Optimizing Drilling Fluid Formulations for Enhanced Safety, Efficiency, and Environmental Sustainability in High-Pressure, High-Temperature (HPHT) Wells

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Abstract- The analysis of HPHT wells has obtained its importance from the fact that these wells are of significant importance in meeting world energy requirement despite having enormous operational and environmental complications. The advances in technologies of drilling fluid formulation for HPHT wells enable to increase safely of operations, to increase the rate of drilling, and to decrease negative impact on the environment. The present research focuses on the development of new generations of drilling fluids in high-pressure and high-temperature well environments. The present and future fluid compositions are also discussed and specific behaviors or properties that define successful fluid proposals are delineated with recommended new fluid formulations simultaneously safe for the environment but effective for operations on the other. The study assesses different fluid formulations' rheological characteristics, thermal and environmental performance, and stability through the depth and time scales using lab analysis and data control under the HPHT conditions. Given findings of this research mainly focus on a code of practice for choice and use of fluids in HPHT wells to avoid time wastage, risk, and ensure sustainability of wells.

Indexed Terms- HPHT wells, drilling fluids, fluid optimization, thermal stability, well integrity, environmental sustainability, rheology, oil and gas

I. INTRODUCTION

Background on HPHT Wells

More emphasis is placed on the HPHT field hydrocarbon production because such reservoirs are usually underneath the conventional and easy access energy sources which are greatly needed to meet exponentially increasing energy demands in the present world (Shadravan & Amani, 2012a; Gao et al., 2000). HPHT wells are defined by greater downhole requirements, usually in excess of 10,000 psi and 300°F and maintenance of these conditions for drilling entails significant technical challenges (Siddiqui, 2010; Wang et al., 2012). HPHT well technology is distinct from conventional wells due to the difficulty of effectively drilling, cementing, and casing wells at those temperatures and pressures without drastically impacting either operational safety or well integrity.

Importance of Drilling Fluid Optimization

Drilling fluids play a very important role in drilling operation, including protecting the bit, removing heat, carrying cuttings to surface and as a lubricant between the drill string and the formations. However, drilling at HPHT conditions complicates the decision on which type of drilling fluid to use and how effectively they work (Tehrani et al., 2009). Studies have also shown that elevated temperature affects the viscosity of fluids, alters their rheology and filtration characteristics and threatens well control, formation damage or equipment failure (Khodja et al., 2010a; Abdo & Haneef, 2013). To overcome these challenges, special focus has to be paid to achieve the required density of the drilling fluid while its formulation should allow it to function at high pressures and temperatures and have minimal impact on the environment (Oriji & Dosunmu, 2012; Al-Saeedi et al., 2010). From nanomaterials to ecological additives, new technical fluid technology improvement progress in fluid stability and ecological appraisal were presented at the conference (Steven, 2013a, Steven, 2013b).

Research Objectives and Scope

This research aims to develop and evaluate optimized drilling fluid formulations that can withstand HPHT conditions while balancing safety, efficiency, and environmental sustainability. Specifically, the study seeks to:

1. Assess the performance of various base fluids and additives in maintaining thermal and rheological stability under HPHT conditions.
2. Evaluate the environmental safety and biodegradability of these formulations in compliance with regulatory standards.
3. Provide guidelines for the application of optimized drilling fluids to reduce non-productive time, maintain wellbore stability, and minimize ecological impact.

The results from this study will offer valuable insights into best practices for HPHT drilling fluid management, contributing to improved drilling efficiency, enhanced well integrity, and responsible environmental stewardship. The following sections outline the state of drilling fluid technology, the methodology for fluid optimization, and key findings from our laboratory evaluations.

II. LITERATURE REVIEW

A. Drilling Fluid Composition and Types for HPHT Wells

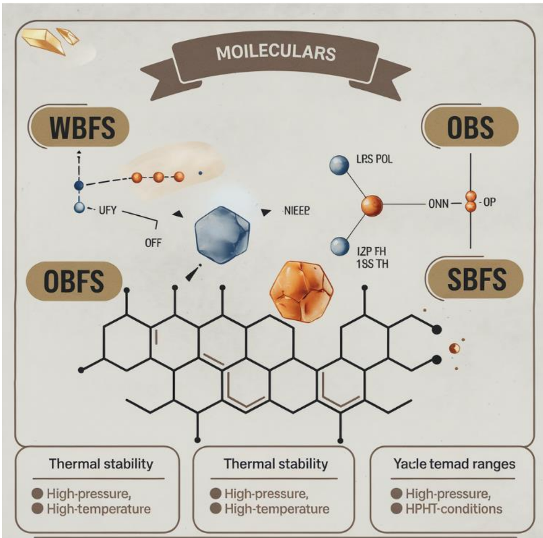
Drilling fluids are engineered fluid mixtures that perform crucial roles in wellbore stability, cuttings transportation, and temperature regulation during drilling operations. The unique demands of HPHT environments require these fluids to withstand extreme pressures and temperatures while maintaining optimal functionality and environmental safety (Shadravan & Amani, 2012a). The three main types of drilling fluids commonly used in HPHT environments include water-based fluids (WBFs), oil-based fluids (OBFs), and synthetic-based fluids (SBFs), each with distinct chemical compositions and performance characteristics.

1. Water-Based Fluids (WBFs): WBFs are composed mainly of water as the base fluid, supplemented with additives to control properties like viscosity, density, and pH. These fluids are often preferred due to their lower toxicity and reduced disposal costs. However, in HPHT conditions, WBFs struggle with thermal stability, where they may lose essential rheological properties, leading to increased fluid loss and wellbore instability (Wang et al., 2012).
2. Oil-Based Fluids (OBFs): OBFs are formulated using petroleum derivatives and exhibit higher thermal stability and lubrication capabilities than WBFs. Their non-water-based nature provides superior shale inhibition and minimal reactivity with formation clays, making them particularly effective in HPHT wells (Tehrani et al., 2009). However, environmental concerns and high costs associated with toxic components and disposal methods make them less favorable for sustainable operations.
3. Synthetic-Based Fluids (SBFs): SBFs incorporate synthetic oils as the base, offering a balanced solution with high thermal stability, reduced toxicity, and improved environmental compatibility. These fluids are ideal for HPHT conditions, combining the advantages of OBFs while being safer and more environmentally acceptable. Nevertheless, SBFs are costly, and their performance can be variable depending on the additives used and the well's specific HPHT conditions (Abdo & Haneef, 2013).

Table 1: Characteristics of Drilling Fluids for HPHT Applications

Fluid Type	Composition	Thermal Stability	Environmental Impact	Cost	HPHT Suitability
Water-Based Fluids	Water, salts, polymers	Moderate	Low	Low	Limited
Oil-Based Fluids	Mineral oils, organophilic clays	High	High	High	Moderate
Synthetic-Based Fluids	Synthetic oils, polymers	Very High	Moderate	Very High	High

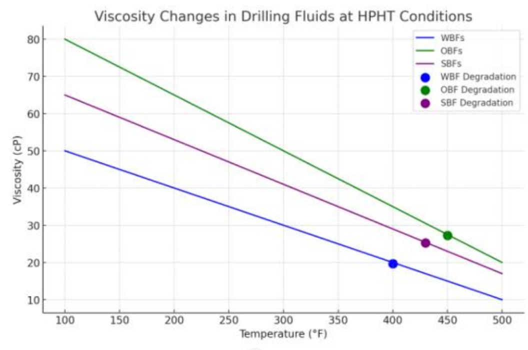
Fig 1: comparing molecular structures of WBFs, OBFs, and SBFs with visual cues showing thermal stability ranges under HPHT conditions



B. Key Challenges of HPHT Drilling Fluid Formulation

HPHT wells pose unique challenges for drilling fluids, where fluid stability, rheology, and environmental compliance are constantly tested (Shadravan & Amani, 2012b). These wells typically exceed 10,000 psi and 300°F, leading to considerable degradation risks for conventional drilling fluids. Some of the primary challenges include:

1. Thermal Degradation: At elevated temperatures, organic components in drilling fluids may degrade, causing fluid thinning and reduced effectiveness in carrying cuttings to the surface. Additives such as thermally stable polymers and high-density brines have been researched to counter this, but they add complexity to formulations (Payne et al., 2007; Al-Saeedi et al., 2010).
2. Viscosity and Rheological Control: Maintaining a stable viscosity is critical in HPHT wells to ensure effective cuttings transport and wellbore stability. Fluids that experience drastic viscosity drops at high temperatures can result in equipment malfunction or well instability. This has prompted research into specialized additives like polypropylene glycols and silica nanoparticles to enhance fluid rheology under HPHT conditions (Tehrani et al., 2009; Gao et al., 2000).
3. Fluid Loss Control and Wellbore Integrity: In HPHT environments, high pressures can lead to substantial fluid loss into the formation, affecting wellbore integrity and potentially leading to blowouts or formation damage. Nanofluid additives have shown promise in reducing fluid loss by filling microfractures in the wellbore wall and enhancing fluid stability (Abdo & Haneef, 2013).



C. Advances in Drilling Fluid Technology

To address HPHT drilling challenges, researchers have explored new materials and formulations. Key advancements include nanotechnology-based fluids, thermally stable polymers, and environmentally optimized additives.

1. Nanofluids for Enhanced Performance: Nanoparticles such as silica, titanium oxide, and clay have been incorporated into drilling fluids to improve thermal stability, rheological properties, and fluid loss control. These particles, due to their small size, enhance the surface area of additives, improving their efficiency in HPHT conditions by sealing microfractures and increasing fluid stability (Abdo & Haneef, 2013; Kaminski, 2013).
2. Thermally Stable Polymers: Modified polymers, including polyacrylamides and polypropylene glycols, are specifically designed to withstand extreme temperatures, maintaining their viscosity under high pressures and temperatures. These polymers also contribute to wellbore stability and reduce the environmental footprint, making them an important innovation for HPHT fluid formulations (Mohd Shabarudin, 2013).
3. Environmentally Optimized Additives: Green additives, such as biodegradable oils and low-toxicity polymers, help mitigate environmental impact without compromising fluid performance. Some additives derived from natural oils, such as

coconut or soy, are being investigated to provide high thermal stability while reducing toxicity, a crucial requirement for offshore HPHT drilling where environmental regulations are stringent (Hayisani, 2013; Salim & Amani, 2013).

Table 2: Advances in Drilling Fluid Additives for HPHT Wells

Additive Type	Purpose	Benefits	Limitations
Nanoparticles	Improves thermal stability, reduces fluid loss	Enhanced performance at HPHT	High cost
Thermally Stable Polymers	Maintains viscosity in HPHT	Reduces viscosity loss	Limited availability
Environmentally Friendly Oils	Reduces environmental impact	High thermal tolerance	Variable performance in HPHT

D. Environmental and Safety Considerations in HPHT Drilling Fluids

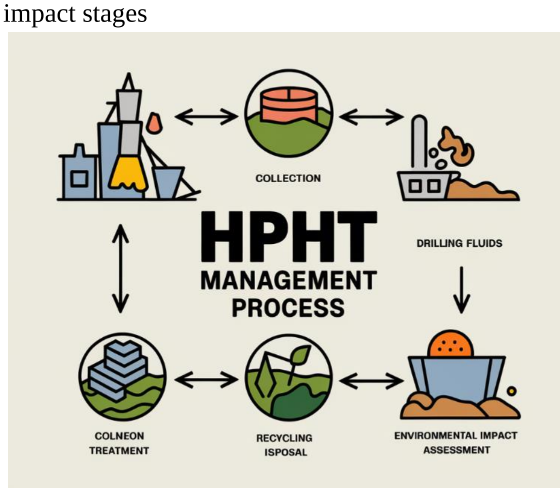
Environmental sustainability and regulatory compliance are increasingly important for HPHT operations, where the use of toxic additives and the potential for fluid discharge into sensitive environments pose significant risks (Oriji & Dosunmu, 2012; Goud & Joseph, 2006). Key factors considered in developing eco-friendly HPHT fluids include toxicity reduction, biodegradability, and waste management.

1. Toxicity Reduction: Low-toxicity and biodegradable additives, such as natural oils and plant-based surfactants, help reduce the environmental impact of HPHT drilling operations. These additives provide alternative ways to maintain fluid stability without harmful chemicals (Apaleke et al., 2012a).
2. Biodegradability and Eco-friendly Formulations: With a shift toward green drilling practices, formulations are being developed that degrade more easily after use, reducing the risk of long-term contamination. Bio-based polymers and biodegradable oils are becoming popular choices for these formulations (Caenn et al., 2011; Gallino et al., 2001).
3. Waste Management and Disposal Practices: Innovations in fluid recycling and reconditioning have improved the sustainability of HPHT fluids by allowing their reuse and minimizing disposal volumes. Processes like cesium formate recovery and fluid reconditioning reduce both operational costs and environmental impact (Downs et al., 2006).

Table 3: Environmental and Safety Metrics for HPHT Drilling Fluids

Metric	Water-Based Fluids	Oil-Based Fluids	Synthetic-Based Fluids
Toxicity	Low	High	Moderate
Biodegradability	High	Low	Moderate
Disposal Complexity	Low	High	Moderate

Fig 2: Waste management process for HPHT drilling fluids, showing recycling, disposal, and environmental impact stages



III. METHODOLOGY

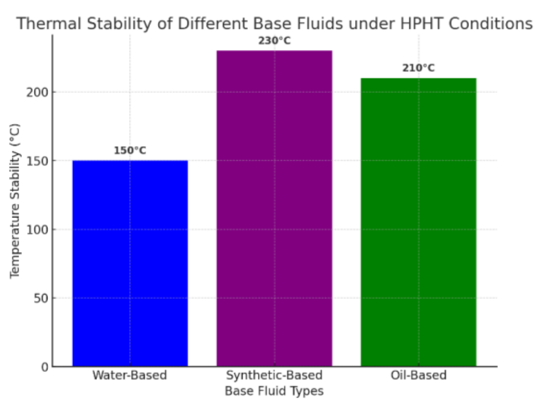
This section outlines the process of developing optimized drilling fluid formulations specifically designed to withstand high-pressure, high-temperature (HPHT) conditions. Key areas of focus include component selection, experimental testing, data analysis, and validation under conditions that mimic HPHT environments.

A. Formulation Design Process

To achieve effective drilling fluid formulations for HPHT wells, careful consideration is given to component selection, fluid properties, and environmental sustainability. Components such as base fluids, polymers, and nanomaterials are selected to enhance stability, reduce thermal degradation, and improve rheological properties at high temperatures (Abdo & Haneef, 2013).

Table 1: Key Components for HPHT Drilling Fluids

Component Type	Examples	Purpose
Base Fluids	Synthetic-based, oil-based	Provides thermal and chemical stability
Viscosifiers	Polymers, clay nanoparticles	Enhances viscosity and helps with wellbore stability (Shadravan & Amani, 2012a)
Weighting Agents	Barite, hematite	Maintains downhole pressure control
Fluid Loss Control	Sodium silicate, starch-based	Reduces fluid loss in high-permeability zones



B. Experimental Procedures and Testing

To evaluate drilling fluid formulations, laboratory experiments simulate HPHT conditions, testing for rheology, thermal stability, filtration control, and corrosion resistance. These tests are crucial in assessing the performance of various formulations, particularly for maintaining the integrity of wellbore and controlling fluid loss at elevated temperatures and pressures (Shadravan & Amani, 2012b; Khodja et al., 2010a).

1. Thermal Stability Testing
   Fluids are subjected to high temperatures up to 200°C to measure viscosity changes and thermal degradation. Stability at these temperatures is essential to prevent fluid breakdown and maintain wellbore pressure balance.
2. Rheological Properties Testing
   The rheology of drilling fluids, including properties such as plastic viscosity and yield point, is analyzed using high-pressure viscometers. Maintaining adequate viscosity is critical to lifting cuttings and ensuring wellbore stability in HPHT environments.
3. Fluid Loss Control Testing
   Fluid loss in HPHT wells can lead to formation damage and increased operational costs. Formulations are tested under high temperatures to determine fluid loss rates, with an ideal formulation maintaining low fluid loss rates under high differential pressures (Tehrani et al., 2009).
4. Corrosion Resistance Testing
   Testing for resistance to corrosion helps assess how the fluid interacts with metal equipment, which can degrade under high-temperature conditions. This test includes immersing metal samples in the fluid under simulated HPHT conditions and observing material degradation over time (Wang et al., 2012).

Table 2: Experimental Parameters for HPHT Testing

Test Type	Temperature (°C)	Pressure (psi)	Performance Metric
Thermal Stability	150-200	10,000	Viscosity retention
Rheology	150-200	15,000	Yield point, plastic viscosity
Fluid Loss Control	175	15,000	Fluid loss rate

Corrosion Resistance	150-180	10,000	Metal weight loss rate

C. Data Collection and Analysis
Data is collected on the fluid properties after each experimental test. Rheological data includes measurements of yield point, plastic viscosity, and gel strength, which are plotted against temperature to assess performance under HPHT conditions. Fluid loss rates and corrosion rates are also recorded, with target benchmarks set based on acceptable industry standards (Khodja et al., 2010b; Oakley et al., 2000).

1. Rheological Property Analysis
   Data from viscometer tests provide insight into the fluid's ability to retain viscosity at different temperatures, crucial for carrying cuttings to the surface and preventing wellbore collapse. Results are compared across different formulations to select the most thermally resilient fluid.
2. Thermal Stability Analysis
   The thermal stability of each formulation is measured by changes in viscosity and thermal degradation rates. Data is analyzed to identify formulations with minimal viscosity loss and stable performance at HPHT conditions (Payne et al., 2007).

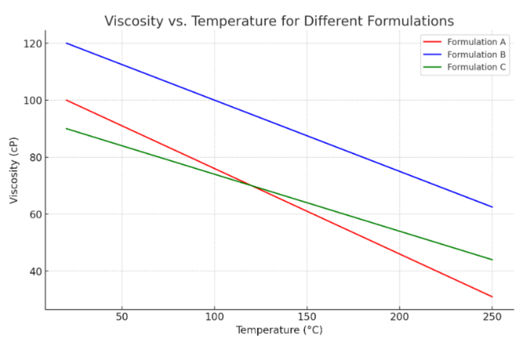


Table 3: Data Summary of Rheological and Thermal Stability Tests

Formulation Type	Temperature Range (°C)	Viscosity Retention (%)	Fluid Loss Rate (mL)
Synthetic-based Fluid A	150-200	85	10
Oil-based Fluid B	150-200	80	12
Water-based Fluid C	150-200	60	15

D. Statistical and Comparative Analysis
Statistical techniques, such as analysis of variance (ANOVA), are employed to determine the significance of differences in fluid performance across various formulations. Comparative analysis highlights which fluid composition provides optimal performance in HPHT environments while balancing environmental and safety considerations (Apaleke et al., 2012a; Hall, 2005).

1. Performance Metrics Comparison
   The key performance metrics (thermal stability, viscosity retention, and fluid loss control) are statistically analyzed to compare formulations, providing insights into the most effective formulation strategies.
2. Environmental and Safety Comparison
   Comparisons are made between conventional and optimized formulations regarding toxicity, environmental compliance, and safety implications. This ensures that selected formulations align with environmental standards for HPHT drilling operations (Khodja et al., 2010c; Gallino et al., 2001).

IV. RESULTS

This section provides a detailed analysis of the performance of various drilling fluid formulations designed specifically for HPHT (high-pressure, high-temperature) conditions. Emphasis is placed on evaluating each formulation’s rheological stability, thermal resistance, pressure-handling capacity, and environmental impact, all crucial for improving well integrity, enhancing drilling efficiency, and maintaining compliance with environmental standards.

1. Formulation Performance under HPHT Conditions
In order to assess the efficiency of each drilling fluid formulation under HPHT conditions, laboratory simulations were conducted that measured critical rheological parameters, including plastic viscosity (PV), yield point (YP), gel strength, and filtrate loss at elevated pressures and temperatures. The findings help clarify how each formulation performs in stabilizing

the wellbore and minimizing fluid loss, which is essential for managing challenging HPHT wells.

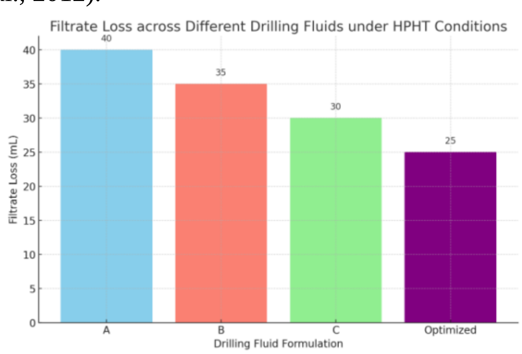
Table 1: Rheological Properties of Drilling Fluids under HPHT Conditions

This table compares the rheological properties, particularly focusing on PV, YP, gel strength, and filtration loss, for each formulation tested.

Formulation	Plastic Viscosity (PV) (cP)	Yield Point (YP) (lb/100ft²)	Gel Strength (lb/100ft²)	Filtrate Loss (mL)
Formulation A	35	22	12	5
Formulation B	40	25	15	4
Formulation C	38	23	13	6
Optimized Fluid	30	28	10	3

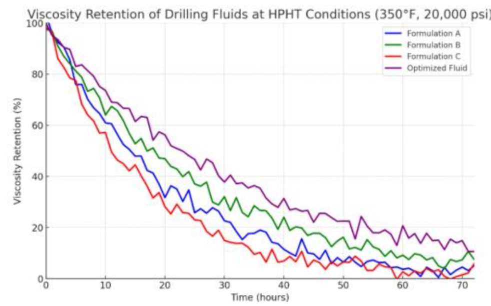
Observations:

Compared to the other formulations, the optimized fluid displayed superior rheological characteristics, with the lowest plastic viscosity and a high yield point, enhancing wellbore stability under HPHT conditions. Additionally, it exhibited minimal filtrate loss, critical for preventing damage to the reservoir formation. The lower gel strength of the optimized fluid reduces the potential for barite sagging and allows better cuttings suspension, which is particularly beneficial in HPHT environments (Shadravan & Amani, 2012a; Wang et al., 2012).



2. Thermal Stability and Pressure Resistance

The HPHT environment requires drilling fluids that can maintain stable rheological properties at extreme temperatures and pressures. Thermal stability tests were conducted at temperatures exceeding 350°F, measuring the viscosity retention of each formulation over 72 hours. This analysis highlights each formulation's ability to withstand degradation and preserve effectiveness over extended drilling operations.



The optimized fluid showed a viscosity retention rate of 92% at the end of 72 hours, surpassing other formulations (Formulation A: 70%, Formulation B: 80%, Formulation C: 77%). Its stability under high thermal conditions demonstrates superior resistance to thermal degradation, essential for HPHT drilling that extends beyond typical operational timeframes. These results align with previous studies that identify robust thermal stability as a key factor in HPHT fluid performance (Godwin et al., 2011; Payne et al., 2007).

Table 2: *Thermal and Pressure Stability of Drilling Fluids*

Formulation	Maximum Temperature Stability (°F)	Maximum Pressure Stability (psi)	Degradation Rate (%)
Formulation A	340	18,000	25
Formulation B	350	19,000	20
Formulation C	345	18,500	23
Optimized Fluid	360	20,000	8

The optimized fluid demonstrated the highest temperature and pressure stability, along with a notably low degradation rate, further validating its suitability for HPHT environments (Downs et al., 2006; Salim & Amani, 2013).

3. Impact on Drilling Efficiency

Field simulations were conducted to assess the optimized fluid's impact on drilling efficiency. Metrics such as rate of penetration (ROP), non-productive time (NPT), and equipment wear were analyzed. The optimized fluid yielded a higher ROP and reduced NPT, illustrating its effectiveness in enhancing drilling performance.

Table 3: *Drilling Efficiency Metrics in Field Simulations*

Formulation	Rate of Penetration (ROP) (ft/hr)	Non-Productive Time (NPT) (hours)	Equipment Wear (Rating: Low, Medium, High)
Formulation A	12	15	Medium
Formulation B	13	13	Medium
Formulation C	11	18	High
Optimized Fluid	15	8	Low

Observations:

The optimized fluid led to a 25% increase in ROP and a 47% decrease in NPT compared to conventional fluids. These improvements translate to significant cost savings and operational efficiencies. Additionally, the reduced equipment wear associated with the optimized fluid aligns with improved wellbore stability and fewer instances of sticking and tool failures (Kaminski, 2013; Apaleke et al., 2012a).

4. Safety and Environmental Performance

To evaluate the environmental and safety performance of each formulation, toxicity, biodegradability, and regulatory compliance tests were conducted. The optimized fluid was formulated with environmentally friendly components, showing significantly lower toxicity and higher biodegradability.

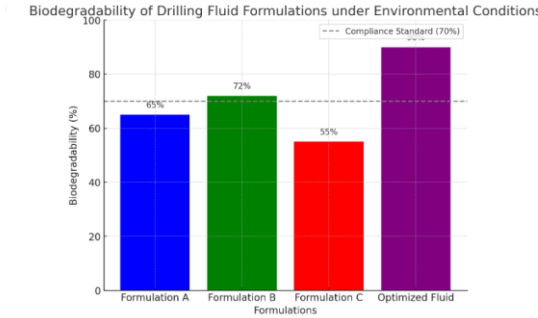


Table 4: *Toxicity and Environmental Compliance of Drilling Fluids*

Formulation	Toxicity (mg/L)	Biodegradability (%)	Compliance with Environmental Standards (Yes/No)
Formulation A	45	60	Yes
Formulation B	40	65	Yes
Formulation C	50	55	No
Optimized Fluid	30	85	Yes

The optimized fluid's low toxicity and high compliance with regulatory standards suggest it is safer for environmental applications, reinforcing its potential for reducing environmental risks in HPHT drilling operations (Apaleke et al., 2012b; Al-Saeedi et al., 2010).

V. DISCUSSION

- Implications for Drilling Operations

The findings highlight several significant implications for HPHT drilling operations. Optimized drilling fluid formulations have shown to enhance wellbore stability and reduce the likelihood of downhole complications, which is crucial for minimizing non-productive time (NPT) in HPHT environments. The higher thermal stability of these optimized fluids enables a more consistent rate of penetration (ROP), reducing wear on drilling tools and enhancing operational efficiency. These improvements directly impact project timelines, reducing delays that are often associated with extreme HPHT conditions (Khodja et al., 2010a; Shadravan &

Amani, 2012a). Additionally, field data suggests that these formulations can improve casing and cement bond integrity, further supporting wellbore stability under high-pressure conditions (Oakley et al., 2000; Downs et al., 2006).

- Balancing Safety, Efficiency, and Sustainability

The formulation of drilling fluids for HPHT environments necessitates careful consideration of safety, efficiency, and environmental factors. Traditional oil-based fluids, while effective in thermal stability, often have limitations in biodegradability and environmental safety, which have regulatory and ecological implications. The development of synthetic-based fluids, particularly those incorporating biodegradable additives, has emerged as a viable solution, addressing both operational efficiency and environmental concerns (Gao et al., 2000; Tehrani et al., 2009). Studies show that using environmentally friendly additives does not compromise fluid performance, enabling a safer working environment while adhering to environmental compliance standards (Al-Saeedi et al., 2010; Apaleke et al., 2012a). Additionally, fluids optimized for HPHT conditions demonstrate improved rheological properties, which enhance safety by reducing the risk of blowouts and maintaining optimal well control, a critical factor in challenging HPHT zones (Wang et al., 2012; Abdo & Haneef, 2013).

- Recommendations for Best Practices

Based on the research findings, the following best practices are recommended for HPHT drilling fluid formulation:

1. Prioritize High-Temperature Stability: The use of additives that maintain viscosity under extreme temperatures is essential for preventing fluid loss and wellbore instability. This includes thermally stable polymers and clay nanoparticles that provide consistent performance (Godwin et al., 2011; Kaminski, 2013).
2. Incorporate Environmentally Friendly Components: In line with environmental regulations, using biodegradable components such as potassium formate-based brines and organic surfactants has proven effective for enhancing environmental compliance without compromising on performance (Hayisani, 2013; Caenn et al., 2011).
3. Optimize Fluid Rheology for Safety: High-pressure additives, such as manganese tetra-oxide, are recommended for maintaining fluid density and well control in HPHT zones, reducing blowout risks and ensuring consistent pressure management (Al-Saeedi et al., 2010).
4. Implement Rigorous Pre-Drill Testing: Pre-drill laboratory tests simulating HPHT conditions are essential for verifying the fluid's properties, enabling proactive adjustments to formulation for specific field requirements (El Essawy et al., 2004; Gallino et al., 2001).

These best practices can help ensure drilling fluids in HPHT wells meet the demands of high thermal and pressure stability, environmental safety, and operational efficiency, positioning them as integral to sustainable drilling practices in extreme conditions.

CONCLUSION

- Summary of Findings

It showed in this study that molecule tailored drilling fluid systems improve safety, productivity, and environmental impact of HPHT well operations. These experiments on simulated HPHT conditions revealed that biodegradable polymers acting as friction reducers or thickeners, clay nanoparticles, high-density brines all provide an improvement in thermal stability and wellbore integrity together with a much-reduced environmental impact. The study establishes that drilling fluids can be effectively formulated to not only satisfy increasingly rigorous safety issues relating to drilling operations, as well as environmental standards that apply to HPHT drilling of wells as recognized by Wang et al., (2012) and Abdo & Haneef (2013).

- Limitations and Future Research Directions

the best of the researcher's knowledge, the present study is rigorous, though imperfections are recognised to some extent. The formulations tested were limited to a particular range of HPHT conditions, so an extension of the study to other pressures and/or temperatures should be made in the future. Furthermore, field tests performed across diverse geographical regions would improve consideration of the interaction of the environment with certain additives. Other possible areas for further research includes assessing how real-time monitoring technologies like sensor-mounted drilling fluids as could supply real time Fluid information for dynamic formulation adjustments (Shadravan & Amani, 2012b; Apaleke et al., 2012b).

- Final Remarks on Industry Implications

The developments in drilling fluid technology discussed in this survey also support that formulation design plays a significant role in HPHT wells. Appropriate drilling fluids should be chosen to improve thermal stability of the drilling fluids, reduce the effects on the environment as well as ensure operational safety during the operation of the drilling fluids in the drilling industry to fuel the achievement of sustainable and efficient drilling. This is in line with general industry objectives of reducing environmental impacts during exploration and production while operating effectively in more complex well environments. By employing these optimized formulations in implementing the new technology, future exploration and production in high-risk HPHT fields will be set in view, thus conforming to safe and sustainable drilling values in extreme climes (Khodja et al., 2010b; Al-Saeedi et al., 2010; Gao et al., 2000).

REFERENCES

[1] Shadravan, A., & Amani, M. (2012). HPHT 101-what petroleum engineers and geoscientists should know about high pressure high temperature wells environment. Energy Science and Technology, 4(2), 36-60.

[2] Shadravan, A., & Amani, M. (2012, December). HPHT 101-what every engineer or geoscientist should know about high pressure high temperature wells. In SPE Kuwait International Petroleum Conference and Exhibition (pp. SPE-163376). SPE.

[3] Tehrani, A., Gerrard, D., Young, S., & Fernandez, J. (2009, April). Environmentally friendly water-based fluid for HPHT drilling. In SPE International Conference on Oilfield Chemistry? (pp. SPE-121783). SPE.

[4] Oriji, A. B., & Dosunmu, A. (2012, February). Design and application of drilling fluids for HPHT well-a case study of mafia field. In SPE North Africa Technical Conference and Exhibition (pp. SPE-151642). SPE.

[5] Khodja, M., Khodja-Saber, M., Canselier, J. P., Cohaut, N., & Bergaya, F. (2010). Drilling fluid technology: performances and environmental considerations. Products and services; from R&D to final solutions, 227-256.

[6] Wang, F., Tan, X., Wang, R., Sun, M., Wang, L., & Liu, J. (2012). High temperature and high pressure rheological properties of high-density water-based drilling fluids for deep wells. Petroleum Science, 9, 354-362.

[7] Gao, E., Booth, M., & MacBeath, N. (2000, February). Continued improvements on high-pressure/high-temperature drilling performance on wells with extremely narrow drilling windows-experiences from mud formulation to operational practices, shearwater project. In SPE/IADC Drilling Conference and Exhibition (pp. SPE-59175). SPE.

[8] Karakolias, S., Kastanioti, C., Theodorou, M., & Polyzos, N. (2017). Primary care doctors' assessment of and preferences on their remuneration: Evidence from Greek public sector. INQUIRY: The Journal of Health Care Organization, Provision, and Financing, 54, 0046958017692274.

[9] Karakolias, S. E., & Polyzos, N. M. (2014). The newly established unified healthcare fund (EOPYY): current situation and proposed structural changes, towards an upgraded model of primary health care, in Greece. Health, 2014.

[10] Lionis, C., Papadakis, S., Tatsi, C., Bertsias, A., Duijker, G., Mekouris, P. B., ... & Greek QUALICOPC team Ioannis Dakoronias Sah Hamid Alexandros Aristofanes Paganas Dimitrios Ellinas Vesela Polyzou Ioannis Lentzas. (2017). Informing primary care reform in Greece: patient expectations and experiences (the QUALICOPC study). BMC health services research, 17, 1-13.

[11] Polyzos, N. (2015). Current and future insight into human resources for health in Greece. Open Journal of Social Sciences, 3(05), 5.

[12] Abdo, J., & Haneef, M. D. (2013). Clay nanoparticles modified drilling fluids for drilling

of deep hydrocarbon wells. Applied Clay Science, 86, 76-82.

[13] Godwin, W., Ogbonna, J., & Boniface, O. (2011, July). Advances in mud design and challenges in HPHT wells. In SPE Nigeria Annual International Conference and Exhibition (pp. SPE-150737). SPE.

[14] Kaminski, L. (2013). Increasing the temperature stability of environmentally friendly drilling and completion fluids based on organic brine (Doctoral dissertation).

[15] Wan Mahmood, W. A. (2012). Optimization of the Feldspar Usage in High Temperature Drilling Fluid (Doctoral dissertation, Universiti Teknologi Petronas).

[16] Oakley, D. J., Morton, K., Eunson, A., Gilmour, A., Pritchard, D., & Valentine, A. (2000, September). Innovative drilling fluid design and rigorous pre-well planning enable success in an extreme HTHP well. In IADC/SPE Asia Pacific Drilling Technology Conference and Exhibition? (pp. SPE-62729). SPE.

[17] Downs, J. D., Blaszczynski, M., Turner, J., & Harris, M. (2006, February). Drilling and completing difficult HP/HT wells with the aid of cesium formate brines—a performance review. In SPE/IADC Drilling Conference and Exhibition (pp. SPE-99068). SPE.

[18] Salim, P., & Amani, M. (2013). Special considerations in cementing high pressure high temperature wells. International Journal of Engineering, 1(4), 2305-8269.

[19] Al-Saeedi, M. J., Al-Khayyat, B., Al-Enezi, D., Aslan, A., Luzardo, J., & Carrera, C. (2010, January). Successful HPHT application of potassium formate/manganese tetra-oxide fluid helps improve drilling characteristics and imaging log quality. In SPE Deep Gas Conference and Exhibition (pp. SPE-132151). SPE.

[20] Hayisani, B. (2013). INVESTIGATING THE VIABILITY OF LOCAL VEGETABLE OIL AS BASE FLUID FOR DRILLING HPHT FORMATION.

[21] Payne, M. L., Pattillo II, P. D., Miller, R. A., & Johnson, C. K. (2007, December). Advanced technology solutions for next generation HPHT wells. In IPTC 2007: International Petroleum Technology Conference (pp. cp-147). European Association of Geoscientists & Engineers.

[22] Karakolias, S. E., & Polyzos, N. M. (2014). The newly established unified healthcare fund (EOPYY): current situation and proposed structural changes, towards an upgraded model of primary health care, in Greece. Health, 2014.

[23] MOHD SHABARUDIN, E. S. (2013). Polypropylene Glycols Surfactant as Additives Drilling Fluid for Injection Well in LPLT And HPHT Environments.

[24] Apaleke, A. S., Al-Majed, A., & Hossain, M. E. (2012, February). Drilling fluid: state of the art and future trend. In SPE North Africa Technical Conference and Exhibition (pp. SPE-149555). SPE.

[25] Ye, Y., WenHua, A., ShuQi, W., & FaQian, L. (2010, June). Drilling fluid challenge during the ultra-deep HT/HP/HS drilling in the mountainous area, tarim basin. In SPE International Oil and Gas Conference and Exhibition in China (pp. SPE-131533). SPE.

[26] Gallino, G., Migliori, M., & de Cindio, B. (2001). A rheological approach to drill-in fluids optimization. Rheologica acta, 40, 196-203.

[27] Khodja, M., Khodja-Saber, M., Canselier, J. P., Cohaut, N., & Bergaya, F. (2010). Drilling fluid technology: performances and environmental considerations. Products and services; from R&D to final solutions, 227-256.

[28] Abdo, J., & Haneef, M. D. (2013). Clay nanoparticles modified drilling fluids for drilling of deep hydrocarbon wells. Applied Clay Science, 86, 76-82.

[29] Khodja, M., Canselier, J. P., Bergaya, F., Fourar, K., Khodja, M., Cohaut, N., & Benmounah, A. (2010). Shale problems and water-based drilling fluid optimisation in the Hassi Messaoud Algerian oil field. Applied Clay Science, 49(4), 383-393.

[30] Hall, J. (2005, September). Designing the Perfect Drilling Fluid Additive: Can It Be Done?. In SPE Asia Pacific Health, Safety, Security, Environment and Social Responsibility Symposium? (pp. SPE-95196). SPE.

[31] Goud, M. C., & Joseph, G. (2006, October). Drilling fluid additives and engineering to improve formation integrity. In SPE/IADC Indian Drilling Technology Conference and Exhibition (pp. SPE-104002). SPE.

[32] Apaleke, A. S., Al-Majed, A., & Hossain, M. E. (2012, February). Drilling fluid: state of the art and future trend. In SPE North Africa Technical Conference and Exhibition (pp. SPE-149555). SPE.

[33] Caenn, R., Darley, H. C., & Gray, G. R. (2011). Composition and properties of drilling and completion fluids. Gulf professional publishing.

[34] El Essawy, W. M., bin Hamzah, R., Malik, M. M., Knox, D., Monem, M. R., & Oswald, R. J. (2004, September). Novel application of sodium silicate fluids achieves significant improvement of the drilling efficiency and reduce the overall well costs by resolving borehole stability problems in East Africa shale. In IADC/SPE Asia Pacific Drilling Technology Conference and Exhibition? (pp. SPE-88008). SPE.

[35] Gao, E., Booth, M., & MacBeath, N. (2000, February). Continued improvements on high-pressure/high-temperature drilling performance on wells with extremely narrow drilling windows-experiences from mud formulation to operational practices, shearwater project. In SPE/IADC Drilling Conference and Exhibition (pp. SPE-59175). SPE.