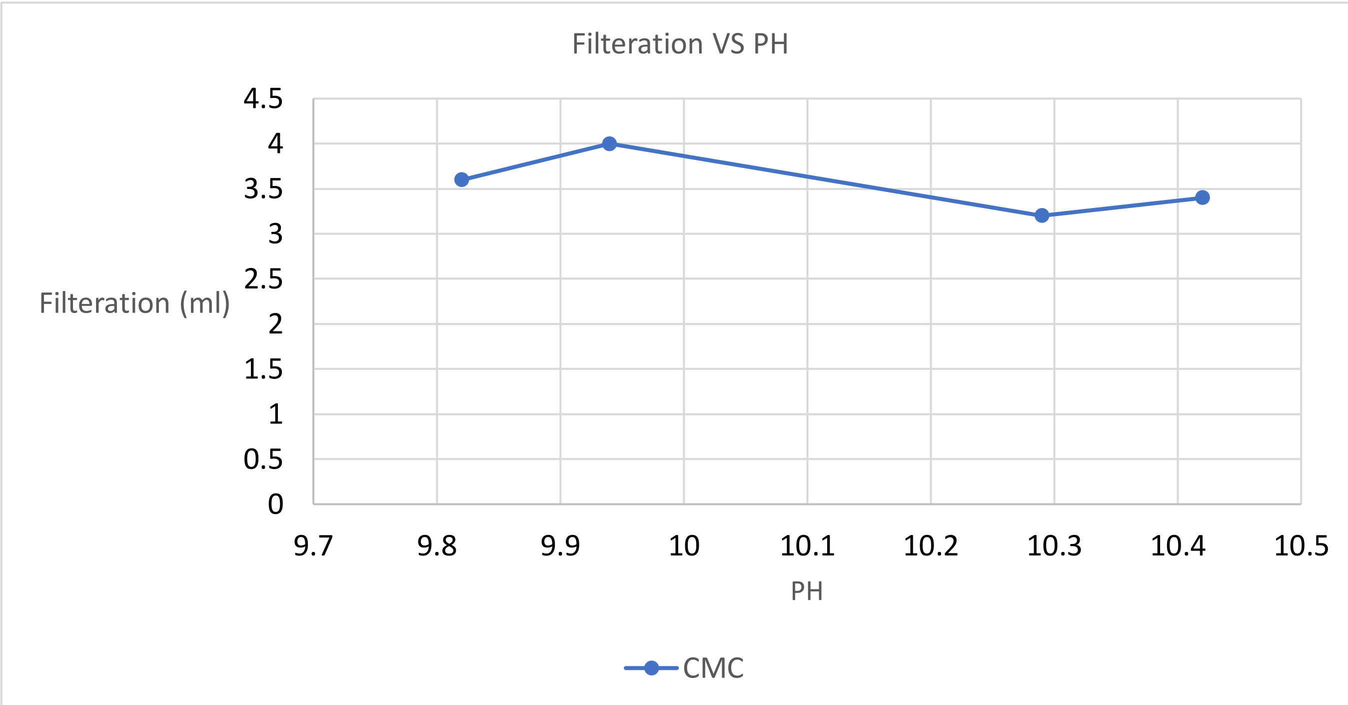

Figure 20 **(**Filtration versus pH for CMC Hv polymers**)**

The graph depicts the effect of increasing pH on the filtration rate of a bentonite water-based mud. The curve shows a very slight downward trend, suggesting a minimal decrease in filtration rate with increasing pH. The effect can be negligible.

4.2 Discussion

4.2.1 Effects of Polymer Concentration on Drilling Mud Properties:

The viscosity of drilling mud largely depends on the number of solid particles in the mud and the shape of them. Hence, adding polymers with any concentrations and complex structures will increase the amount of the viscosity of drilling mud. Moreover, they will form long molecule chains that will cause an increase in drilling mud viscosity.

At high salinity that Montmorillonite platelets tend to flocculate, addition of polymer has also another effect. Polymers can form a sealing layer around the clay platelets that will inhibit cations to substitute between clay platelets.

CMC Hv have chemical structure that have a carboxymethyl group on it structure, CMC Hv. has a high D.P. (Degree of polymerization). It causes CMC Hv. to exert higher viscosity. It is true for plastic viscosity, yield point and gel strength.

As Figures 7 through 10 shows at low concentration of polymers, there is little difference between rheological properties of different polymers. But at high concentration this difference will be clearer. It is due to the polymers structures, meaning the long chain polymers will make more viscous fluid than the short types at the same concentration. So the difference between them will become more obvious at high concentrations.

As Figure 11 shows, filtration graph of CMC-Polymer. XC Polymer is an excellent choice for enhancing the rheological properties of mud while having a relatively minimal impact on filtration properties due to that XC polymer may not strongly interact with water molecules, limiting its ability to form a dense, filtration-resistant layer around the drilled solids with the increasing with its concentrations. Therefore, its filtration was not measured.

CMC Polymers are more effective for controlling fluid loss of drilling mud in comparison with others.

4.2.2 The effect of Salinity on Drilling Mud Properties:

With the addition of NaCl, the double layer of the clay particles is compressed enhancing flocculation of the suspension. In other words, the separation between the clay platelets was reduced with increasing concentration of salt. It will decrease the viscosity of drilling fluid. When a polymer is added to water, the cations (usually Na+) release from the polymer chain and leave behind a negatively charged site. The polymer is now anionic and free in hydrate water. As the polymer hydrates the water, the envelope surrounding the polymer increases in size and along with it viscosity increases. With the presence of salt the availability of water is limited and polymer cannot hydrate and expand easily. It means that hydrogen bonding is not formed between the polymer chains and water molecules; therefore the gel strength of this fluid will become negligible

Figures 12 show the Plastic Viscosity Versus Polymers Concentrations (CMC Polymers and XC-Polymer) in various drilling muds with different salinities. As these figures show apparent viscosity of drilling mud at 670 ppm (fresh water) and 13000ppm for CMC and 11000ppm for XC polymers are close to each other. But at high salinities the apparent viscosity values decreased sharply. It is also true for the yield point and Gel Strength. (See Figures 13 through 14).

Another effect of salinity is increasing filtrate volume of drilling mud. It is probably due to the sticking of clay platelets together, in other words the hydration of freshwater clays decreases rapidly with increasing concentrations of the salts. (See Figures 15)

The high concentration of salt ions in the water competes with the polymer for water molecules, disrupting the polymer network and leading to a decline in mud properties like viscosity and filtration control.

4.2.3 The effect of pH on Drilling Mud Properties:

Caustic soda were used for increasing pH of drilling mud. Therefore, comparative diagrams were created for these two additives. As Figures 16 through 20 show, Rheological Properties (Plastic viscosity, Apparent Viscosity, Yield Point and Gel strength) of drilling mud will increase gradually until pH = 10 but it has a sharp increase after this point. It will confirm dispersion of clay minerals at high pH values. Therefore, adding Caustic soda is effective for increasing the viscosity of drilling mud. It is due to the Monovalent cations such as Na^+ in Caustic Soda. Existence of cations will increase the attractive force between platelets. Monovalent cations give rise to a lesser attractive force and allow more water to penetrate between the platelets. So platelets will be dispersed well, while adding Caustic Soda and consequently rheological properties of the mud is more efficient Yield point is a measurement of the electrochemical or attractive forces in a fluid at dynamic conditions, but Gel strength in this measurement are at static condition. Therefore increasing caustic soda concentrations will lead to an increase in Yield Point and Gel Strength of drilling mud. Figure 20, confirms that increasing pH will lead to a decrease in the filtration volume. It is probably due to increasing viscosity of drilling mud.

Chapter Five: Conclusion

Chapter Five: Conclusion

5.1 Conclusion

CMC HV is a viscosity modifier, so adding more directly increases the mud's resistance to flow. The thicker, more viscous mud created by higher CMC HV concentration hinders filtrate flow, leading to less liquid passing through the filter.

increasing the pH of bentonite mud can have a complex effect on its rheological properties, potentially leading to an increase in some parameters. This includes plastic viscosity, apparent viscosity, yield point, and gel strength.

The mechanism behind this is likely related to the enhanced flocculation of sodium montmorillonite platelets. As pH rises, the negative charge on the clay surface decreases. This allows for increased attraction between the clay particles, causing them to clump together (flocculate).

XC-polymer exhibits a pronounced effect on the viscosity of drilling mud, although its fluid loss control capabilities are not as effective as those of CMC polymers.

The effect of salinity on the performance of XC-polymer is minimal compared to other polymers like CMC.

Salinity exerts a significant influence on the rheological (flow behavior) and filtration properties of drilling mud.

increasing salinity has detrimental effects on the filtration properties of drilling mud. This translates to a rise in filtrate volume, indicating greater fluid loss into the formation as salinity increases.

5.2 Recommendation

1- Measure pH with each addition for each effect of salt and polymer concentration .
2- Analyze the combined effects of salinity, pH, and temperature on the drilling mud properties. Real-world drilling encounters varying temperatures downhole. Understanding this three-way interaction is crucial for proper mud design.

3- Measuring the effects of polymers used in drilling mud.

4- Develop a mathematical model to quantify the relationship between salinity/pH and key mud properties like viscosity, yield point, and filtration rate. This allows for better prediction and optimization of mud formulation in real-world drilling scenarios.

5- Investigate how XC and CMC polymers interact with each other at different salinity and pH levels. Do they exhibit synergistic effects, where the combined action is greater than the sum of their individual effects?.

6-for optimal performance depending on wellbore conditions. We recommend to do field application of the bentonite-XC-CMC mud system. This could include specific salinity and pH ranges

References

References

1- Alaskari, M. K. G., & Teymoori, R. N. (2007). TECHNICAL NOTE EFFECTS OF SALINITY, pH AND TEMPERATURE ON CMC POLYMER AND XC POLYMER PERFORMANCE. In IJE Transactions B: Applications (Vol. 20, Issue 3).

2- Balaga, D. K., & Kulkarni, S. D. (2023). Investigation of Thermal Degradation Kinetics of Synthetic Polymers in High-Performance Water-Based Muds for Designing Drilling Automation Processes for Viscosity and Fluid-Loss Control. Society of Petroleum Engineers - Gas and Oil Technology Showcase and Conference, GOTS 2023.

3- European_Journal_of_Chemistry_14_2_2023_184_192_2392. (n.d.).

4- Gamal, H., Elkatatny, S., Basfar, S., & Al-Majed, A. (2019). Effect of pH on rheological and filtration properties of water-based drilling fluid based on bentonite. Sustainability (Switzerland), 11(23).

5- Kuma, M., Das, B. M., & Talukdar, P. (2020). The effect of salts and haematite on carboxymethyl cellulose–bentonite and partially hydrolyzed polyacrylamide–bentonite muds for an effective drilling in shale formations. Journal of Petroleum Exploration and Production Technology, 10(2), 395–405.

6- Misbah, B., Rahuma, K. M., Omer, M. A., & Balhan, S. A. (2015). Effect of Salinity on Polymers Performance. Scientific Journal for Damietta Faculty of Science, 5(2), 64–67.

7- O, I., F, C., O, A., & L, U. (2019). The Effect of pH and Salinity on the Rheological Properties of Drilling Mud Formulation from Natural Polymers. International Journal of Engineering and Management Research, 09(05), 126.

8- Rheological Properties of Terminalia Mantaly Exudate as Drilling Mud Additive _ SPE Nigeria Annual International Conference and Exhibition _ OnePetro. (n.d.).

9- Fox, R. W., McDonald, A. T., & Pritchard, P. J. (2004). Introduction to Fluid Mechanics (6th ed.). Wiley.

10- Bird, R. B., Dai, G. C., & Yarusso, B. J. (1983). The rheology and flow of viscoplastic materials. Reviews of Modern Physics, 55(1), 1-47