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Comprehensive Analysis of Water Based Emulsion Drilling Fluids in GHARRAF Oil Field in Southern Iraq: Properties, Specifications, and Practical Applications

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ABSTRACT

The WBM's viscosity, gel strength and ability to filter and control the filtration rate are central to the stabilization of the well bore as well as the transportation of the cuttings to the surface. WBM is comprehensively inexpensive and eco-friendly; it does not hinder the biodegradation process as compared to other chemicals that may be used in the drilling involving rig activities. It cans thermally change, regulate formation pressure, and support cuttings. WBM is also can be used in all types of formations and is not complicated in terms of its handling as well as disposing as compared to other drilling fluids. However, WBM has some limitations as it is influenced by shale hydration, formation water salinity and thermally less stable at high temperature formations. Hindered by formation solids, fluid loss to the formation and formation damage are other issues that must be dealt with efficiently during the drilling process using WBM. WBM is used in most practices of drilling especially in offshore drilling areas, environment sensitive areas, and areas that have certain restrictions on the types of fluids to be used in drilling. Effectiveness and flexibility in relation to various platforms and various rigs make it a prime candidate for the most orthodox as well as the most innovative operations. Some of the regular water based muds that are often in use are Spud mud, Low solid polymer mud KCl, PHPA polymer mud KCl, Glycol polymer mud, Salt Saturated mud and Drill – in mud.

1. INTRODUCTION

During the last few years, oilfield technology has advanced significantly for making drilling operations more favorable, both on-land and offshore, in support of the world energy supply. In this aspect of oil and gas explorations, drilling fluids play a vital role and are considered as an important category of chemicals used [1]. They come in direct contact with the geology of the borehole and provide essential support for oilfield drilling operations by lubricating drilling bits, carrying drilling cuttings, and maintaining the stability of boreholes, the integrity of formations, and minimizing differential sticking—a problem in deviated cased wells. Moreover, they help in controlling downhole pressures, sealing permeable formations, and cooling and cleaning the drilling bit and the borehole [2]. It is obvious that without drilling fluids, the objectives of drilling an oilfield, which can lead to the largest and most important recoverable resource worldwide, would be impossible [3]. Water based muds (WBM) are environmentally favorable drilling fluids, and they are the most widely used drilling fluids. Significant advantages, which have made these fluids so popular, are: mud densities are easily kept in the range of 7–9.5 pounds per gallon (lb/gal) due to economic and environmental concerns; overall cost control is better than oil- and synthetic-based drilling fluids; it is usually simple to maintain WBM shale stability by means of wellbore stabilization; all additives can be readily mixed and halt; it is a basic requirement that additives should have equitable performance in hard water (20,000 ppm) conditions [4]. Furthermore, health and safety requirements are simple to fulfill. The use of WBM in domestic onshore fields has always been important. For environmental legislation, the commitment to WBM is second to none. They are often preferred for drilling protected environmental regions as the U.S. permits water to be the drilling fluid in environmentally sensitive coastal and inland waters [5].

The advancement of water based emulsion drilling fluid technology has generally been around acid, salt, or supplemented bentonite. The remarkable research work undertaken in this area has been presented. Comprehensive literature has been surveyed for gathering required information regarding the formulation, performance, field applications, advantages, and specifications of the water based emulsion drilling fluid. The work has been discussed and coordinated into analysis, presentation, formulation screening, and experimental investigation for laboratory development. With regard to performance in sum, the comprehensive investigation leading to laboratory development and field applications successfully indicates that the water based emulsion drilling fluid has significant potential for use in ready-to-use, cost-effective, and environmentally friendly drilling fluid systems. After the developments are carried out, several well tests have been undertaken to evaluate the performance of the water based emulsion drilling fluid in drilling operations. The field applications indicate that the water based emulsion drilling fluid can not only effectively lubricate the drill bit but also prevent lost circulation, easily wash the rock cuttings as showed Figure 1, and stabilize the borehole wall. The emulsion could be prepared either by mechanical agitation or mixing and high-shearing. The emulsification of water in oil takes place with the reduction of the droplet size under high energy. Mechanical emulsification requires large machines, while the latter is practically widely used in the preparation of laboratory formulations. Continuous mixers can be thought of as high-shear devices with narrow piping configurations, where the energy input is between centrifugal and peristaltic types of mixers. Quality control of petrolatum emulsions is important for the application; control value is the sabotage of drill pipes due to the formation of tarry deposits. The drilling fluid viscosity is divided into the useful and the monomeric viscosity; the latter is very important for the preparation of stable emulsions. The diluted dynamic viscosity is recommended as the raw emulsion is prepared first, and it is then diluted with diesel oil to the required ratio and viscosity. Commercial water based emulsions are adjusted to address operational difficulties. Surfactants having a high valence are capable of forming thermodynamically stable emulsions, oil emulsification occurs, and specific gravities of emulsions are higher than that of water.

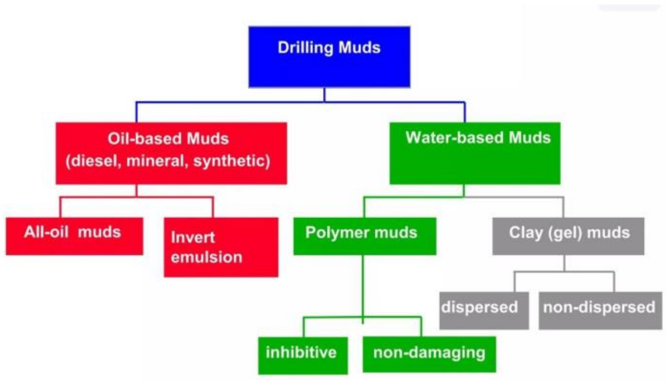

Figure 1. Flowchart showing the different type of drilling mud based on the type of base fluid [6]

1.1 Background and significance

During drilling operations, cooling, cuttings removal, suspending and lubrication of the bit, cleaning, and transportation of the rocks to the surface take place. In order to achieve these goals, the drilling fluid should have suitable properties. The fluids used in drilling operations are classified according to their basic functions as flushing, protective, and suspending fluids and as water based and oil-based [7]. Water fluids have the undesirable feature of swelling clays and blocking pore channels, creating high filtration pressures, reducing the well-bores' stabilities, and reducing the fluid holding capabilities of the fluid. However, the most widely used drilling fluid in the world is a type of water based drilling fluids that are usually prepared from natural clays [8]. These clays are used for cooling lubricant fluids at the top of the drill pipes, adding weight to the well bore, containing the circulation pressure, facilitating the waste removal from the well-bore, and preventing the eruption and caving of the pipes.

The point is that the components of unwanted water fluids are replaced by water based substances with a structure similar to betonies. It has presented different water based mud systems such as polymer mud, xanthan gum, guar gum and their derivatives, etc. In this study conducted to stabilize tactic, sepiolite-containing water based drilling fluids were used [6]. Parameters that should be considered in designing a fluid include the nature of the rock and the presence of hydrocarbons, the properties of the formation water from the well, the hydraulic stability of the fluid, the desired properties in the suspension, the physiological effects of the fluid on the components and the environment at the wellhead, and the security and ease of using the fluid at different times in the well work [9]. Due to the physical and chemical sensitivity of the drilling fluid to changes in the properties of the mud system, the objectives set for a fluid and the conditions in the borehole should be taken into consideration and intended results should be achieved.

1.2 Scope and objectives

This project is formulated to address different problems related to water based emulsion drilling fluids (WBM) formulated with ester as the external phase. The emphasis is on understanding the various chemical, physical, and rheological properties. The study has laid the foundation for formulating new generation drilling fluids based on dispersion technology for difficult drilling environments. The objectives achieved in this project include understanding the importance of variables and determining their constraints in relation to the final properties of drilling fluids [10]. New generation water based emulsion drilling fluids are versatile and have been successfully formulated and tested in the laboratory. Water based emulsions are designed to be tailored by the addition of polymers to reach the optimum density, shear rate, gel strength, thixotropic, and filtration loss properties. The filtration loss of water based emulsions is comparable with or exceeds that of oil-based or synthetic-based drilling fluids [11].

Oil-based drilling fluids have traditionally been preferred over water based drilling fluids because of their improved technical performance, flexibility, environmental benefits, and economic efficiency, especially in harsh drilling conditions. With the present emphasis on environmental responsibility and economic concerns, the acceptable level of permissible discharges and the need to take safety, health, and wellbore stability into account, a major effort has been made to implement research aimed at developing new generation water based drilling fluids with enhanced performance properties, which meet the requirements of deep water locations [12]. The use of water based emulsion drilling fluids for high-performance drilling applications has taken on renewed importance. Water based emulsion drilling fluids are designed to improve technical performance compared with conventional water based systems that were developed with surfactants and liquid-liquid emulsion technology [13].

2. FUNDAMENTALS OF DRILLING FLUIDS

Drilling operations can be done in various ways. However, the application of water, oil, or synthetic-based emulsion fluids has increased in oil and gas production zones. In this chapter, the basic knowledge of various types of drilling fluids and general properties has been elaborately discussed. The development of emulsion drilling fluids has been broadly reviewed.

Drilling fluids are materials used during drilling operations for many purposes. Essentially, fluids have to prevent or limit the contamination of water, soil, or groundwater aquifers that will be traversed by boreholes passing near or through these formations [14]. These fluids, in essence, must be non-deleterious. Therefore, the development of fluids adequate for this task ranks high in the scientific community. The first and most important point concerning the use of a specific drilling fluid is to define the requirements of this drilling fluid [15]. The most important properties to be considered are the type of drilling operation, temperature requirements, blasting particularities, compatibility of the drilling fluid with the drilling process, and some other requirements like type and concentration of additives, density range, filtration volume, rheological considerations, and encrustation effects, presence of water-sensitive or reactive minerals [16].

2.1 Types of drilling fluids

There are two major types of drilling fluids to be considered:

1. Water based drilling fluids: These systems are formulated by using water as the basic dilution phase and other materials as additives, which may be both soluble and insoluble in water. Other water based systems are named non-aqueous. Figure 2 illustrates common for the purpose of comparing the characteristics and performances of water based and oil-based drilling fluids.

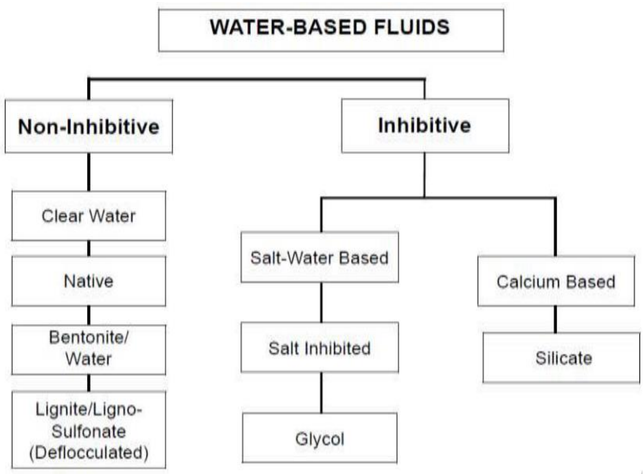

Figure 2. Water based fluids

2. Oil-based drilling fluids: These systems, like their counterpart, are formulated through the handling or mixing of oil and other additives— both soluble and insoluble in oil.

In conclusion, a water based drilling fluid is a circulating fluid containing water, whereas an oil-based or non-aqueous drilling fluid is a system containing oil. Due to the growing environmentalist attitude of wide sectors of the population and the national governments of almost all countries, it is necessary to consider the water based systems, the care for using water efficiently, and the reuse of water circulating in the drilling process [17]. In the development of water based emulsion drilling fluids, the main objective is to diminish the swelling capacity of clays due to the presence of water in its composition, preventing or reducing the dispersion of these clays. Other important factors to be observed for these systems are the control of the fluid density, the stability of the fluid, the moisture (content of water), and the reduction of filtration volumes. Throughout the entire section, the drilling fluid systems given as examples are related to water based systems in order to introduce the water based emulsion drilling fluids [18].

2.2 Importance and functions

Drilling fluid stability is one of the crucial properties during drilling operations. Therefore, any change in drilling fluid stability can have vital effects in drilling operations. Drilling is conducted during the production of oil, natural gas, and water or drilling in different areas like mining. If the drilling operations are not feasible, it may not reach the purpose of the operation. Drilling fluids can be utilized as energy supplies in the load-imposed area in formations where the pressure is below the hydrostatic pressure and for the removal of detritus formed. It also has another function, the transport of cuttings from the bottom of the well to the surface by utilizing the hydrostatic pressure present in the fluid, or by the velocity generated [19]. The fluid also makes it feasible to maintain a positive pressure at the surface to keep fluids or gases present in the underground in the formations. Moreover, it also provides specific drilling fluid properties to safeguard the whole stability and prevent fluid losses which can be due to the collapse or hydration of the formation. The formation can encounter damage if promised by the solid constituents like drilling fluids.

Water based emulsion drilling fluids can be used in various areas for different purposes. They are the most preferred types of drilling fluids. The use of these fluids is preferred based on various advantages, such as less well-bore damage, lower cost, and the ability to meet the environmental regulations. However, it is not ideal for every drilling operation. In special drilling applications, including wells drilled through particularly known unstable formations, water based drilling fluids can be avoided in order to circumvent certain contributing events to the instability and the resultant formation damage. In some formations, swelling type clays and other hydration sensitive formations may be found [20]. To overcome well-bore instability caused by swelling type clays, both the properties of fluid walls and the hydrous salt can be taken into consideration. In summary, WBM drilling fluids have a wide range of applications in surface or underground engineering construction, requiring tailor-made modifications for various industrial purposes, such as water-blocking screens, plugging agents for water loss in tunnels, and backfill substances.

3. WATER BASED EMULSION DRILLING FLUIDS (WBM)

A water based emulsion is a mixture of water with oil for three or more components and other raw material ingredients. There are essential oils and non-essential oils in a water based emulsion. Essential oils act as emulsifiers to allow the combination of water and other oil ingredients in the product formula to form the emulsion. Non-essential oils are included in the product to add moisture, lipids, and other nourishing and hydrating ingredients. However, too much of the oil phase may lead to a poor water quality emulsion that leads to some safety hazards related to the instability and incompatibility of WBM with oil well formation. Hence, Figure 3 formulated WBM as direct, invert, and multistage emulsion systems to meet field requirements.

Figure 3. Mud balance

Figure 4. De-sander

Saline water based emulsion drilling fluids (WBM) are systems wherein the proportion of water and emulsified external phase is much less than 60% water content by volume. Saline WBM, thanks to its rich properties, including high temperature and high-density tolerance, is commonly utilized in the current oilfield. The development of the drilling method has made it possible for the oil and gas fields to operate optimally. Because of that, WBM has recently become more popular and available as an environmentally conscious option as well due to environmental concerns being high. Although WBM possesses an increasing number of advantages over non-aqueous drilling fluids (NAEs) as showed Figure 4, it still has volatility problems that are severe in the upper shale while encountering the recycle conditions of dispersed solids [21]. To rein in the problem, some solid-control management methods and techniques, as well as circuits and processes, have been developed. Additionally, WBM is formulated with key substances as emulsifiers and inverse emulsifiers. The combination of the key substances in the formulation and the sequence of addition, high shear mixing, high temperature, and pressure conditions throughout the entire drilling operation will affect the drilling dynamics and drilling engineering input costs [22].

3.1 Definition and composition

Aqueous fluid systems are an essential category of drilling fluids in drilling operations, which supply the required hydrostatic pressure and cool the drill bit. These fluids can affect the stability of the wellbore and have other significant impacts on the evaluation of the formation. Aqueous drilling fluids can be divided into water based drilling fluids, oil-in-water emulsion drilling fluids, and water-in-oil emulsion drilling fluids. In recent years, water based fluids have become the predominant category owing to their lower environmental impact compared with oil-based fluids. The WBF systems typically require the optimization of the properties to meet different demands under various drilling conditions. As a critical component, the emulsion has an important impact on the properties and performance of WBF. In this survey, we detail the composition of WBM by summarizing the main features of the water phase, the dispersed phase, emulsifiers, viscosities, fluid loss reducers, and some additives. Emulsification, emulsion stability, rheology, and filter loss of WBM that contain the non-ionic and anionic emulsifiers are also presented.

Over the years, many methodologies and experimental studies have been performed by scholars to improve the drilling fluid performance for WBM by adding the right amount of emulsifier and compound based on emulsion stabilizer, fluid loss additive, rheology modifier, and corresponding adjustment of solid phase content. However, the questions of how to achieve several excellent characteristics such as the minimum emulsion phase volume, maximum emulsion intactness, maximum rheological and fluid loss property, and minimum consumption of chemicals, which are the focus of many research groups, are worth exploring and solving to develop excellent drilling fluids under current complex situations. Careful selection of these components and their amounts and forms may, to a certain extent, meet the design and demand of drilling projects.

Water based mud density must be adjusted to gelling formation pressures and must balance the borehole stability with the formation drilling rate as showed Figure 5. Density varies with the proportion of solids, such as baryte or bentonite. The first contributes to the volumetric increase of the mud and the second to the densification of the mud system, as a function of the mud purity. At the beginning of a drilling operation, the density of the mud is frequently below the density of the gravel containing formation "balancing the gravel," or it may be balanced with the overburden pressure. Gravel volume can be determined from well information anticipated from the drilling process. Even if the drilling idea or first pass is a dry run, drilling began for the field experience. Often, borehole security problems have involved high pressures occurring where the formation contains fluid and low pressures occurring where insufficient rock bonds exist to allow hole independence. These "bridging" and "balancing" techniques have sometimes entailed temporary clogging of the mud cake, bit balling, wedging, sticking, or reaming of the hole by the drilling assembly.

Figure 6 is investigated analysis is obtained by measuring the following parameters: loss of filtration and density (density, sodium chloride, calcium chloride, chromium lignosulphonate, walnut shell, and starch, bentonite, and PAC LV prices). The wet properties of mud are measured using a mud balance. Viscosities are measured using a six-speed viscometer, filtered return, and APARATUS LPLT HTHP. The methods are briefly discussed and reviewed for each of these measurements.

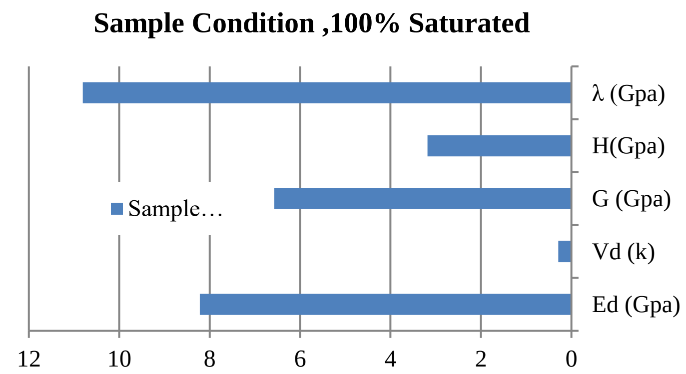

Figure 5. Weighted salt saturated mud [14]

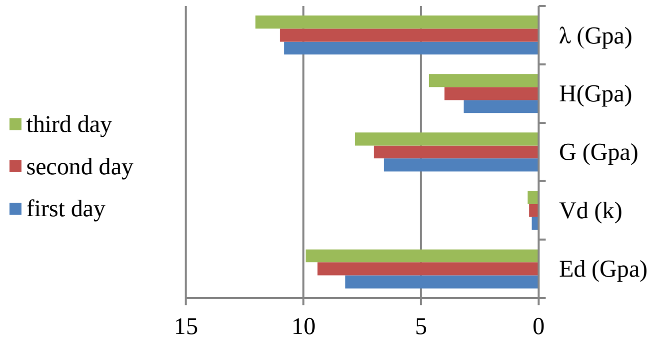

Figure 6. The formulation for mixing drill-in mud, the strength alteration with the extended time of mud interaction

WBM quality control aims to prevent mud from deteriorating and losing its properties in circulation, particularly when it is a well-controlled drilling fluid in terms of viscosity, filtration, density, and the properties of the mud sludge at the borehole variance, particularly the rheological properties.

The WBM is generally formulated from bentonite, additives (calcium chloride, sodium chloride, chromium lignosulfonate, walnut shell, starch, PAC LV, etc.), sulfuric and hydrochloric acids. They are placed on the surface to be transported to the drill site in concentrate form. These additives ensure the density of the fluid, maintenance of filtration rate and loss of fluid, groove stability, the suspension of cuttings, cleaning of the well, protection of the wall of the well against hole problems and pressure loads, and transporting the cuttings from the bit to the surface without premature wear on the drill stem or pump elements. These are the properties of an efficient drilling fluid.

The chemical properties of drilling mud and the measurement procedures used to evaluate these properties (density, filter loss, rheology) were determined. The data provided by the tests and the specifications of these tests for the mud control are shown. The mud properties must fall within the standard range of specifications; otherwise, the base may be adjusted. The methods and specifications of standard tests are detailed in the three following sections.

Formation A:

Formation pressure of sand A = 0.48 x 5500 = 2,640 psi with over balance of 250 psi, the hydrostatic pressure required is 2,890 (2640 + 250) psi. Convert pressure into mud weight = 2890 ÷ (0.052 x 5500) = 10.2 ppg.

Formation sand B:

Formation pressure of sand B = 0.49 x 8800 = 4,312 psi with over balance of 250 psi, the hydrostatic pressure required is 4,562 (4312 + 250) psi. Convert pressure into mud weight = 4562 ÷ (0.052 x 8800) = 10.0 ppg The effect of the oil/water ratio can be observed in Figure 6 which shows an increase in emulsion viscosity as the oil content is increased. A slight increase existed in emulsion viscosity at 30% deionized water content to 40%. At the oil/water ratio 50%/50%, a significant increment in the water content causes a material falling down in the emulsion viscosity. Changes in emulsion viscosity at a lower oil/water ratio could be attributed to coalescing of water droplets through shearing forces while a lower viscosity at a larger water component to the abound surfactant preventing flocculation and subsequent eccentric steering effect. Therefore, 40% oil is a suitable oil-to-water ratio for fresh oil-based emulsified Nano drilling fluid with a suitable behavior in the storage stability of a prototype system at a negligible cost and the theoretic support validates the simulated results.

In the Gharraf oil field of Thi-Qar Oil Company, the first and second bore fields are made using water based clay as follows. Figure 7 shows the simulation of drilling proses:

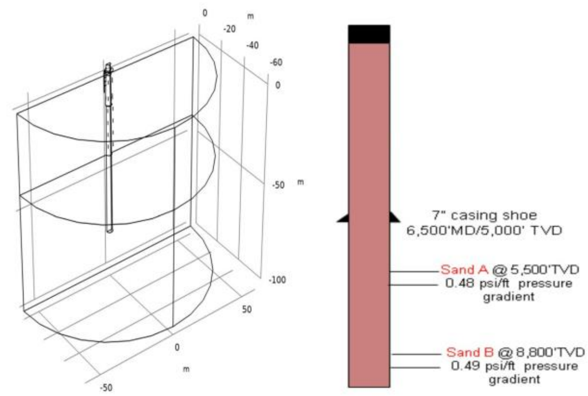

Figure 7. 3D modeling of drilling prosses

1- Betronite mud

Betronite mud is used in the first cavity instead of water to avoid loss of fluids and to reinforce the wall of the well from collapsing, as the mud has a high viscosity to clean the well and transfer the rock fragments from the bottom of the well to the surface. This is because the drilling speed is high in addition to the large size of the first cavity.

Table 1. Betronite mud mixed [14]

Product	Function	Percentage
Bentonite	Viscosifier	25-60
Sods ash	Hardness reducer	0.64-1.43
Caustic soda	Alkalinity control	0.5-4
Fluid loss control	PH stability	2.0-3.3

Preparation method: The mud is prepared by mixing water and bentronite with some additives to obtain the appropriate clay properties for drilling the first cavity, as shown in the Table 1.

2- Lime polymer

This type of mud is used in drilling the second cavity, where hydrophilic layers containing calcium such as anhydrite are drilled. The proportions of materials used in its preparation are as shown in the Table 2.

Table 2. Lime polymer mixed

Chemical	Function	Percentage lb./bbl.	Percentage kg/m^3
Lime	Ca^{28} provision	2.85-5.70	10-20
Gypsum	Ca^{2} provision	3.86-6.32	11-18
FCLS	Thinner	1.05-4.20	3-12
SMT	Thinner & FL control	2.10-4.90	6-14
SMC	Thinner & FL control	2.10-4.90	6-14
KHm	Thinner & FL control	2.10-4.90	6-14
CMC	FL control	1.05-2.81	3-8
PAC	FL control	1.05-2.81	3-8
Starch derivative	FL control	2.10-4.90	6-14
SPNH	HTHP FL control	1.75-5.26	5-15
SMP	HTHP FL control	1.75-5.26	5-15
RH-3	Lubricant	2.85-10.5	10-30
Caustic soda	pH control	1.05-2.81	3-8

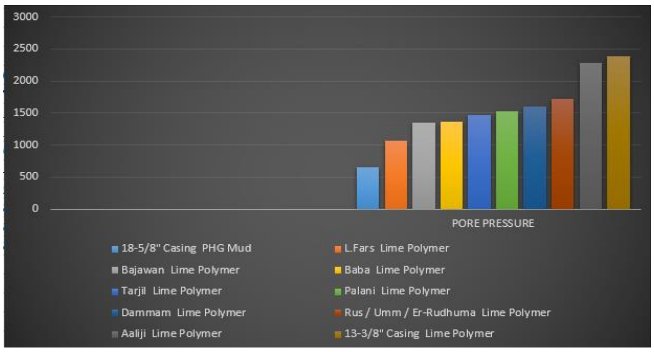

Figure 8. Mud type suitable for drilling each formation as well as the pore pressure for each formation

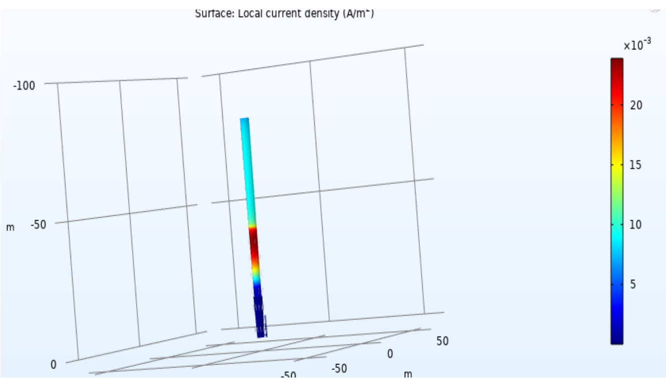

Figure 9. Each type of mud suitable for drilling each formation as well as the density of clay suitable for each formation

Figure 8 shows each mud type suitable for drilling each formation as well as the pore pressure for each formation We notice that pore pressure increases with increasing depth. We also note that the first section represented by 18-5/8 casing is drilled by PHG Mud. The second section, which represents the rest of the formation, is dug using lime polymer mud.

Figure 9 displays each type of mud suitable for drilling each formation as well as the density of clay suitable for each formation. We notice that the first section represented by 18-5/8 casing is drilled with a small amount of mud, which is 8.7ppg. As for the second section, which represents the rest of the formation, it is drilled with higher mud densities, starting from 9.3ppg to 9.5ppg, depending on the pore pressure of each formation.

3.2 Advantages and disadvantages

These drilling fluids have higher weighted solids when compared with oil-based drilling fluids and hence are used in the drilling of high pressure, high temperature wells. The only cost-effective version of the water based drilling fluids, which are used in a certain set of environments, is the water based emulsion drilling fluids. The oil phase can be expensive, and the addition of emulsifier, wetting agent, pH control agents, etc. increases the costs. The development of water based drilling fluids enabled drilling of high pressure, high temperature wells in an environmentally friendly manner. Especially the technology related to drilling fluids has developed a lot in the last 20 years, which put drilling fluids as high-performance drilling fluids [2].

Advantages and Disadvantages Water based drilling fluids are very effective in preventing borehole instabilities and have very few environment-polluting properties. They are biodegradable, stable at down hole conditions, and provide excellent inhibition to clays, shale's, and rock formations. These fluids are found to control filtrate loss effectively and can easily be maintained in the specific gravity. These drilling fluids are used in high pressure, high temperature wells, deep water wells, and UBD wells. The significant advancements in the additives and developments in the solid-free systems have improved the performance of the water based drilling fluids. The water based drilling fluids provide better lubricity, exceptional thermal stability, minimal reactive clays, etc. The lower prices of the raw materials and simpler system have substantially decreased the net expenditure on the drilling fluids.

4. RHEOLOGICAL PROPERTIES OF WBM

Rheology is the study of the deformation and flow of matter under the influence of an applied force. The rheological behavior of WBM is important in drilling operations in order to improve hole cleaning, thus preventing drilling mud flapping, reduce consumption of drill string torque, help minimize the formation of cuttings rather than shale dispersion, and improve the flow regimen of the cutting transport. When choosing a WBM, it is important to consider the rheological behavior at rest, at rotation, and in dynamic conditions. The relative importance of rheological properties in different applications depends on different factors such as type of well, depth, temperature, circulation velocities, and equipment used for mud processing and elevation. Various laboratory and simulation approaches are available to investigate and predict the behavior of WBM within different laboratory environments.

Common techniques to simulate the shear conditions in a drilling hole are by using the viscos meter in a static or dynamic mode, stress ramp, and flow loop. The dynamic stability of the fluid within a circulating environment is determined in a good approximation by the filtration coefficient. The pressure loss of WBM in the annulus depends on the apparent viscosity. The behavior of WBMs during drilling and pressure loss in the well are also influenced by the yield point and plugging index, such that limiting values are recommended in relation to the dynamic flow condition. The ultimate tensile strength determines the cohesion of WBMs and thus the capacity to maintain a stable wall. The consistency index and flow index of WBMs are established by the model of Herschel-Bulkley. This is a simple and practical method to understand the flow of WBMs and calculate their characteristics.

4.1 Viscosity and yield point

This parameter is used to indicate the flow and effectiveness of the emulsion fluid. There are two types of this parameter, namely: dynamic viscosity and plastic viscosity. Dynamic viscosity is a measure of the amount of force required for a material to maintain a constant velocity at a constant temperature over a specific time period. On the other hand, the other factor, that is, the plastic viscosity, is the descending portion of the flow curve, or a segment that follows Newton's law of fluids that are being removed for the sample, usually expressed in centipoise (Cp) or milli-pascal second (mPas). The result in low and yield number properties is given back to fluids.

4.2 Gel strength

The structure of a fluid shows the ability of the fluid to transport fluids and cuttings. The gel strength is important at such times as circulating and tripping, when pressure differentials can cause formation of contaminants or fall of cuttings in the well, causing be stuck with the column. The fluid gel strengths measurements are made 10 seconds test, called gel strength 10 – seconds (10 sec), and the 10-minute test, by 10-minute called gel strength (10 min), whit wellhead temperature. To mineral-based muds, gel strength is inversely proportional flow a potential, where a gel strength increase indicates a fluid loss decrease; however, at water based muds, the flow increases with an increase in gel strength. Showed that the gel strength and breaking power of relax (gel strength 10 second and gel strength 10 minute) are required controlling cuttings suspension, especially at low annular velocities and concentrations in emulsion fluids with high density and less stable in the high-pressure can breakdown the emulsions and allow the recreation of the water based drilling fluids. In emulsions with high stability, low gel strength could have implications for the capacity for suspension of cuttings (solids). Therefore, there are other critical factors that should be formulated to allow optimal well control while preventing the solid plugging of the wellbore.

5. CHEMICAL AND PHYSICAL PROPERTIES OF WBM

Water based muds are the most commonly used muds. Besides, they have good lubrication and high performance. Today, many useful mud additives are marketed. The most important existing properties of the mud are obtained by these additional properties. To control and improve the mud properties, they should be used in the intended formulations and concentrations. These kinds of mud derivative products work in more than one way and have been produced by introducing more than one functional group. The following information is known in most of these materials: In more than one of these additives, some controlling activity might be expected as shown in the Table 3.

Table 3. Classification of drilling fluid systems [13]

Mud Type	Principle Component	General Characteristics
Aqueous		
Simple freshwater	freshwater	Low cost, onshore applications; fast drilling in stable formations; need space for solids settling, flocculants may be used
Simple seawater	seawater	Low cost, offshore applications
Spud mud	Bentonite, water	Low cost, surface hole
Saltwater	Seawater, brine or saturated saltwater; saltwater mud, starch, cellulosic polymer	Moderate cost, drilling salt and work overs
Lime or gyp	Fresh or brackish water; bentonite, lime, or gypsum, lignosulfonate	Moderate cost, shale drilling; simple maintenance, high temp, tolerance to salt, anhydrite, cement, drilled solids
Lignite or lignosulfonate (chrome or chrome free)	Fresh or brackish water; bentonite, caustic, lignite or lignosulfonate	Moderate cost, shale drilling; simple maintenance, high temp, tolerance to salt, anhydrite, cement
Potassium	Potassium chloride; acrylic, bio or cellulosic polymer, some bentonite	Moderate cost, hole stability; low tolerance to drilled solids, high pH
Low solids (‘‘non dispersed’’ when weighted up)	Fresh to high saltwater; polymer, some bentonite	High cost, hole stability; low tolerance to drilled solids, cement and divalent salts
No aqueous		
Oil	Weathered (oxidized) crude oil; asphaltic crude, soap, water 2–5%	Moderate cost, low-press well completions and workovers, low-press shallow reservoirs; water used to increase density and cuttings-carrying capacity; strong environmental restrictions may apply
Asphaltic	Diesel oil; asphalt, emulsifiers, water 2–5%	Moderate cost, any applications to 600^0F; strong environmental restrictions may apply

The mud, prepared using these derivatives, will have several activity levels than others. This derivative system, parts or full of the chemical products, which are ordered in large numbers groups (salts, ester, acid, amine, alcohol, or one of the surfactants), has relationships with these forms, and they have ionic properties in these regions. This kind of situation is present in a couple of the same groups (alkyl or aryl, for example) pop out. There are many multifunctional chemical agents. Their structures are in an octal feel a circle. They have a quite high-level hydro carbonic region structure in their structures. These make contacts possible in more than one of amphiphilic groups that disperse mud rheological problems, problems of propagation and filtrate, stabilization of rocks, emulsification of oil, and so on. WBM chemical mud parts are usually water-soluble, and they disperse faster than synthetic oil-based mud materials. This usually means that the chemicals quickly form a useful, three-dimensional integrated polymeric network, bridges the surfaces, disrupt the plates, and make them the premud additive substances. Due to the presence of many functions in the octa branch structures, the amphiphilic organics must not be treated as a dietary polymer to produce these same effects. Since each amphiphilic material is often two monomeric, such behavior should be kept in mind. Use of LLENVD derivatives and other appropriate components, especially replacing water based muds, requires significant amounts of research and product development.

5.1 Density and pH

It is well known that water based mud systems (WBM) can be less expensive, stable, and more environmentally friendly than oil based mud systems (OBM). In addition to density, rheological behavior, and filtration, the ionic content and pH degree play a significant role in the WBM properties. In the case of muds with high ionic content, these properties are directly related to the presence of cationic and anionic polymers, which are used in their formulation. However, in the case of muds with low ionic content, the presence of salts and potassium or sodium hydroxide is required to obtain a suitable pH for drilling, and therefore, preserving the clay particle stability and rheological properties. In addition, the formation's interstitial brine's potential reactivity with the clays present in complex geological formations must also be considered. In this sense, a well defined mud compatibility study should always be carried out in order to provide the adequate mud system with the highest efficiency to drill the geological formation as shown in the Table 4.

Table 4. The standard formulation for mixing spud mud [14]

Product	Function	Concentration ppb
Bentonite	Viscosifier	25
Sods ash	Hardness reducer	1.43
Caustic soda	Alkalinity control	0.5-1

5.2 Salinity and alkalinity

One nonstandard one can encounter is formation water salinity. As discussed before, ion exchange properties may bring about phase separation. However, most clays have a salinity limit which is significantly higher than that typically encountered in formation water. Alkalinity, on the other hand, is an important specification as it is directly related to the pH of the mud. For the primary purpose of high temperature stability, the mud pH must be kept at an optimum level. This is 9 - 10.5 for primary mud and 9 - 10 for the second grade. If the pH is much less than that, alum will start to degrade and release OH groups. It is these groups that are responsible for the bridging of organophilic clays into sheets. The final jelly becomes a soup.

The next to take note of is filtration control. In a saturated salt solution of the right salinity, a WBM filtration is typically 2 - 4 cc. However, due to the viscosification, salt and other clay contaminants could be held on the filter medium, dropping the final cake volume to 1 cc. Finally, it means a saturated salt solution of 10% has formed, and the drilling operator has an immediate additive response in its mixing water. Restricted properties of the mud's primary interest are always viscosity and gel strength. They are just as important as standard API muds. This is because they can hold cutting better than the thinnest API mud, and reduces erosion. It also helps in maintaining effective carrying capacity. After all, the mud exists to carry maximum tonnage. Anything that reduces its viscosifying ability is bad. However, other properties must be considered as well.

6. SPECIFICATIONS AND QUALITY CONTROL OF WBM

Water-based drilling fluids (WBM) are the most widely used in drilling. This type of fluid is employed to drill all types of wells, including oil, gas, and water, onshore or offshore, deep or slim hole, and development or injection wells. Protecting the environment, particularly avoiding polluting water sources such as rivers and lakes when using WBM, has become an essential feature of these systems.

The Table 5 discusses the quality control of water based drilling fluids, whose main purpose is to identify the quality and freshness.

Table 5. The standard formulation for mixing LSP mud [14]

Product	Function	Concentration ppb
Bentonite	Viscosifier	10-13
Sods ash	Hardness reducer	0.6
Caustic soda	Alkalinity control	0.45
Pas-lv	Fluid loss reducer	4
CMC-HV	Viscosifier	0.5
MD Mud detergent	Mud detergent	1.5
Lube	PH stability	0.643

6.1 API standards and testing procedures

The American Petroleum Institute (API) and the American National Standards Institute (ANSI) released recommended practices and standards for water based drilling fluids. The API standards were incorporated and extended efficiently to regulate the general aspects of undertaking with water based drilling fluids in the active form of what would be called "in-service" fluids. Associated laboratory testing practices for WBM are also given within API RP 13I and those for field testing are provided by API RP 13B-1 and 13B-2. Also, for those using hole size designations in the SI metric system, recommended test procedures and evaluation tests are presented by API RP 13L.

Drilling fluids, which are also popularly known as muds, are used to remove the drill cuttings and for the cleaning and cooling of the drill bit during the complex process of drilling wells to great depths in search of underground resources like gas, crude oil, minerals, thermal water, and so on. They also balance the pressure, thereby preventing the unexpected blow-off of high-pressure resources and preventing the collapse of the boreholes. Different types of muds are commercially available, such as oil-based muds, water-based muds, and gas-based or foam muds. There are several comparative advantages and disadvantages of these drilling fluids with respect to each other. A detailed comparative analysis of water-based emulsion drilling fluids with other types of drilling fluids is provided below:

Oil-Based Drilling Fluid: Oil-based fluids, such as invert emulsions, are preferable for drilling in highly temperature and pressure-sensitive formations, such as gas hydrates and geothermal formations, due to their superior thermal stability, low filtration loss, low friction, lubricity, and enhanced shale stability. However, an oil-based drilling fluid requires the use of toxic base oils or surfactants. Another disadvantage is a high polluting tendency, which limits their use in environmentally sensitive areas.

Water-Based Drilling Fluid: Water-based muds are the most commonly used drilling fluids for active wells due to their easy availability, economic feasibility, nontoxic nature, and easy disposal and cleanup. The cheapest rock-water systems, commonly used as water-based muds, are often found unsuitable for drilling due to excessive filtration and borehole collapse, especially in clayey and shale formations. Such drilling conditions require more expensive but eco-friendly and less toxic water-based emulsion systems than conventional drilling muds, such as sandy or spud muds. Generally, emulsions are adopted in reserves with excessive water ingress. Environmentally sensitive drilling, like gas hydrates, requires oil-in-water type emulsions to safely transport and store crude oil without environmental hazards. Oil-manipulated systems are preferable in ultra-deep formations since they can maintain pore pressure and inhibit clay swelling, even more than conventional invert emulsion systems.

Standard testing results cannot fully ensure the behavior of fluid in situ, but useful and beneficial correlations are readily established between fluid behavior in the laboratory and the actual performance in a given borehole, e.g., working rheology tests and offshore drilling success for deep water applications. Standard tests and published correlations for specific application are valuable to the drilling engineer for initial fluid selection and for the resolution of certain drilling problems. The standard testing methods require laboratory methods to be carried out on field sampled mud in air, so portable drilling rig mud testing equipment is available and widely used.

7. APPLICATIONS OF WBM IN DRILLING OPERATIONS

Water-based drilling fluids have environmental compatibility. Furthermore, they increase penetration rate, maintain wellbore stability, reduce fluid disturbance, and minimize problems of lost mud. Drilling fluids are made of a base substance, which is usually water, despite the term "oil" mud being often used. An addition of oil or synthetic material to the water should be significant enough to prevent the formation of emulsions under the severe conditions found in the deep hole of the well or to use as the external phase of the drilling fluid. Generally, when we use oil, prices tend to fluctuate widely because of problems worldwide. However, the problem with water is its high surface tension value. It is said that water has an apparent cohesion that allows the development of a strong and thick natural filter cake. Thus, many emulsions and foams are used in drilling fluids.

Drilling fluid formulation incorporates three generic systems: water based, oil- or synthetic-based, or gas, and so on. There are various types of drilling fluids used as base mud, such as unweighted mud, which is mud that has no solids added to it. It usually comes in three categories: Bentonite, Inhibitive or dispersion polymers, and combination. These additives frequently work together synergistically. This paper will provide a detailed study on the properties and optimization of water based emulsion drilling fluids and several related aspects.

7.1 Onshore and offshore applications

As for types (IOWEF), it can be applied for almost all fields such as drilling, completion, work over, coring, underground storage, reverse circulation, horizontal and deviated drilling, etc. And due to its better inhibitive property and its also balanced to High temperature High Pressure (HTHP) wells of having High Density. HPWBM will safeguard the Formation damage, enhance wellbore stability, raise the Rate of Penetration (ROP), and decrease the whole cost. Ensure good rate of penetration in sensitive formations. The clay platelets in whole mud will hold the drill cuttings but do not affect ROP while air and foam solutions will restrict the flow of drilled cuttings to the surface which will result in drop the ROP. The plastic muds present very high levels of fluid loss and having low level of wellbore stability related problems which can be solved by adding weighting agent to reach a higher level of filtrate control and also increased mud density at low range of shear rate and also to hold the drilled cuttings at high range of shear rate.

WBM is water and clay-based/modified muds which will produce few environmental impacts, low degree of borehole instability which can result in borehole collapse, loss of circulation, contamination of productive zones. Having low lubricity behavior during drilling, completion work, and cementing which the adverse effects can prevent by adding lubricants. LCM is an important part of the fluid system in which the problems occur. Power Law model is used for characterization of WBM properties while looking on the control of friction and minimize the well sliding during the advance and contraction of the drillstring. The purpose of mud additives is to eliminate the remaining cuttings and to enhance the well clean-up. Not only onshore, offshore also, WBM muds used. Accidental release drilling fluids and drill cuttings from offshore drilling operations may impact marine life and marine systems nearby the rig operation. Data of environmental elements after 5 years baseline study provides valuable data to assessing potential impacts, and was provided to the BHP Billiton via a report by BMT Oceanica. Summary of the assessment is as follows: About 100,000 t of drilling fluids will be discharged into the seafloor during drilling (tailed object).

7.2 Environmental considerations

The disposal of water based mud (WBM) is generally less expensive than oil-based mud (OBM) since WBM has lower chemical costs, causes fewer formation damage problems, and has lower environmental concerns. Furthermore, the cost associated with the disposal of WBM is less than that of oil-based muds since more treatment expenses are involved in treating oily cuttings from OBM. Furthermore, cuttings from WBM can be utilized as landfill, mixed with cement concrete, encapsulated, buried under the ocean seabed or on the land, and can be mixed with soil. The cuttings generated from drilling with WBM in the North Sea are generally discharged to the ocean since the environmental effects of cuttings disposal have been extensively evaluated in a number of studies. Land treatment is now more frequently applied to drill cuttings because of the increasing costs of water based mud and the reductions in allowable disposal of drill cuttings over land and water. The ability of the soil to retain the cuttings is also a factor to be considered.

The American Conference of Governmental Industrial Hygienists (ACGIH) has concluded that average daily exposures to free diesel fuel in the air of the workplace should be limited to 20 mg/m^3 in a time-weighted average of 8 hr. /day during a 40 hr. work week required to be maintained by the Occupational Safety and Health Administration (OSHA). The transportation of diesel engines to the lease, to a dumpsite, and/or to the leasing company for rebuilding, repair, or replacement is sometimes used to reduce fuel exposure. The use of a high level of mud in mud systems leads to an increase in the proportion of oil to water and could increase fuel exposure to workers, resulting in irritant dermatitis, skin disorders, and respiratory symptoms commonly reported in the industry.

8. CASE STUDIES AND INDUSTRY EXAMPLES

El Sol de Mexico is an example where WBM-UND LCM was applied in a natural flow blowout situation. This well suffered a kick using a non-ester glycol-based oil system (OBM) in which proper treatment was used to control. The well, due to poor mud management and lack of inhibitory characteristics during waiting on cement, allowed circulation to be lost. Drilling mud was fortified and conditioned with lignin and a lathe waste WBM-UND ready for use treatment. Once mixed and conditioned in the field, the barren WBM-UND was pumped into the well until good returns were obtained. The well was killed effectively stopping the circulation loss condition.

Statoil is the first drilling company that ran a WBM-UND for the drilling operation of the well Norne HPHT project 6405/6 well. It was the first time in the world that such a formulation was used. The mud pump capacity was increased from 950 hp to 1160 hp and 1,730 hp. Statoil reported that the clay-free WBM did not release fluids to formation, presented lower corrosion rates, and reduced a number of contaminants and problems associated with diesel-based WBM. Differentials and the fluid density that can be achieved with WBM-hemiramic facilitate the drilling of the wake-up column of an HMAC in deep levels even in the presence of previous solubilization. WBM has been successfully used in 25 wells where 11 of them displayed a higher pressure gradient than the maximum maneuvers recorded in the field.

9. FUTURE TRENDS AND INNOVATIONS IN WBM TECHNOLOGY

Water based drilling fluid (WBM) technology has been effective for drilling for a long period, indicating that the current WBM technology has been almost well-established. However, the challenges faced by WBM are that there is no good solution with better performance. In the future, it may be possible to develop WBM technology based on an association between NF-WBM and the use of natural Nano-extract materials. In this respect, additional enhancing and enhancing the NF-WBM property and the association of natural Nano-extract materials should be used. All of these research areas are upcoming future research for NWBM. Additionally, the development of a formulation that enhances the use of the existing WBM is identified as an important area of future research. Water based emulsion drilling fluids consist of a water-well service chemical agent as a continuous phase, controlled by a hydrophilic surfactant, and an oil or hydrophobic surfactant as a discontinuous phase. These fluids exhibit unique properties, including low filtration rates and substantially different viscosity-shear rate curves compared to conventional oil-based or water based fluids, making them suitable for addressing problems such as low-pressure reservoirs, mud loss, borehole collapse, hydrate formation, and overbalanced pressure.

This text describes the current state of knowledge on the properties and specifications of water based emulsion drilling fluids, with a focus on the investigation of surfactant systems and their potential application in the construction of water based emulsion drilling fluids for different types of water quality and formations. Special emphasis is placed on the discussion of emulsifying systems and the selection of suitable surfactants in combination with controlled surfactants in the oil and water phases to improve emulsion stability. The investigation also highlights the importance of controlling the composition to ensure optimal emulsion stability during formulation.

Conversely, to make this formulation, future WBM research may be based on the synthesis of a novel additive and the utilization of advanced technology. Micro powder technique development in WBM technology is also an important future research area. The development of a good filtration loss for WBM has not been well-defined, pinpointing the importance of certain gap and asking for additional filtration loss mechanism research. In addition, how filtration loss influences wellbore cleaning, leak-off performance, formation fracture, hydraulic pressure loss, insufficient circulation, and shale drilling remains to be resolved, resulting in important future filtration loss related to paper research. Finally, remaining issues concerning WBM remain to be addressed and must be resolved. Advances in the technology of WBM depend on the commitment, utilization of advanced research strategy, and investment by broad actors involved in the future scientific community guiding the WBM technology team.

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