Management of the Drilling Wastes in the Eastern Province of Saudi Arabia

BY

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This Thesis is Gratefully

Dedicated

To

My Parents

and

My Family

for their excellent care and efforts

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THESIS ABSTRACT

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TILTLE OF THE STUDY: MANAGEMENT OF THE DRILLING WASTES IN THE EASTERN PROVINCE OF SAUDI ARABIA

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The oil and gas drilling operations are more concentrated in the Eastern Province of Saudi Arabia which hosts the biggest Oil and Gas Reserves in the world. In fact, the Eastern Province has more than (90%) of the oil and gas reserves in contrary. The drilling operations have increased and expanded in this area to meet the global demand and to increase the amount of reserves of the Kingdom. Unfortunately, the drilling operations and activities are associated with several serious impacts on the surrounding environment. The improper handling of the large quantities of drilling wastes produced from the various drilling activities represents one of these serious negative impacts that need to be considered. Drilling wastes consist mainly of drilling fluids and solid cuttings. These drilling wastes need a proper environmental management to avoid the negative effects on the environment. In this study, data on the current oil and gas drilling activities was collected with cooperation with oil and gas companies working in Eastern part of Saudi Arabia, the main data was collected through distributed questionnaire to members of the companies, then extraction of the results and analyses of the data were conducted .The study has found generally that highest percentage of the drilling companies with used Water Based Fluids (63.2%), on the other hand 31.6 % of the respondent companies used the Oil Based Fluids. The study also has found that the volume of drilling wastes produced is not consistent, most respondents companies produced a range between (500 - 4000) tons of fluids wastes and (300-3000) tons of the solids cuttings. Finally the study recommends some measures to best practices to mange drilling wastes.

الملخص

تتركز عمليات الحفر عن البترول والغاز الطبيعي في الجزء الشرقي من المملكة العربية السعودية والتي تحتضن أعلى الاحتياطيات في العالم ، وفي الحقيقة فأن المنطقة الشرقية تتواجد فيها أكثر من 90 % من الاحتياطيات في المملكة، لقد ازدادت عمليات الحفر في هذه المنطقة بشكل كبير لتلبي احتياجات العالم وكذلك المملكة من النفط،وللأسف ، فأن عمليات الحفر يتصاحب معها بعض التأثيرات البيئية المختلفة على البيئة المحيطة،أن عدم التعامل الجيد مع الكميات الكبيرة من المخلفات الناتجة عن عمليات الحفر قد ينتج عنه تأثيرات سلبية جسيمة على البيئة ولهذا فأنه من المهم التعامل معها بطرق سليمة .

تحتوي مخلفات الحفر بشكل عام على المخلفات السائلة (سوائل طينة الحفر) وكذلك المخلفات الصلبة (الفتات الصخري) الناتجة عن تفتيت الصخور إثناء الحفر.هذا المخلفات تحتاج إلى إدارة بيئية مناسبة لتجنب الآثار السلبية على البيئة، لقد تم في هذه الدراسة تصميم استبان ة لجمع بعض المعلومات المتعلقة بعمليات الحفر ،المخلفات الناتجة عنها ، كمياتها ،تركيبها ، خصائصها ، طرق معالجتها و إدارتها وذلك بتعاون مع عدد من شركات التنقيب عن الغاز والبترول ومقاولين الحفر في المنطقة الشرقية.

لقد تم جمع وتحليل المعلومات المتعلقة بأهداف الدراسة واستخدام التحليلي الوصفي لعمل مقارنات مهمة بين ما تطبقه شركات الحفر في المملكة وبين ما يعمل به في الدول المتقدمة.

من نتائج هذا البحث المهمة عدم وجود أنظمة ومعايير بيئية حكومية للتعامل مع مخلفات الحفر، كذلك استمرار بعض الشركات في استخدام بعض أنواع سوائل الحفر الغير أمنه والتخلص منها بطرق تقليدية قديمة أقل تكلفة وأكثر خطراً على البيئة .لقد استنتجت الدراسة أن (63.2%) من شركات الحفر تستخدم طينه الحفر المائي،بينما (31.6%) من الشركات تستخدم طينة الحفر الزيتي ، كما استنتجت الدراسة أيضا أن حجم مخلفات الحفر غير ثابت في معظم الشركات، لقد تم في نهاية هذا البحث تقديم بعض التوصيات والحلول التي سوف تساهم في التخفيف من الآثار المترتبة على البيئة.

CHAPTER 1

INTRODUCTION

1.1 Background

Along with technological and cultural advances of humanity, the utilized energy be the main energy source in the beginning of the industrial revolution, oil and natural gas became the primary energy source. World records show that oil and gas energy resources represent more than 63 % of the overall world energy sources. The annual report issued in 2009 by the international energy agency (IEA, 2009) indicated that the world needs from all the energy materials will be 50 % higher in 2030 than the current level. The report also indicated that more than 60 % of this increase will be from oil and natural gas. In this regard, the agency expects the world consumption of oil to increase to 92 million barrels a day in 2020 and to 115 million barrels a day in 2030. In fact, the ever increasing world needs of energy will remain the main driving force for the development of oil and gas industry in the coming years(Ajaj, 2010).

The oil industry sectors with its different aspects and activities (exploration, drilling, production, transportation and refinement) constitute one of the most important industries in the world. The industry has prominent influence on the local and international economy since it is considered the continuous primary industry for all industries and other activities as a fuel and commodity. It still constitutes the main energy source to provide the needed energy for all of them and plays the role of the main engine for the wheel of development (Oort, et,al 1999).

Saudi Arabia is one of the largest countries in producing and reserves of oil and gas in the world. With the increasing oil production, the exploration activities have been increased in the last years. Based on data from OPEC at the beginning of 2011 the highest proved oil reserves including non-conventional oil deposits are in Venezuela (20 % of global reserves), Saudi Arabia (18 %,of global reserves), Iran (9 %).(OPEC Share of World Oil Reserves, 2011)

Saudi Arabia contains approximately 260 billion barrels of proven oil reserves (plus 2.5 billion barrels in the Saudi-Kuwaiti shared "Neutral" Zone), amounting to around one-fifth of proven, conventional world oil reserves. Although Saudi Arabia has around 100 major oil and gas fields (and more than 1,500 wells), over half of its oil reserves are contained in only eight fields, including the giant 1,260-square mile Ghawar field (the world's largest oil field, with estimated remaining reserves of 70 billion barrels). The Ghawar field alone has more proven oil reserves than all but six other countries. (The U.S. Energy Information Administration (EIA), it is also the largest oil consuming nation in the Middle East. In 2009, Saudi Arabia consumed approximately 2.4 million barrels/day of oil, up 50 percent since 2000, due to strong economic and industrial growth and subsidized prices.

Saudi's main producing fields are located in the eastern province, those fields include, onshore oilfields as Ghawar which is the largest oilfield in the word with more than 5 million bbl/d, Khurais, Qatif, Abqaiq,Shaybah, Zuluf and Safaniya in offshore area. In addition, the Saudi-Kuwait Divided Zone or the Neutral Zone contains an estimated 5 billion barrels of proven oil reserves, shared between the two countries, from which approximately 600,000 bbl/d is produced.

In the coming years, it is expected that the Kingdom's production will increase due to rapidly rising world oil demand. Research centers and international organizations forecasts indicate an annual growth of 1.6 percent in oil demand which translates to 1.5 MMBD. Additionally, two other factors will cause an increase in the Kingdom's share in international oil markets. First is the dwindling production output from major countries and production zones such as the U.S. and the North Sea. Second is that the diminishing chances to discover an alternative to oil during at the coming two decades due to the high economic cost and the inefficiency of current alternative fuels. To counter the expected increase due to these factors, the Kingdom completed the development project for Qatif and Abu Sa'fah fields that produce a total of 800 MBD. This mega project, completed ahead of schedule, will boost the Kingdom's total production capacity from 10.5 MMBD to 11 MMBD (Ministry of Petroleum – Saudi Arabia).

The Ministry of Petroleum and Mineral Resources, which is the authorized governmental agency for observing and monitoring exploration, development, production, refining, transportation, distribution activities related to petroleum and petroleum products. The Ministry monitors the activities of the oil and gas companies, and those companies are: Saudi Aramco, the national oil company which is the largest oil company in the world with the largest oil reserves, and it produces more oil per day than any other country or company in the world. The Saudi Aramco host the most of oil and gas activities in the Kingdome, other companies that have operations in the Kingdom are; Saudi Chevron, Aramco Gulf Operation Ltd (AGOC).Additionally, Four exploration joint ventures with Aramco in the Empty Quarter were launched in 2004 and signed agreements with the Ministry of Petroleum to explore, develop and produce un-associated gas, joint ventures are Royal Dutch Shell, Russia’s Lukoil, China’s Sinopec and a consortium of Italy’s Eni and Spain’s Repsol (SaudiAramco).

1.2 Drilling Fluids

Drilling fluids (also known as drilling fluids or fluids) are suspensions of solids and dissolved materials in a water, oil, or synthetic base that are used in rotary drilling operations. The rotary drill bit is rotated by a hollow drill stem made of pipe, through which the drilling fluid is circulated. Drilling fluids are formulated for each well to meet specific physical and chemical requirements. Geographic location, well depth, rock type, geologic formation, and other conditions affect the fluids composition required. The number and nature of fluids components varies by well, and several products may be used at any time to create the necessary properties. The primary functions of a drilling fluid include the following:

- Transport drill cuttings to the surface
- Control subsurface pressures
- Lubricate the drill string
- Clean the bottom of the hole
- Aid in formation evaluation
- Protect formation productivity
- Aid formation stability (Moore, 1986)

The functions of drilling fluid additives and typical additives are listed on Table 1. Five basic components account for approximately 90 percent by weight of the materials that compose drilling fluids: barite, clay, lignosulfonate, lignite, and caustic soda (Conklin and Rao, 1999).

Barite is a chemically inert mineral that is heavy and soft. In water based fluids, barite is composed of over 90 percent barium sulfate. Synthetic-based fluids contain about 33% barium sulfate. Barium sulfate is virtually insoluble in seawater. Barite is used to increase the density of the drilling fluid to control formation pressure. The concentration of barite in drilling fluid can be as high as 700 lb/bbl (Perricone, 1980). Quartz, chert, silicates, other minerals, and trace levels of metals can also be present in barite. Barium sulfate contains varying concentrations of metals depending on the characteristics of the deposit from where the barite is mined. One study indicates that there is a correlation between cadmium, mercury and other trace metals in the barite (SAIC, 1991). EPA currently regulates cadmium and mercury concentrations in barite and refers to the stock barite that meets EPA limitations as “clean” barite.

Bentonite is the most commonly used drilling fluid additive and consists of finely ground sodium bentonite clay, which is composed mainly of sodium montmorillonite clay (60 to 80%). It can also contain silica, shale, calcite, mica, and feldspar. Bentonite is used to maintain the rheologic properties of the fluid and prevent loss of fluid by providing filtration control in permeable zones. The concentration of bentonite in fluids systems is usually 5 to 25 lb/bbl. In the presence of concentrated brine, or formation waters, attapulgite or sepiolite clays (10 to 30 lb/bbl) are substituted for bentonite (Perricone, 1980). When mixed with water, the resulting slurry has a viscosity greaterthan water, possesses the ability to suspend relatively coarse and heavy particles, and tends to form a thin, very low permeability cake on the walls of the borehole. Because of these attributes, bentonite drilling fluids is superior to water as a drilling fluid for many applications. Bentonite for drilling is generally available in a standard grade which complies with the American Petroleum Institute

Lignosulfonate:Lignosulfonate is used to control viscosity in drilling fluids by acting as a thinning agent or deflocculant for clay particles. Concentrations in drilling fluid range from 1 to 15 lb/bbl. It is made from the sulfite pulping of wood chips used to produce paper and cellulose. Ferrochrome lignosulfonate, the most commonly used form of lignosulfonate, is made by treating lignosulfonate with sulfuric acid and sodium dichromate. The sodium dichromate oxidizes the lignosulfonate and cross linking occurs. Hexavalent chromium supplied by the chromate is reduced during reaction to the trivalent state and complexes with the lignosulfonate. At high down hole temperatures, the chrome binds onto the edges of clay particles and reduces the formation of colloids. Ferrochrome lignosulfonate retains its properties in high soluble salt concentrations and over a wide range of alkaline pH. It also is resistant to common fluids contaminants and is temperature stable to approximately 177^{o}C (Conklin and Rao, 1999).

Lignite: Lignite is a soft coal used in drilling fluids as a deflocculant for clay, to control the filtration rate, and to control fluids gelation at elevated temperatures. Concentrations vary from 1 to 25 lb/bbl (Perricone, 1980). Lignite products are more commonly used as thinners in freshwater fluids.

Caustic Soda: Sodium hydroxide is used to maintain the pH of drilling fluids between 9 and 12. A pH of 9.5 provides for maximum deflocculation and keeps the lignite in solution.

It can be concluded that the drilling fluids is generally toxic and it is difficult and expensive to dispose of it in an environmentally friendly manner.

1.3 Functions of Drilling Fluids

A drilling fluid, or fluids, is any fluid that is used in a drilling operation in which that fluid is circulated or pumped from the surface, down the drill string, through the bit, and back to the surface via the annulus. Drilling fluids satisfy many needs in their capacity to do the following:

- Suspend cuttings (drilled solids), remove them from the bottom of the hole and the well bore, and release them at the surface.
- Control formation pressure and maintain well-bore stability.
- Seal permeable formations.
- Cool, lubricate, and support the drilling assembly.
- Transmit hydraulic energy to tools and bit.
- Minimize reservoir damage.
- Permit adequate formation evaluation.
- Control corrosion.
- Facilitate cementing and completion.
- Minimize impact on the environment.
- Inhibit gas hydrate formation.

The most critical function that a drilling fluid performs is to minimize the concentration of cuttings around the drill bit and throughout the well bore. Of course, in doing so, the fluid itself assumes this cuttings burden, and if the cuttings are not removed from the fluid, it very quickly loses its ability to clean the hole and creates thick filter cakes. To enable on-site recycling and reuse of the drilling fluid, cuttings must be continually and efficiently removed.

Just as the nature of drilling-fluid solids affects the efficiency of solids control equipment, the nature of the solids also plays an integral role in the properties of drilling fluids, which in turn affect the properties of the solids and the performance of the equipment. This intricate and very complex dynamic relationship among the solids, drilling fluid, and solids-control equipment is represented in Figure 1. Any change made to one of these affects the other two, and those in turn affect all three and so on. To optimize a drilling operation, it is important to understand how the solids affect bulk fluids properties, particularly rheology, hole cleaning, filtration, drilling rate (rate of penetration [ROP]), along with surface properties such as shale inhibition potential, lubricity, and wetting characteristics.

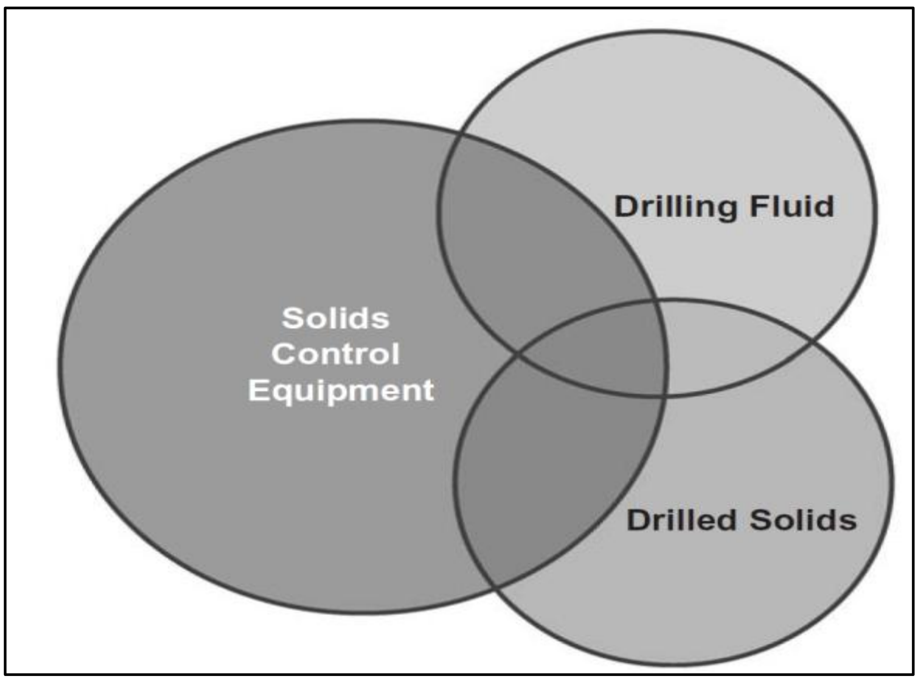

Figure 1.Fluids Processing Circle (American Society of Mechanical Engineers, 2005)

The drilling steps can be summarized as shown in Figure 2 and including the following:

- A drill bit designed for the expected type of formation to be drilled is lowered into the well on the drill string.

- The drill string and bit are rotated by the rotary drive on the rig floor, a top drive in the derrick, or a fluids motor directly above the bit which is powered by the force of the fluids flowing through it.
- The bit crushes or grinds the rock beneath it into pieces called cuttings
- Drilling Fluids is circulated down the drill pipe and through openings called "jets" in the bit.
- The fluids washes the formation cuttings from beneath the bit and carries them to the surface.
- When the bit fails or wears out, all of the drill string must be pulled from the hole to replace it. This is called a trip.
- 25% - 50% of the time on location is used for non-drilling activities such as running casing and tripping for new bits (Candler, 2008).

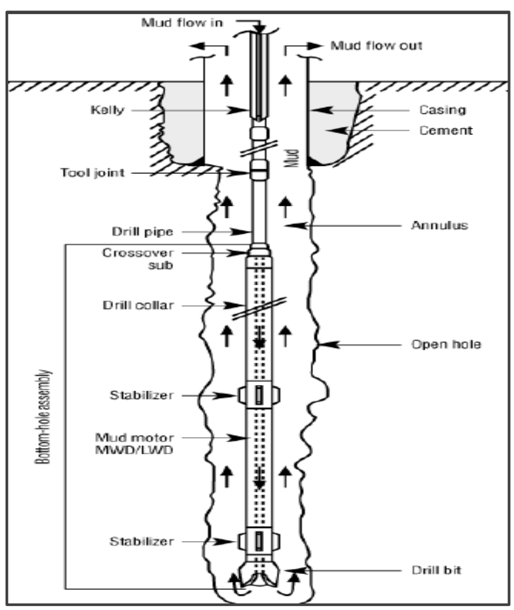

Figure 2. Drilling steps using drilling fluids (Candler, 2008)

1.4 Types of Drilling Fluids

1.4.1 Water Based Fluids (WBF)

Water-based fluids are used in drilling operation due to its environmental friendly nature. Water Based Fluids (WBMs) which are the most commonly used drilling fluids, both onshore and offshore. WBMs use water as their base fluid and do not contain any oil. WBMs are widely used in shallow wells and often in shallower portions of deeper wells, but are not effective in deeper wells. The usage of WBMs generates about 7000 to 13000 bbl of waste per well. Depending on the depth and diameter of the well, about 1400 to 2800 bbl of that amount are drill cuttings (Soegianto et. al 2008).

However, water-based fluids systems are usually associated with shale problems that can cause shale hydration, swelling, dispersion and abnormal pressure thus causing drilling problems like washout, stuck pipe and hole enlargement (Ismail, and Lim 1995).

The pollutants of concern from water based fluids discharges are primarily metals, most of which are associated with the barite added to the fluids system and organics, which are added for lubricity or to free stuck pipe.

1.4.2 Oil-Based Fluids (OBF)

A primary use of oil-based fluids is to drill troublesome shales and to improve hole stability. They are also applicable in drilling highly deviated holes because of their high degree of lubricity and ability to prevent hydration of clays. They may also be selected for special applications such as high temperature/high pressure wells, minimizing formation damage, and native-state coring. Another reason for choosing oil-based fluids is that they are resistant to contaminants such as anhydrite, salt and $CO_2$and H_2S acid gases.

Cost is a major concern when selecting oil-based fluids. Initially, the cost per barrel of an oil-based fluids is very high compared to a conventional water-based fluids system. However, because oil fluids scan be reconditioned and reused, the costs on a multi-well program may be comparable to using water-based fluids. Also, buy-back policies for used oil-based fluids can make them an attractive alternative in situations where the use of water-based fluids prohibits the successful drilling and/or completion of a well.

Today, with increasing environmental concerns, the use of oil-based fluids is either prohibited or severely restricted in many areas. In some areas, drilling with oil-based fluids requires fluids and cuttings to be contained and hauled to an approved disposal site. The costs of containment, hauling, and disposal can greatly increase the cost of using oil-based fluids (AMOCO, 2010).

1.4.3 Synthetic Based Drilling Fluids (SBF)

Synthetic based drilling fluids represent a new technology which developed in response to the widespread permit discharge bans of oil-based drilling fluids. An SBF has a synthetic material as its continuous phase and water as the dispersed phase. The types of synthetic material which have been used include vegetable esters, polyalpha olefins (PAO), linear alphaolefins, internal olefins, and esters (USEPA, 1996). A model SBF formulation consists of 47% synthetic base fluid, 33% solids, and 20% water (by weight), a 70%/30% ratio of synthetic base to water, typical of commercially available SBFs (Carmody, 1999).

SBFs are reported to perform as well as or better than OBFs in terms of rate of penetration, borehole stability, and shale inhibition. Due to decreased washout (erosion), drilling of narrower gage holes, and lack of dispersion of the cuttings in the SBF, compared to WBF the quantities of fluids and cuttings waste generated is reduced, reportedly in some cases by as much as 70 % (Candler et al, 1993).

According to standard formulation data, all of the solids in synthetic based fluids are barite, making SBF a source of heavy metals and total suspended solids. SBFs are also one source of the conventional pollutant oil and grease.

1.4.4 Gaseous or Air Drilling

Drilling a hole, when using air or Gaseous/Compressed Air drilling, is a very effective drilling fluid for drilling in dry formations in arid climates, in competent consolidated rock, or in frozen ground. Only minor modifications to a conventional drilling rig and drill bits are required to drill with compressed air as compared to drilling with fluids. This technique is used to cool the drill bit and lift cuttings out of the wellbore, instead of the more conventional use of liquids. The advantages of air drilling are that it is usually much faster than drilling with liquids and it may eliminate lost circulation problems. The disadvantages are the inability to control the influx of formation fluid into the wellbore and the destabilization of the borehole wall in the absence of the wellbore pressure typically provided by liquids (Schlumberger, 2012).

Generally, air more efficiently cleans the drill bit which extends its life, probably as a result of less grinding of the cuttings. Although, rotary bit speeds are practically identical to drilling with water and fluids, air drilling is usually faster than fluids drilling due in part to the increased weight (approximately 20 percent) on the drill bit. However, in softer formations the penetration rate must be reduced to prevent squeezing around the bit and blocking fluid ports (Fluids Engineering handbook, 2001).

When air drilling, since there is no carrying or suspension capacity, the air volume must be sufficient to blow the cuttings out of the hole. This typically limits the depth of utilization since the deeper the hole, the more difficult to bring to the surface. The velocity also creates hole-enlargement through erosion, making hole cleaning even more difficult. Because this process allows fluid to enter the borehole, high volume gas or other flows may present a well control problem. This can become even more hazardous when H_2S or CO_2 are present (Masi Technologies LLC).

1.5 Drill Cuttings

Drill cuttings are fragments of the geologic formation broken loose by the drill bit and carried to the surface by the drilling fluids that circulate through the borehole. They are composed of the naturally occurring solids found in subsurface geologic formations and bits of cement used during the drilling process. Cuttings are removed from the drilling fluids by a shale shaker and other solids control equipment before the fluid is recalculated down the hole (U.S. EPA, 2003).

The volume of cuttings generated while drilling the SBF intervals of a well depends on the type of well (development or production) and the water depth. According to analyses of the model wells provided by industry representatives, wells drilled in less than 1,000 feet of water are estimated to generate 565 barrels of cuttings for a development well and 1,184 barrels of cuttings for an exploratory well. Wells drilled in water greater than 1,000 feet deep are estimated to generate 855 barrels of cuttings for a development well, and 1,901 cuttings for an exploratory well (Carmody, 1999). These values assume 7.5 percent washout, based on the rule of thumb reported by industry representatives of 5 to 10 percent washout when drilling with SBF. Washout is caving of the well bore. Washout, therefore, increases hole volume and increases the amount of cuttings generated when drilling a well. Assuming no washout, the values above become, respectively, 526, 1,101, 795, and 1,768, barrels of dry cuttings.

As the drilling fluid returns from down hole laden with drill cuttings, normally, its first passed through primary shale shakers, vibrating screens, which removes the largest cuttings, ranging in size of approximately 1 to 5 millimeters.

The drilling fluid may then be passed over secondary shale shakers to remove smaller drill cuttings. Finally, a portion or all of the drilling fluid may be passed through a centrifuge or other shale shaker with a very fine mesh screen, for the purpose of removing the fines. It is important to remove fines from the drilling fluid in order to maintain the desired flow properties of the active drilling fluid system. Thus, the cuttings waste stream usually consists of larger cuttings from a primary shale shaker, smaller cuttings from a secondary shale shaker, and fines from a fine mesh shaker or centrifuge. As a final step, the wet cuttings are sent to a dryer, which uses high temperatures to separate SBFs from cuttings. The dried residue from the dryer consists of fine cuttings and SBF material and is transported to an onshore waste handling facility. The cleaned cuttings are then discharged overboard (U.S. EPA, 2003).

The recovery of SBF from the cuttings serves two purposes. The first is to deliver drilling fluid for reintroduction to the active drilling fluid system and the second is to minimize the discharge of SBF. The recovery of drilling fluid from the cuttings is a conflicting concern, because as more aggressive methods are used to recover the drilling fluid from the cuttings, the cuttings tend to break down and become fines. The fines are more difficult to separate from the drilling fluid (an adverse effect for pollution control purposes), but in addition they deteriorate the properties of the drilling fluid. Increased recovery from cuttings is more of a problem for WBF than SBF because in WBFs the cuttings disperse more and spoil the drilling fluid properties. Therefore, compared to WBF, more aggressive methods of recovering SBF from the cuttings waste stream are practical. These more aggressive methods may be justified for cuttings associated with SBF so as to reduce the incidental discharge of SBF. This, consequently, will reduce the quantity of toxic organic and metallic components of the drilling fluid discharged (U.S. EPA, 2003).

1.6 Environmental Impacts of Drilling Waste

It is obvious, from the preceding discussion, that drilling waste contains a large amount of base fluid, whether that fluid is diesel oil, mineral oil, olefin, ester, or water. A more detailed discussion about the nature or characteristics of the waste should consider the place of disposal. In a broad sense, this can be accomplished by considering that all waste must be disposed in the water, on land, or in the air. For example, the characteristics of drilling waste when discharged offshore (disposal in water) will be viewed from the potential effects between the waste and water.

These are effects to the seabed, to the water column itself, and to the air/water interface at the surface. In this scenario, diesel oil is an obvious contaminant. Diesel oil creates a sheet on the water surface, disperses in the water column, and creates a toxic effect in cuttings piles on the seabed. For this reason, diesel oil-based drilling fluids and the cuttings generated while using them are not discharged into the sea (Labat et al, 2000).

While it is beyond the scope of this text to fully discuss the nature of drilled cuttings, it is important to at least identify some of the common characteristics. Water-based fluids are generally considered relatively benign. The main concern is with the smothering effect of potential cuttings piles, although the creation of piles can be somewhat moderated by the manner of discharge, water depth, and strength of prevailing currents. There is also a concern for entrained oil, either from the formation or from surface additions. With modern emulsifiers, it is possible to entrain fairly large amounts of oil without detection by standard rig site testing.

There is also a concern for toxicity, as defined by the standard toxicity test run in the Gulf of Mexico. This is not truly a test of toxicity, but simply an indicator with a discharge/no discharge implication. Modern drilling fluids formulated for high inhibition can run close to the boundary of this test. Another concern is with heavy metals. With the use of barium sulfate (barite) to increase the drilling-fluid density, there is little direct concern with barium solubility or the biological availability of barium. However, there is concern for trace heavy metals within barite, such as mercury and cadmium (Labat et al, 2000).

All of the water-based considerations are also considerations with NAFs. In addition, there are specific concerns with the NAF itself. Generalized concerns associated with offshore discharges and NAFs include (Deis, 2005):

- benthic smothering.
- toxicity (aquatic or in sediments).
- sheen or entrained oil.
- biodegradability (aerobic and anaerobic).
- bioaccumulation
- dispersibility.
- Persistence.
- taint (alteration of flavor or smell of fish).
- heavy metals.

Most of these concerns are addressed by some sort of stock (base fluid) limitation and by limiting the amount of fluid to be discharged. Some areas restrict the type of base fluid that can be discharged based on biodegradation rate. There may also be limits on the amount of fluid retained on the cuttings when discharged. In this manner, any fluid on cuttings discharged (whole fluid is not discharged) will biodegrade rapidly and any effects will be short term.

The preceding discussion applies to discharges at sea when no special environmental condition exists. Special environmental conditions might be reefs, oyster beds, kelp beds, subsistence fishing grounds, or sites near shore. In freshwater environments such as lakes and rivers (or enclosed brackish waters), discharges may also pose a hazard due to simple sedimentation (Labat et al, 2000).

When considering land disposal options, the concerns are of a different nature. The concern with oil is still present, but to a much less extent. The type of oil is also important. Oil can be incorporated into dirt or soil and will biodegrade. The major concerns are about the concentration of oil remaining after biodegradation and potential plant toxicity of some portions of diesel oil. Some types of NAF will biodegrade to very low concentrations and do not exhibit toxicity to plants. Salts are a major concern. Salt is toxic to plants even at fairly low concentrations. Associated with the salt is the concern over sodium from sodium chloride. Sodium replaces calcium and magnesium in clays, causing a condition known as sodicity. Sodic soils collapse, causing a low permeability to water and a hard surface. Since water cannot infiltrate the soil matrix, there is no water available to support plant life. Further, salt inhibits the transport of water via osmosis to the plant(Deis, 2005).

Heavy metal content is the third major concern with drilled cuttings disposed onshore. While barium from barite has low solubility and bioavailability, there is still a concern with the concentration of barium in dirt or soil. Other heavy metals of potential concern that are found in drilled cuttings are lead and zinc, although these are found to be a problem.

Among the various contaminants discussed in this section, excess solids are by far the most prevalent and detrimental to all types of drilling fluids. Solids problems are often magnified by the presence of other contaminants because excess solids and contaminant ions can strongly interact to create a more serious fluids problem than either one separately.

Sources of solids in fluids are threefold: (1) cuttings or sloughing from the wellbore, (2) commercial solids added to the fluids, and (3) chemically precipitated solids (AMOCO, 2010).

1.7 Saudi Arabian Environmental Regulations for Waste Disposal

1.7.1 The Basic Law

In 1992 Saudi Arabia adopted the Basic Law (commonly referred to as the Constitution of the Kingdom of Saudi Arabia), which sets out the system of government for the country, and the obligations of the government to the people of Saudi Arabia. Article 32 of the Basic Law states that “the State works for the preservation, protection, and improvement of the environment, and for the prevention of pollution”.(Presidency of Meteorology and Environment (PME, 1992).

1.7.2 General Law on the Environment

According to Article 5 of the Saudi Arabia General Law on the Environment, the licensing authorities are required to ensure that environmental assessment studies are made part of feasibility studies for any project that may have an impact on the environment. The party in charge of executing the project shall be responsible for conducting environmental impact assessment studies in accordance with such environmental principles and standards as may be determined by PME in the Implementing Regulations. According to Article 6, the party in charge of executing new or upgraded projects is required to use the best possible technologies congenial to the local environment as well as the least environment-polluting materials.(PME, 1992).

In addition to the Upstream Rules and Implementation Guidelines, companies are responsible for full compliance with all applicable regulations, decisions of the Council of Ministers, and rules and directives issued by the Government.

The PME regulations categorize the exploration, extraction, and petroleum and gas development operations as “Third Category Projects” that require performance of comprehensive Environmental Impact Assessment (EIA). The EIA should be carried out in accordance with the regulations, and also according to the principles of Islamic stewardship of the natural environment, the standards of good international practice, and generally meet the requirements of the World Bank Guidelines.

1.7.3 International Environmental Standards for Oil& Gas Extraction Industry

Oil and Gas Exploration and Production operations generate large volumes of drilling waste every year. Drilling waste includes drilling fluids, drill cuttings, wash water, and other related wastes. Drilling fluids usually contains bentonite clay, water, barium sulfate (barite), specialized additives, and some types of fluids also contain hydrocarbons. Due to generation of large quantities of drilling waste and typical characteristics such as it being oily, saline, and sometimes toxic, drilling waste management is a significant issue for the oil and gas industry. Drilling waste management practices vary by region and are governed by regulatory agencies charged with the protection of human health and the environment (Sengupta, 2006).

Effluent standards for pollutants present in treated waste water discharged from any industry are essential. In case of oil drilling and gas extraction industry the limits based on quantum may not be feasible as the quantity of waste water generated goes on varying over the years of exploitation of oil well. Initially the produced water content of crude oil produced may be 20% water and 80% crude and during the tag end of the well it may be reversed to 80% water and 20% oil.

1.7.4 International Guidelines for Disposal of Drilling Waste

Wastes suitable for burial are generally limited to solid or semi-solid, low-salt, low-hydrocarbon content inert materials, such as water-based drill cuttings. Costs for disposing of cuttings that have been stabilized prior to dilution and burial are estimated at $9-10 per barrel of waste (Bansal and Sugiarto 1999).

As the Drilling Waste Management Information System (DWMIS) , US Federal and State Regulations), motioned that there are several factors to consider for burying drilling wastes surmised the following:

1. Depth above and below pit. Areas with shallow groundwater are not appropriate; a pit location of at least five feet above any groundwater is recommended to prevent migration to the groundwater. The top of the burial cell should be below the rooting zone of any plants likely to grow in that area in the future (normally about three feet).
2. Type of soil surrounding the pit. Low-permeability soils such as clays are preferable to high-permeability soils such as sands.
3. For offsite commercial landfills, any protocols required by the facility accepting the waste (not all facilities have the same acceptance criteria).
4. Prevention of runoff and leaching. Appropriate types and degree of controls to prevent runoff and leaching should be implemented. Natural barriers or manufactured liners placed between the waste material and the groundwater help control leaching.
5. Appropriate monitoring requirements and limits.
6. Time required to complete the burial.
7. Chemical composition of the buried cuttings.
8. Moisture content or condition of buried cuttings.

1.7.5 Disposal of Drill Waste for On-shore Installations

Drill cuttings (DC) originating from on-shore or locations close to shore line and separated from Water Base Fluids (WBM) should be properly washed and unusable drilling fluids (DF) such as WBM, Oil Base Fluids (OBM), Synthetic Base Fluids (SBM)) should be disposed of in a well-designed pit lined with impervious liner located off-site or on-site. The disposal pit should be provided additionally with leachate collection system.

Design aspects of the impervious waste disposal pit, capping of disposal pit should be informed by the oil industry at the time of obtaining consent. Use of diesel base fluids is prohibited. Only WBM should be used for on-shore oil drilling operations.

In case of any problem due to geological formation for drilling, low toxicity OBM having aromatic content < 1 % should be used. If the operators intend to use such OBM to mitigate specific hole problem.

The chemical additives used for the preparation of drilling fluids should have low toxicity i.e. 96 hr LC_{50}> 30,000 mg/I as toxicity test conducted on locally available sensitive Sea species. The chemicals used (mainly organic constituents) should be biodegradable. (Ministry of the environment,India-2005)

Drilling cuttings separated from OBM after washing should have oil content at < 10 gm/kg for disposal into disposal pit. The waste pit after it is filled up shall be covered with impervious liner, over which, a thick layer of native soil with proper top slope be provided.

Low toxicity OBM should be made available at installation during drilling operation.

Drilling wastewater including drilling cuttings DC wash water should be collected in the disposal pit, evaporated or treated and should comply with the notified standards for onshore disposal. Barite used in preparation of DF shall not contain Hg > 1 mg/kg & Cd > 3 mg/kg.

Total material acquired for preparation of drill site must be restored after completion of drilling operation leaving no waste material at site. SPCB should be informed about the restoration work.

In case, environmentally acceptable methods for disposal of drill waste such as: (i) Injection to a formation through casing annulus, if conditions allow, (b) land farming at suitable location (c) bio-remediation, (d) incineration or (e)solidification can be considered(Sengupta, 2006).

1.7.6 Disposal of Drilling Waste for Off-shore Installations

Use of diesel base fluids is prohibited. Only WBM is permitted for off-shore drilling. If the operators intend to use low toxicity OBM or SBM to mitigate specific hole problems in the formation, The low toxicity OBM should have aromatic content < 1 %.

The toxicity of chemical additives used in the DF (WBM or OBM or SBM) should be biodegradable (mainly organic constituents) and should have toxicity of 96 hr LC_{50} value > 30,000 mg/I as per toxicity test conducted on locally available sensitive Sea species.

Hexavalent chromium compound should not be used in DF. Alternate chemical in place of chrome lignosulfonate should be used in DF. In case, chrome compound is used, the DF/ DC should not be disposed of-shore.

Bulk discharge of DF in off-shore is prohibited except in emergency situations. WBM/ OBM/SBM should be recycled to a maximum extent. Unusable portion of OBM should not be discharged into sea and shall be brought to on shore for treatment & disposal in an impervious waste disposal pit.

Thoroughly washed DC separated from WBM/SBM & unusable portion of WBM/SBM having toxicity of 96 hr LC50 > 30,000 mg/I shall be discharged off-shore into Sea intermittently at an average rate of 50 bbl/hr/well from a platform so as to have proper dilution & dispersion without any adverse impact on marine environment.

Drill cuttings of any composition should not be discharged in sensitive areas.In case of specific hole problem, use of OBM will be restricted with zero discharge of DC. Zero discharge would include re-injection of the DC into a suitable formation or to bring to shore for proper disposal. In such a case, use of OBM for re-injection should be recorded and made available to the regulatory agency. Such low toxic OBM having aromatic content < 1 % should be made available at the installation.

In case, DC is associated with high oil content from hydrocarbon bearing formation, then disposal of DC should not have oil content > 10 gm/kg.The DC wash water should be treated to conform limits notified under EPA, before disposal into Sea. The treated effluent should be monitored regularly. Discharge of DC from the installation located within 5 km away from shore should ensure that there is no adverse impact on marine eco-system and on the shore. If, adverse impact is observed, then the industry has to bring the DC on-shore for disposal in an impervious waste disposal pit.

If any, environmental friendly technology emerges for substitution of DF and disposal technology, if the operator desires to adopt such environment friendly technology a prior approval from etherize agency.

Barite used in preparation of DF shall not contain Hg > 1 mg/kg & Cd > 3 mg/kg. n) Oil drilling operators are required to record daily discharge of DC & DF to offshore and also to monitor daily the effluent quality, and submit the compliance report once in every six months (Sengupta, 2006).

1.8 Drilling Wastes Management

1.8.1 Quantifying Drilling Waste

Drilling waste consists of waste drilling fluid, drilled cuttings with associated drilling fluid, and, to a lesser extent, miscellaneous fluids such as excess cement, spacers, and a variety of other fluids. The amount of drilling waste depends on a number of factors. These include hole size, solids control efficiency, the ability of the drilling fluid to tolerate solids, the ability of the drilling fluid to inhibit degradation or dispersion of drilled cuttings, and the amount of drilling fluid retained on the drilled cuttings.

One simple expression states the amount of wet drilled solids to be discarded as:

$$S = \varepsilon \times HV/F_s$$

Where:

S

= volume of wet drilled solids, in bbl

ε = efficiency of solids control, expressed as a fraction

HV= hole volume, in bbl

F_s= fraction of solids in the discard stream.

The fraction of the solids in the discard stream varies from a maximum of about 50% to a lower value of about 25-30%. There is always some amount of drilling fluid associated with drilled cuttings being discarded.

Solids-control systems, no matter how good, cannot totally separate the drilling fluid from the drilled cuttings. By the same token, rarely can all of the drilled cuttings be separated from the circulating system. This means that, with time, drilled solids will build up in the circulating system (Duel, 1994).

1.8.2 Drilling Waste Minimization, Recycle and Reuse

It can be said that the proper administration of drilling wastes requires dealing with it from the comprehensive system perspective of the diverse aspects and components of interconnected rings, each ring depends on its preceding, and represent at the same time the base for the next ring, and in all cases, it is necessary in each stage to use proper means for the outstanding circumstances, and available resources and limitations. That means adopting the best options that fulfill the technical and environmental safety standards, and social harmony, and the least cost, and the highest possible recovery of resources, and commitment to legislation and regulations, keeping flexibility and good understanding for the cycle of life.

Waste Minimization is one of the most importance practices that can reduce volumes or impacts of wastes, this step may include using one or more options as drilling smaller diameter holes ,some drilling techniques can consume or use less drilling fluid , reducing the impacts of drilling fluids by choosing the non-toxic additives or selecting the less environmental impacts fluids as synthetic based fluids could be a good way for minimizing program.

Waste minimization or reuses of resources that can become waste are key strategies in waste avoidance and a sound waste management plan. Two general approaches to waste minimization have developed. They can be called total fluid management (TFM) and environmental impact reduction (EIR) (Greaves and Lawson, 2003).

The first step in managing drilling wastes is to separate the solid cuttings from the liquid drilling fluids. Once solid and liquid drilling wastes have been separated, the companies can use a variety of technologies and practices to manage the wastes. For some applications, drilling wastes are solidified or stabilized prior to their ultimate management practice. The management technologies and practices can be grouped into four major categories: waste minimization, recycle/reuse, treatment and disposal.

Most water-based fluids (WBMs) are disposed of when the drilling job is finished. In contrast, many oil-based fluids (OBMs) and synthetic-based fluids (SBMs) are recycled when possible. Sometimes the physical and chemical properties of the used fluids have degraded somewhat, and the fluids must be processed to rejuvenate the necessary properties. In other cases, the fluids have been degraded sufficiently that they cannot economically be reused as new fluids, and they must be put to a different type of reuse or final fate. (Cordah, 2001).

Many practices that can be used to reduce volumes or impacts of wastes as below;

- Drilling Practices That Minimize Generation of Drilling Wastes
- Directional Drilling
- Drilling Smaller Diameter Holes
- Drilling Techniques That Use Less Drilling Fluid
- Using Fluids and Additives with Lower Environmental Impacts
- Synthetic-based Fluids
- New Drilling Fluid Systems
- Alternate Weighting Agents

Road Spreading *is* one use of cuttings to stabilize surfaces that are subject to erosion, such as roads or drilling pads. Oily cuttings serve the same function as traditional tar-and-chip road surfacing. Not all regulatory agencies allow road spreading. Where it is permitted, operators must obtain permission from the regulatory agency and the landowner before spreading cuttings. Some jurisdictions limit road spreading to dirt roads on the lease, while others may allow cuttings to be spread on public dirt roads, too.

Cuttings can also be reused as Construction Material, after primary separation on shale shakers, cuttings are still coated with fluids and are relatively hard to reuse for construction purposes.

Various further treatment steps can be employed to render the cuttings more innocuous. Some cuttings are thermally treated to remove the hydrocarbon fractions, leaving behind a relatively clean solid material. Other cuttings are screened or filtered to remove most of the attached liquid fluids. If cuttings contain too much liquid, they can be stabilized by adding fly ash, cement, or some other materials to improve their ease of handling (Greaves and Lawson, 2003).

Another new application for drilling wastes involves using them as a substrate for restoring coastal wetlands (Veil, J.A., 2002). Additionally, several trials have been conducted in the United Kingdom using oily cuttings as a fuel at a power plant.

One of the largest sources of drilling waste for onshore operations is location water. This happens to be the source that can be reduced most. Most wastewater originates from drilling-fluid usage, storm water, rig wash water, or cooling water. The volume of location water requiring handling and disposal could be as much as 30 times the hole volume (Bradford, et al, 1999).

The approaches taken to reduce wastewater generation were based on reuse of as much water as possible. They included the following techniques:

1. Single-pass systems, such as cooling water, brake water, and seal water, were eliminated. These should be contained by enclosed systems. Recycling these fluids is inexpensive and can save a large amount of fluid.
2. Storm water was reused. Storm water can be reused for fluid makeup water, although the drilling personnel may not like it much. It can also be used for rig wash water. Rig wash water (which falls into the same ditches as the storm water) should be reused until it is too dirty to be used as wash water. It is surprising how many times wash water can be used effectively.
3. The dirtiest water (such as drilling-fluid waste) was used for slide wash water. Desanders and desilters generate copious amounts of drilling-fluid waste (usually calculated at two or three parts liquid to one part solid), yet still require washing to the disposal pit. Shaker slides and centrifuge slides almost always require wash water. Slide wash water does not need to be clean, and the introduction of any clean water into the waste solids and fluid chemicals is an unnecessary addition of water that becomes difficult to separate during disposal.
4. Liquid waste was not generated needlessly. The use of rig vacuums rather than washing is increasing precisely because of the expense involved with disposal of waste liquids. Pistol-grip shutoff valves on hoses are a great idea. When the floor hand is called for a connection, the hose that is thrown down will shut off automatically rather than run the whole time during connections. High pressure/low-volume washers are a favourite with rig crews, because they clean better with less effort. They also save liquid waste volume. Vacuums and washers are usually a breakeven cost unless the disposal cost is high, but pistol grips always pay off.

5. Wastes that were to be handled in different ways were separated. For instance, do not combine oil-based wastes with water-based wastes, unless they will be handled together. In this project, all liquid from the reserve pit was injected, so all liquid went to the reserve pit(Bradford, et al, 1999).

Another form of minimization strategy is to evaluate the environmental impact of the project and attempt to reduce it. In the EIR method, all fluids are evaluated for their chemical components. Certain environmental data are collected on each of the chemicals. The data might include parameters of:

- toxicity
- biodegradation potential.
- Persistence.
- Bioaccumulation.
- Heavy metal concentrations (Deis, 2005).

A review of the chemicals to be used would be made, and those chemicals with the least environmental impact would be selected.

A simple example of this is prequalifying a drilling-fluid system. In the prequalification, every chemical to be used is examined for the desired environmental characteristics and approved for use. In addition to each chemical individually, the entire system would be approved. Only approved chemicals, and only at the maximum approved concentration, would be allowed. This is, of course, a very complex system. Many fluid programs contain contingency chemicals that are used under only certain circumstances for a small portion of the hole (Deis, 2005).

1.8.3 Treatment of Drilling Waste

The drilling wastes treatment program depend many in many factors such as drilling types used, the compositions and characteristics of the wastes and the quantity of the wastes generated. The treatment methods can be chemical, physical, thermal or biological treatment. Selecting of the proper treatment program needs an environmental study of the drilling wastes generated and good management plan for the handling and the future disposal.

Thermal treatment is the most efficient treatment for destroying organics, and it also reduces the volume and mobility of inorganics such as metals and salts (Bansal, K.M., and Sugiarto, 1999).

Thermal treatment technologies have been applied in many drilling companies, it use high temperatures to reclaim or destroy hydrocarbon-contaminated material. Thermal treatment technologies can be grouped into two categories. The first group uses incineration to destroy hydrocarbons by heating them to very high temperatures in the presence of air. Incineration is not commonly used for drilling wastes but has greater applicability for materials like medical waste. The second group uses thermal desorption, in which heat is applied directly or indirectly to the wastes. (The E&P Forum, 1993).

Biological treatment or biotreatment uses microorganisms (bacteria and fungi) to biologically degrade hydrocarbon-contaminated waste into nontoxic residues. Some advantages of biological treatment are: it is relatively environmentally benign; it generates few emissions; wastes are converted into products; and it requires minimal, if any, transportation. Sometimes, bioremediation is used as an interim treatment or disposal step, which reduces the overall level of hydrocarbon contamination prior to final dispose (Getliff, J., and other 2002).

Biological treatment may contain also composting which is similar to land treatment, but it can be more efficient. Also, with composting systems, treated waste is contained within the composting facility where its properties can be readily monitored. With composting, mixtures of the waste, soil (to provide indigenous bacteria), and other additives may be placed in piles to be tilled for aeration, or placed in containers or on platforms to allow air to be forced through the composting mixture. Bioreactors work according to the same aerobic biological reactions that occur in land treatment and composting, but the reactions occur in an open or closed vessel or impoundment (McMillen, S.J., and N.R. Gray, 1994).

1.8.4 Solidification and Stabilization

The solidification refers to techniques that encapsulate the waste in a monolithic solid of high structural integrity. The encapsulation may be of fine waste particles while *Stabilization* refers to those techniques that reduce the hazard potential of a waste by converting the contaminants into their least soluble, mobile, or toxic form. (U.S. Department of Energy,2012).

Not all drilling wastes are amenable to chemical fixation and stabilization treatments. Solidification/stabilization should be adapted for site-specific applications depending on the end-use of the treated material and the chemical characteristics of the waste.

Conducting laboratory tests to determine the proper blend of additives to achieve the desired material properties is recommended.

Some companies have used solidification/stabilization for drilling wastes. The resulting materials have been used for road foundations, backfill for earthworks, and as building materials (Morillon et al., 2002).

1.8.5 Waste Disposal

Drilling fluids, synthetic oil–based drilling fluids, and other fluids with expensive additives provide a great incentive to use good solids-control procedures. However, minimizing the waste products from these expensive systems will also have a great impact on drilling costs (Friedheim, 1999).

Most drilling operations have a targeted drilled-solids concentration. Failure to remove drilled solids with solids-control equipment leads to solids control with dilution. This creates excessive quantities of fluid that must be handled as a waste product. If this fluid must be hauled from the location, the excess fluid becomes a large additional expense. Even if the fluid can be handled at the location, larger quantities of fluid frequently increase cost.

Smaller quantities of waste products can significantly decrease the cost of a well. Decreasing the quantity of drilling fluid discarded with the drilled solids will decrease the cost of rig-site cleanup. Dilution techniques for controlling drilled-solids concentrations greatly increase the quantity of waste products generated at a rig. This results in an additional expense that adds to the total cost of drilling (Robinson, 2005).

The drilling-fluid program should address environmental issues concerned with the discharge of drilling fluid, products, and removed solids. Personnel managing the solids-separation equipment must be very familiar with this part of the drilling-fluid program and have a good understanding of governmental regulations and operator requirements (Bradford et al., 1999).

Many drilling operations have strategies in place for drilling-fluid recovery and will have established some general guidelines for the disposal of materials classified as waste. However, situations can arise that present the engineer managing the solids-control equipment with the issue of whether to discard or recycle some types of waste and how to do it. If disposal costs are not a factor, then all waste can be disposed of and treated, if necessary, onsite or sent to a processor offsite. However, if it is possible to recycle some of the products to the fluids system, it may prove economical to do so (Hollieret al, 2001).

There are several practices to get rid and disposal of drilling wastes summarize as bellow;

- Onsite Burial (Pits, Landfills)
- Bioremediation:
- Composting
- Bioreactors
- Vermiculture

- Discharge to Ocean
- Offsite Disposal to Commercial Facilities
- Slurry Injection
- Salt Caverns
- Thermal Treatment:
- Incineration
- Thermal Desorption

Burial is the most common onshore disposal technique used for disposing of drilling wastes (fluids and cuttings). Generally, the solids are buried in the same pit (the reserve pit) used for collection and temporary storage of the waste fluids and cuttings after the liquid is allowed to evaporate. Pit burial is a low-cost, low-tech method that does not require wastes to be transported away from the well site, and, therefore, is very attractive to many operators**.**

Simply pushing the walls of the reserve pit over the drilled cuttings is generally not acceptable. The depth or placement of the burial cell is important. A moisture content limit should be established on the buried cuttings, and the chemical composition should be determined. Onsite pit burial may not be a good choice for wastes that contain high concentrations of oil, salt, biologically available metals, industrial chemicals, and other materials with harmful components (Bansal and Sugiarto, 1999).

The use of earthen or lined pits is integral to drilling waste management. During most U.S. onshore drilling operations, the cuttings separated by the shale shaker are sent to a pit called the reserve pit located near the drill rig. The pit is generally open to the atmosphere, so it also accumulates storm water and washes water from the rig. The strategic location of small pits near drilling sites can also help minimize spillage of waste materials.

It is important to know that significant threat to water resources can occur, liners are generally required. Engineering precautions incorporated into the design will help to ensure pit integrity. Precautions should be taken to prevent disposal of any contaminates.

Landfills are used throughout the world for disposing of large volumes of municipal, industrial, and hazardous wastes. In landfills, wastes are placed in an engineered impoundment in the ground. The waste is covered with a layer of clean soil or some other inert cover material. Modern design standards require clay or plastic liners.

The advantages of onsite burial of drilling wastes include the following:

- Simple, low-cost technology for uncontaminated solid wastes.
- Limited surface area requirements.

Concerns include the following:

- Potential for groundwater contamination if burial is not done correctly or contaminated wastes are buried, and the resulting liability costs.
- Requirements for QA/QC, stabilization and monitoring(Sugiarto, 1999).

1.9 Description of the Problems

It can be said that oil and gas are the lifeblood and the primary engine for all the processes of economic and social development and they will remain the same in the future due to the limited resources of nontraditional energy either from its availability or utilization, and due to this high importance of oil and gas a great attention was given in many oil producing countries, where oil is considered the main tributary for the state treasury of foreign exchange, so the processes of exploration and drilling for oil and natural gas accelerated and grown in order to extract them and produce oil derivatives.

The problem of the study stems from the negative environmental effects resulting from drilling processes, especially that the drilling wastes of oil gas wells are of harmful and negative environmental effects, this wastes contains some toxic heavy metals, chemicals, additives which are harmful to soil, sea air groundwater, with the knowledge that these residues increase as a result of increased drilling and exploration for oil. the lack of laws and regulations on the management of this wastes in Saudi Arabia which makes it necessary for the officials of exploration and drilling companies to dispose off these wastes in the proper way to guarantee making use of recycling them and limiting pollution to the surrounding environment either land or sea, which leads into pushing in the direction of implementing the concept of administering resulting wastes from oil and natural gas exploration and extraction.

From the above the study problem can be summarized by answering the following questions:

- What are the drilling wastes with regard to volume, types, chemical and physical characteristics and compositions?
- What are the current management practices and policies followed by various drilling companies?
- What are the main legislation and environmental standards and government agencies responsible for implementation?
- What international environmental regulations or standards following by drilling company to deal with drilling waste?

1.10 Importance of the Study

The importance of the study stems from the subject importance itself where setting plans for managing the drilling wastes of exploration and drilling generated from the oil and gas industry. Improving the drilling wastes management methodologies through minimizing, recycling, treating and disposing these wastes is expected to lead to the protection of the surrounding environment. It also expected to make the exploration of oil and gas industry a sustainable industry through minimizing the resource depletion and preserve the ecological systems.

This study is considered as one of the first of its kind in Saudi Arabia and its results and information will be very important and useful to build a significant baseline database about the drilling wastes in Saudi Arabia that may be used by the researchers and decision-makers in governmental environmental agencies as well as the drilling companies.

1.11 Objectives of the Study

In general, the main objective of the study is to investigate the problem of drilling wastes management in oil and gas companies in the Eastern Province of Saudi Arabia. In specific, the study aims at:

- Surveying of the drilling wastes with regard to volume, types, chemical and physical characteristics and compositions.
- Assessing the current management practices and policies followed by various drilling companies.
- Comparing the current drilling wastes management practices in Saudi Arabia with other international experience.

CHAPTER 2

LITERATURE REVIEW

There are many studies and research aimed at identifying the best practice for the management and disposal of drilling wastes through a review of the concept of drilling wastes that appear as a result of drilling and exploration for oil wells, natural gas, and to identify the legislation and standards that are taken into account when carrying out drilling operations.

Hossain (2011) explained that the drilling wastes need more stringent pollution-control procedures. Different environmental agencies around the globe are very much aware and concern about the increasing toxicity level of the environment, surface, marine, and subsurface areas due to drilling waste. The disposal of toxic fluids residue and contamination of subsurface structure are the biggest challenges for the petroleum industry. Therefore, it is very important to look for sustainable diagnostic tests before disposal of toxic drilling fluids. It is also important during the development of new drilling fluids which are not harmful for the human, environment and the subsurface formation. He also addressed in his research the pathway comparison for current (unsustainable) and natural (sustainable) methods for drilling fluids. It depicts a guideline how to develop asustainable drilling fluid technology. The study gives a sustainable technology diagnostic

test as a flow chart that would be used as a guideline for sustainable drilling fluid. The article proposes future guidelines for the development of a sustainable drilling fluid technology, the diagnostic test procedure will enhance the understanding of how to handle the current challenges coming from drilling fluid to the environmentalists, manufacturers, government agencies and petroleum industry.

Tawabini (2010) addressed some general environmental concerns related to the drilling fluids management and compared the various fluids types. The paper also highlighted on the negative environmental impacts of the improper disposal practices of drilling wastes. The researcher explained different types of the drilling fluids and their characteristics and compositions, environmental issues associated with drilling fluids, the researcher mentioned the impacts of this fluid of the imposes on the surrounding environment. For instance, OBM is an effective drilling fluid but toxic to marine plants and animals, the paper suggested some options to minimize environmental impacts of drilling waste like recycling of drilling fluids components and drilling cuttings components and to reduce the amount of fluids discarded or spilled or reused it, also some popular methods of drilling waste treatment and disposal are can be used to manage the drilling waste. In addition, the researcher give an example from Saudi Arabia as potential effect of disposal drilling cutting in Sabkhasoils which can be considered potentially environmentally significant areas. Huge amounts of drilling fluids including oil-based, water-based as well as synthetic-based fluids are being used in the wells drilling operations. Some of these wells are located with the sabkha area covering large areas of the eastern part of the Arabian Peninsula.

In Kokeljetal., (2010), the researchers explain that Permafrost can provide a containment medium for drilling wastes deposited to in-ground sumps, but tall shrubs may proliferate on covers causing snow to accumulate, active layers to deepen and the ground to thaw. They evaluated the effects using a 2-dimensional heat transfer model to simulate the thermal evolution of sumps in warm and cold permafrost under varying snow and climate conditions characteristic of the Mackenzie Delta region.

The study of Zhang et, al (2009) about Thermal remediation of the soil contaminated with crude oil using microwave heating enhanced by carbon fiber (CF) The experimental results in this study indicated that CF could efficiently enhance the microwave heating of soil even with relatively low-dose, the soil could be heated With 0.1 wt.% CF to approximately 700 degrees C within 4 min using 800 W of microwave irradiation. Correspondingly, the contaminated soil could be highly cleaned up in a short time. Investigation of oil recovery showed that, during the remediation process, oil contaminant in the soil could be efficiently recovered without causing significant secondary pollution.

The study of Gonzalez et al., 2010, showed that new waste treatment and disposal practices are being used in Texas and Louisiana to reduce, reuse and recycle (R3) drilling waste. In these areas, R3SM technologies and programs can convert drill cuttings to beneficial and environmentally friendly road base and levee fill reuse material to help minimize exploration and production (E&P) operator liability. Land treatment has been used for years to segregate water, cuttings and oil so that soluble salt content is decreased, oil concentration is reduced by recovery or degradation, and clean cuttings or reuse materials can be separated and stored in secure onsite stockpiles and landfills. What's new about the R3 Process is that converting the reuse material to road base and levee fill can safely transform an otherwise waste material to a reusable product. Lab tests of the new road base recyclable R3 Product conducted in Texas have proven that it is environmentally sound, more affordable than traditional asphalt paving materials and has comparable engineering qualities. Pending rule changes by the Railroad Commission of Texas to reclassify treated cuttings as reuse material may allow and encourage the industry to safely recycle a drilling waste into a recyclable product.

Robinson et al., (2009) showed that the continuous pilot-scale microwave treatment process for the remediation of oil-contaminated drill cuttings from North Sea drilling activities. The underlying scientific methodology is highlighted, and the development of the continuous processing concept is discussed.

Pivelet al., (2008) explained that the discharge models allow the prediction of the potential impact associated with drilling activities based on estimates of the initial spatial extent and thickness of accumulations on the seabed. As such, they are a valuable tool for both the oil industry and regulatory agencies. The comparison of modeling results with field observations showed that the estimates of both the area affected by the deposits and maximum thickness are satisfactory.

In conclusion, despite the importance of the subject from environmental point of view, the literature search conducted revealed that little work has been done that investigate and assess the various aspects of drilling wastes management in Saudi Arabia. For this, this study is expected among the first studies conducted to evaluate the drilling waste management methodologies.

Santos et al., (2008) assessed the effects of non-aqueous fluids (NAFs-type III) cuttings discharge from exploratory drilling activities on deep-sea macrobenthic communities in the Campos Basin, off the southeastern Brazilian coast, Rio de Janeiro State. In addition results of same study showed that drilling activities led to measurable effects on the community structure related to NAF cuttings discharge but were limited to a 500 m radius from the drilling well. Such effects were much more evident at isolated sites in the impact area (WBF and WBF+NAF areas) and are characterized as localized impacts. One year after drilling, a recolonization was observed, with the probable recovery of the macrobenthic community in most of the study area; only at part of the WBF+NAF area (stations 05, 24 and 36) was the community still undergoing recovery.

In the special issue of Deep-Sea Research Elírioet al., (2008) included the results of the Project Environmental Monitoring of Offshore Drilling for Petroleum Exploration-MAPEM in a deep-water showed the effects of the discharge of non-aqueous fluids (NAFs) impregnated drill cuttings. The study by (Rojas et al., 2007) reported that the remediation of drilling fluids-polluted sites in the Southeast of Mexico is a top priority for Mexican oil industry.

Nilsen, et al. 2008 presented novel technology for treatment of the tar sands drilling waste generated from SAGD and other tar sands drilling operations. The continuous treatment process is based on hot water addition, mixing and separation techniques to reduce the viscosity and specific gravity of the bitumen to separate it from the sand. Treatment of cuttings with light to heavy bitumen contamination and varying quantities of fine sand and clay particles has shown this treatment method to be a simple and effective means of producing clean sand and recovering the bitumen component. The energy used to heat the circulating water is recycled to minimize waste and maximize energy efficiency. The cleaned sand can be blended with natural soil and safely disposed in the environment. The recovered bitumen can be used as feedstock for further processing and refining.

As stated in the study by Richard et al., (2007), the principal aim of drilling waste management is to ensure that waste does not contaminate the environment at such a rate or in such a form or quantity as to overload natural assimilative processes. Sustainable development of petroleum resources requires careful monitoring and appropriate disposal of all waste streams generated over the life cycle of a development, from the initial planning of projects and operations through decommissioning and site restoration.

Muhereil and Junin (2007) indicated that the offshore direct discharge is a simple and economically feasible method in which the contaminated drill solid cuttings are released to the environment onsite. Recently, disposal of oily drilling waste is strictly regulated. Allowable oil on cuttings particularly offshore is set at limits far difficult for current cleaning technologies to deal with. Therefore there is an urgent need to develop cost-effective methods for cleaning oil well contaminated drill cuttings and grant their direct discharge offshore.

In Jerry and Duxbury's (2005) study, the researchers explain that the Water based drilling fluids (WBM) consist of fresh or salt water containing a weighting agent (usually barite: $BaSO_4$), clay or organic polymers, and various inorganic salts, inert solids, and organic additives to modify the physical properties of the fluids so that it functions optimally. Drill cuttings are particles of crushed rock produced by the grinding action of the drill bit as it penetrates the earth.

In Veil (2004) study, researcher tried to explain that the offshore oil and gas operations generate a variety of solid and liquid wastes. Some of these wastes are attributable to exploration and production (E&P) activities (drilling wastes, produced water, treatment and work over fluids), while others are due to either human presence (sanitary wastes, food wastes) or generic industrial operations (wastepaper, scrap metal, used paints and solvents). This paper focuses on the E&P wastes, nearly all of which are disposed of in one of three ways – by discharge to the ocean, by injection into a dedicated injection well or into the annulus of a well being drilled, or by transport to a disposal site onshore.

In Nweke and Okpokwasili, 2003 study, researchers explain that Staphylococcus sp. isolated from oil-contaminated soil was grown in 1% drilling fluid base oil, HDF-2000, as a sole source of carbon and energy. The organism has strong affinity for the substrate, growing at the rate of 0.16 h^{-1}. It uses adherence and emulsification as mechanisms for oil uptake. In a nutrient-rich marine broth, base oil (up to 2.0% v/v) and glucose (up to 1.6%

w/v) have no significant effect on the growth rates. This showed that the Staphylococcus sp. is a strong primary utilizer of the base oil and has potential for application in bioremediation processes involving oil-based drilling fluids. The results showed that there was an increase in growth rates and decrease in generation times at all concentrations of the base oil and glucose.The growth rates varied between 0.60 and 0. 66 h^{-1} for the base oil and between 0.64 and 0.77 h^{-1} for glucose. On the other hand, the generation times varied between 1.16 and 1.06h for the base oil and between 1.08 to 0.90 h for the glucose. However, the analysis of variance at 95% confidence limit showed that these variations were insignificant. It therefore could be reasoned that 2% drilling fluid base oil and 1.6% glucose are below toxic or inhibitory concentrations for the *Staphylococcus* sp. Glucose toxicity and impaired glucose transport and utilization have been reported for *Bacteroidesruminicola*. The results of this work showed that this organism has potential application in the bioremediation of sites polluted by oil-based drilling fluid base oil.

Kinigoma, (2001) show in his studies that the effect of drilling fluid additives on the Soku oil fields environment has been examined. Soil and reserve pits in various locations were assessed for some physic chemical characteristics and heavy metal content using standard methods for water and wastewater analysis. Plant growth and other biomass were also assessed.

The result showed that the levels of most physiochemical characteristics are generally within the limits of guidelines by regulatory authorities. However, trace metal levels are generally below toxic levels, except Fe, Ca and Mg, which were higher than recommended values. These high values of Fe, Ca and Mg (17.70-220.2 ppm; 11.03-296.80 ppm; and

12.62-75.71 ppm) respectively are characteristic of the Niger Delta Swamp soils. Also a poor plant growth was observed in the immediate vicinity of location of drilling operations, an indication of the toxic effect of drilling fluids on the environment.

Study of (Melton et al., 2000) explain that the most effective regulations or public policies are developed cooperatively by government and industry based on sound scientific understanding of the potential impacts, risk considerations, and evaluation of the costs and benefits of alternative approaches. This paper reviews the scientific framework that helped achieve general regulatory acceptance of the discharge of water-based drilling fluids and cuttings and discusses information being considered in current efforts to develop policies for the discharge of cuttings drilled with non-aqueous fluids (NAF). Development of effective policies for discharges depends on consideration of the specific local environmental conditions that govern the fate of discharge materials, the scientific basis for assessing the potential for effects in that environment, and balanced consideration of the environmental effects and relative costs of discharge versus other disposal options. This approach can lead to policies that provide for environmental protection and encourage adoption of mitigation measures that provide benefits commensurate with their cost.

Abu Khamsin (1997) explained in his paper presented in Middle East Drilling Technology Conference "The Environmental Regulations for Drilling Operations in Saudi Arabia”,that there are several environmental regulations that any drilling and work over contractor must follow when working in Saudi Arabia onshore and offshore areas. These regulations are corporate, national, regional and global in nature. These environmental regulations are established to control drilling operations to minimize its impact on the environment. Most importantly, that researcher stated some Aramco's regulation/standards related Oil-Based Fluids/Toxic Fluids/Cuttings from Toxic Fluids. All oil-based drilling fluids, toxic fluids, and cuttings from toxic drilling fluids must be hauled back to an approved onshore disposal site. For alternative oil based fluids, LC-50 toxicity tests shall be run to determine toxicity of the cuttings. If fluids are toxic then fluids and cuttings should be disposed in an approved disposal site.

From the above studies, it can be concluded that there were not many studies that address the issue of drilling waste management in Saudi Arabia. This study can be considered as one of the first studies in this subject that assess the practice of drilling waste management in Saudi Arabia.

CHAPTER 3

METHODOLOGY

3.1 Study Boundaries

Spatial boundaries: Eastern Region - Kingdom of Saudi Arabia.

Subject boundaries: the study is conducted on the subject (Management of the Drilling Wastes).

3.2 Population and Sample of the Study

Oil and Gas companies and drilling contractors operating in the Eastern Province of Saudi Arabia have been chosen for this study. four Gas and three oil companies in eastern part of Saudi Arabia were selected, including Sino Saudi Gas Company, South Rub' Al-Khali Company (SRAK), Luksar Energy, EniRepSa Gas, Saudi Aramco, Aramco Gulf Operation and Saudi Chevron, respectively. The study was also distributed to approximately 25 drilling contractors working with the oil and gas companies.

The study included both drilling operations in land (onshore) and marine (offshore) environment. The sample of the study will be simple random sample workers in these companies.

3.3 Data Collection

The data collected in this study was based on two types of information sources namely: primary (preliminary) and secondary data. The primary information was collected through the answers of respondents to the questionnaire of the study, and it covers all aspects addressed by the theoretical framework for the study. The secondary data was collected through the review and survey of books and references, articles and previous studies on the field of study in order to develop the scientific foundations and theoretical frameworks and have access to the hypotheses based on the foundations of the theory.

3.4 Study Design and Methodology

This study depends on descriptive analytical methodology (mixed methods research) that describes a phenomenon in order to identify the reasons for this phenomenon and the factors that control it, and extraction of the results to generalize them. The follower of the development of sciences can grasp the importance that the descriptive approach has occupied in this development, which relates to its appropriateness in studying cultural phenomena. This methodology describes phenomena in objective terms through data collected using tools and techniques of scientific research. (Ebel, etal., 2003).The descriptive approach depends on gathering facts and information and comparing, analyzing and explaining them in order to arrive at accepted generalizations, or studying, analyzing and explaining the phenomenon in question by defining its dimensions and characteristics and describing the relations between them, in order to reach a comprehensive scientific description. Thus, it contains a number of sub-approaches and assistant styles (Teseleanu, 2007).

3.5 Nature of the study

The study depends on quantitative methods. Quantitative data is obtained through the questionnaires in the form of numbers in an attempt to give precision to the range of responses to the statements contained in the questionnaire.

This study can be classified as an exploration and field study. It may be considered exploration because it tries to explore the views held by employees work in oil drilling company. As a field study, it is based on collecting the elementary data through a questionnaire developed and distributed to oil drilling company. Therefore, the researcher has implemented the comprehensive scanning approach in collecting data, classifying and analyzing it in order to arrive at conclusions that serve the objectives of the research.

3.6 Study Tool (Questionnaire)

The study tool is a set of different means that the researcher depends on in order to obtain the data and information needed to accomplish the research. If the research tools are versatile, then the nature of the subject or problem determines the size, quality and nature of the study tools that the researcher has to use in accomplishing the task. The proficiency of the researcher plays an important role in defining the way in which the scientific study tools will be used (Collins et. al., 2004). The study tool considered as the data collecting means is versatile and might be in the form of a questionnaire, an interview or notice. Choosing the tool depends on the approach used and the extent to which it is suitable for the study. It also depends on the knowledge, understanding and experience of the researcher in using the tool.

The questionnaire is regarded as one of the specific data collecting methods of descriptive research and is one of the most widely used, due to the difficulty of interviewing a large number of participants, living sometimes in very disparate areas.

- For the purposes of the field study, the researcher designed a questionnaire, to be distributed among individual sample, is composed of four parts:
- The first part deals with the Background information about the company.
- The second part deals with the types, volume and composition of drilling fluids and cuttings.
- The third part deals with the Drilling wastes management.
- The fourth part deals with the Environmental Regulations & Standards.

3.7 Methodology of Developing Study Tool (Questionnaire)

The process of developing the study tool consisted of many steps until it has reached the point in this study where it has been accredited as fit for purpose. These steps can be summarized as follows:

- Fifty five (55) questions were defined in terms of four aspects in the questionnaire to be distributed to individual sample.
- After all of the study aspects related to individual sample were accredited, the questions contained in the questionnaire were sorted and reviewed to make sure of their relevance and comprehensiveness.

Following the construction of the elements that formed the elementary structure of the questionnaire, based on the format of previous studies, it was shown to academic specialists in the field for approval.

The questionnaire elements were rearranged randomly so that the elements representing or measuring each variable did not follow in a sequential manner. The Questionnaire is shown in Appendix 1.

3.8 Quality Test of the Questionnaire

A group of experts were selected to determine whether or not the quality of questions are effective and understandable, this will improve questionnaire and make them more accurate.

The questionnaire sent to three experts with more than 15-years' experience in the field of drilling wastes management as fowling;

- One expert is a professor from a university
- Second expert is a manger in environmental consultation company
- Third expert is a senior supervisor in drilling operations from Ministry of petroleum.

All comments received from the experts were classified and carefully considered, the researcher added, deleted and corrected some questions depending in their advices and after arrangement with the thesis committee. This was done to help improve the quality of the questionnaire. The Questionnaire evaluation reports are attached in Appendix 2.

3.9 Ways Used for Distributing the Questionnaire

The researcher designed three copies of questionnaire as following;

1. Creating an online questionnaire

With the growth of the Internet (and in particular the World Wide Web) and the expanded use of electronic mail for business communication, the electronic survey is becoming a more widely used survey method. Electronic surveys can take many forms. They can be distributed as electronic mail messages sent to potential respondents. They can be posted as World Wide Web forms on the Internet. Electronic surveys are placed on laptops and respondents fill out a survey on a laptop computer rather than on paper, data analysis tools will either be an integral part of the website or data can be copied or ported directly into analysis software such as SPSS or Microsoft Excel. Typically both options are offered.

This means the results are available as the data is entered, and transcription errors and the chore of manual data entry into separate analysis software are eliminated. In fact, the online questionnaire has many advantages listed as below;

- Cost-savings: It is less expensive to send questionnaires online than to pay for postage or for interviewers.
- Ease of Editing/Analysis: It is easier to make changes to questionnaire, and to copy and sort data.
- Faster Transmission Time: Questionnaires can be delivered to recipients in seconds, rather than in days as with traditional mail.
- Easy Use of Preletters: You may send invitations and receive responses in a very short time and thus receive participation level estimates.
- Higher Response Rate: Research shows that response rates on private networks are higher with electronic surveys than with paper surveys or interviews.
- More Candid Responses: Research shows that respondents may answer more honestly with electronic surveys than with paper surveys or interviews.
- Potentially Quicker Response Time with Wider Magnitude of Coverage: Due to the speed of online networks, participants can answer in minutes or hours, and coverage can be global.

2. Creating a soft copy

   This includes the A PDF and WORD format that can be sent and received easily by Email.

In addition to the online version, twenty six (26) hard copies of the questionnaire were distributed to a number of drilling companies. The responders had the option of answering the hard copy on site or answering it later then sending it back via fax or e-mail.

The number of responses according to the way of distribution was 72% from online website and 28% from hardcopies distributed to the drilling companies. The total percentage of responses was 54% (46% did not respond).

CHAPTER4

RESULTS AND DISCUSSIONS

4.1 Types, Compositions and Volumes of Drilling Fluids Used

In this part of the study, results extracted from the answers related to the types of the drilling fluids used in drilling operations are discussed; including the compositions of the fluids used and the volume of both drilling wastes generated during the drilling operations.

4.1.1 Usage of Water Based Fluids (WBF) in Drilling Operations

The usage of the water based fluids in the drilling operations has been widely considered in this study. There might be some advantages and disadvantages for WBF but such drilling operations are done Given the great environmental impact as its asset, and additional factors considered include drilling performance, anticipated well conditions, worker safety, fluid cost, and waste disposal costs, questions were asked to know the frequency of using WBF in the drilling operations. The answers are subdivided into: never, sometimes, often and nearly always. Figure3 shows that the usage of WBF is generally high among the drilling contractors. 63.2% of these contractors nearly always use WBF and 36.8 % often use it. This result indicates clearly that most drilling companies use WBF in their drilling operations constantly.

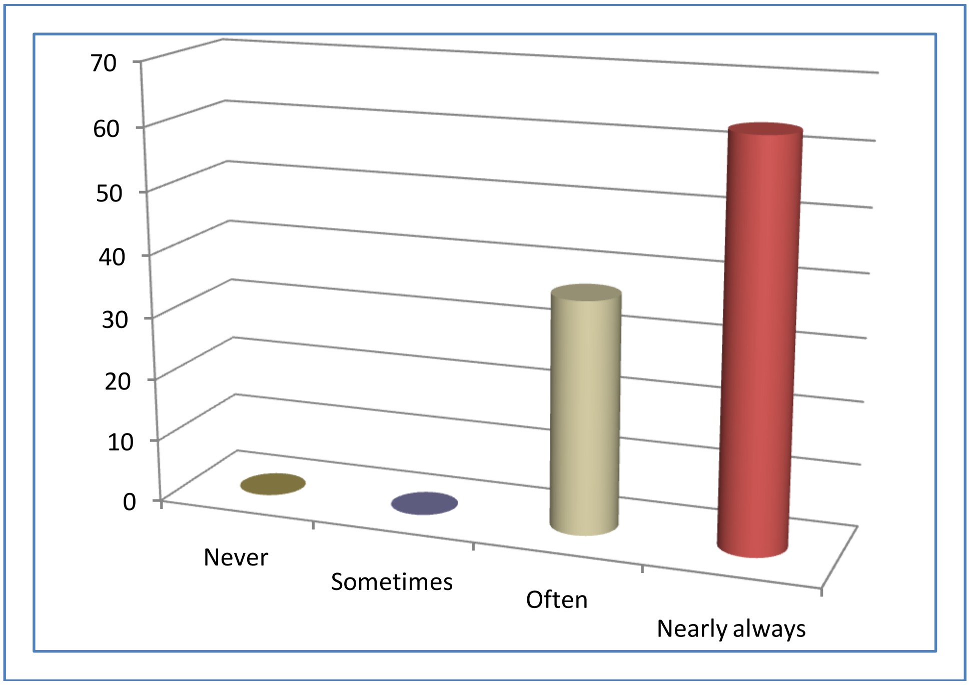

Figure 3. Frequency of using (WBF) in the drilling operations

WBF has lower environmental impacts since it mainly contains water, but it also has clays and other chemicals that incorporate into the water to create a homogenous fluid. Water based fluids commonly consists of bentonite clay (gel) with additives such as barium sulfate (barite), calcium carbonate or hematite. Various thickeners are used to influence the viscosity of the fluid. Other components are added to provide various specific functionalities. Some other common additives include lubricants, shale inhibitors and fluid loss additives (to control loss of drilling fluids into permeable formations).

Water based fluids are non-toxic or practically non-toxic to marine animals, unless they contain elevated concentrations of petroleum hydrocarbons, particularly diesel fuel. Most drilling fluids ingredients are non-toxic or used in such small amounts in WBM that they do not contribute to its toxicity.

Chrome and ferrochrome lignosulfonates are the most toxic of the major WBF ingredients. Effects of WBM cuttings piles on bottom living biological communities are caused mainly by burial and low sediment oxygen concentrations caused by organic enrichment. Toxic effects, when they occur, probably are caused by sulfide and ammonia byproducts of organic enrichment. Recovery of benthic communities from burial and organic enrichment occurs by recruitment of new colonists from planktonic larvae and immigration from adjacent undisturbed sediments. Ecological recovery usually begins shortly after completion of drilling and often is well advanced within a year. Full recovery may be delayed until concentrations of biodegradable organic matter decrease through microbial biodegradation to the point where surface layers of sediment are oxygenated. Thus, the compositions and characteristics of WBF play an important role in identifying the proper waste management technique to adopt before final land disposal or discharge into sea, especially in the sensitive environments.

EPA placed limits on the concentrations of cadmium and mercury concentration in drilling fluid barite in 1993, some of the barite used in drilling fluids contained elevated concentrations (compared to concentrations in natural marine sediments) of several metals (American Petroleum Institute,2005).

Ten days exposure of cockle to the solid phase sample shows that water based fluid indicates the highest mortality (87%) compared to the oil based fluids (diesel) which is 73% and oil based fluids (mineral oil) which is 53%. These results suggest that drilling fluid systems should be carefully formulated to minimize the effect of pollution to the environment (Issham, 2007), the consumption of bentonite clay in the drilling operations in Saudi Arabia alone can reach over 100 thousand tons a year (Tawabini, 2010).

4.1.2 Usage of Oil Based Fluids (OBF) in Drilling Operations

As by far the WBF has deficient application, OBFs have been refined and developed for the past 30 years, covering up for the aforementioned deficiencies. OBMs have traditionally been used to improve lubricity, minimize problems associated with water-sensitive formations, and deal with other site-specific conditions (such as high temperature) for which WBMs are not suited. OBFs are used where WBF are dangerous, additionally impossible, or uneconomical to use. Furthermore, questions were asked to know the frequency of using (OBF) in the drilling operations. From the data described in Figure 4, 68.2% of respondents never used Oil Based Fluids (OBF) in drilling operations. While 21.1% of respondents sometimes used it and 10.5%used it often.

Oil-based fluid can be a fluid where the base fluid is a petroleum product such as diesel fuel. OBF is used for many reasons; some being increased lubricity, enhanced shale inhibition and greater cleaning abilities with less viscosity.

The use of OBF has special considerations. These include cost and environmental considerations. Cost is a major concern when selecting oil-based fluids. Initially, the cost per barrel of an oil-based fluid is very high compared to a conventional water-based fluids system. However, because oil fluids can be reconditioned and reused, the costs on a multi-well program may be comparable to using water-based fluids (Amoco, 2010).

Today, with increasing environmental concerns, the use of oil-based fluids is either prohibited or severely restricted in many areas. In some areas, drilling with oil-based fluids requires fluids and cuttings to be contained and hauled to an approved disposal site. The costs of containment, hauling and disposal can greatly increase the cost of using oil-based fluids.

Because of the toxicity of the OBF, the discharge of OBF and the associated cuttings generated can possess great environmental impacts specially in the marine environment, in the USA, some EPA regions do not allow any discharges overboard, others require bioassay information for the drilling fluid prior to discharge, and some allow almost any discharge into state or federal waters. Many industry experts expect that sooner or later, the Federal EPA and related agencies will require all discharges to be "non-toxic" or hauled to shore for disposal. Moreover, it appears that state waters will follow suit. Thus, the ultimate fate of waste material generated in offshore drilling operations will need to be handled according to onshore disposal regulations. Unfortunately, there is no regulations and standards related directly to drilling wastes in Saudi Arabia. However, some drilling companies indicated in their answers in the study that they applied American regulations and standards in their operations. So there is urgent need for the environmental governmental agencies to start building drilling wastes regulation and standards to control and manage drilling wastes.

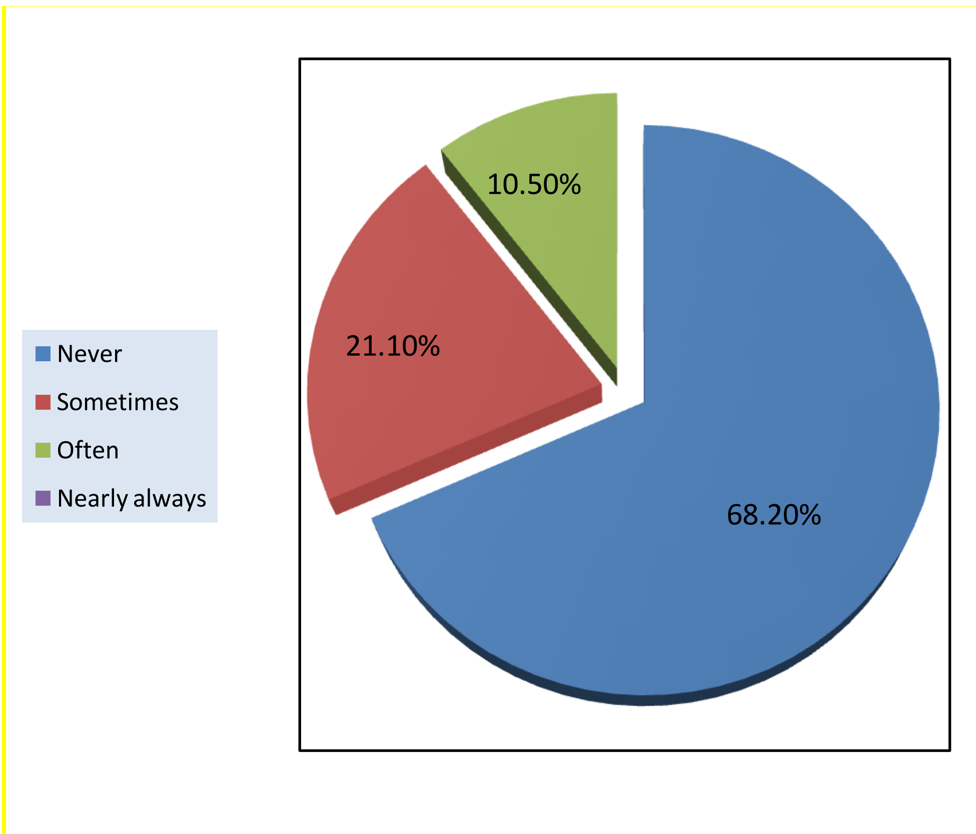

Figure 4.Frequency of using oil based fluids

4.1.3 Usage of Synthetic Based Fluids(SBF) in Drilling Operations

Synthetic-based fluids is one of the most important fluids that usually help to reduce the risk of severe downhole losses and reduced overall well costs on many deepwater projects while providing an environmentally friendly alternative to oil-based fluids. Low toxicity mineral oils are unlikely to meet many recognized industry standards to evaluate biodegradation properties of base oils. In order to evaluate the usage of SBF in the drilling contractors , a question was asked to know how often they use it in their operations.

Results in Figure 5show how often SBF is used in drilling operations 10.5% of respondents nearly always use SBF. It can also be clearly seen that 47.4% of respondents sometimes use SBF, 5.3% often use it, while 36.6% say they never use it.(Figure 5).

SBFs are reported to perform as well as or better than OBFs in terms of rate of penetration, borehole stability, and shale inhibition. Due to decreased washout (erosion), drilling of narrower gage holes, and lack of dispersion of the cuttings in the SBF, compared to WBF the quantities of fluids and cuttings waste generated is reduced, reportedly in some cases by as much as 70 per cent (Candler, et al, 1993).

Synthetic based drilling fluids represent a new technology which developed in response to the widespread permit discharge bans of OBF, it actually less toxic than the OBF, compared to conventional oil based fluids, the wastes generated from synthetic. Based fluids (SBFs) have lower toxicity, lower bioaccumulation potential and faster biodegradation rates (Sadiq, 2003),SBF's associated wastes still have a certain amount of pollutants due to contamination with formation oil and the presence of trace heavy metals in barite, which may pose environmental risk. Several field studies have been performed to monitor the biological effects of SBF cuttings discharges on the benthic environment. The studies show that where base fluids accumulate to high concentrations in sediments, adverse effects in benthic communities are evident. The usual pattern of response in sediments is a decrease in the number of marine animals in the sediments, accompanied by little change or even an increase in the number of individuals present(J.M. Neff,2000). SBFs are can be also one source of the pollutant especially in the sensitive marine area. father studies should be done in the effects of SBF and its characteristics and compositions which will help minimizing its impacts and make it more environmentally friendly fluids.

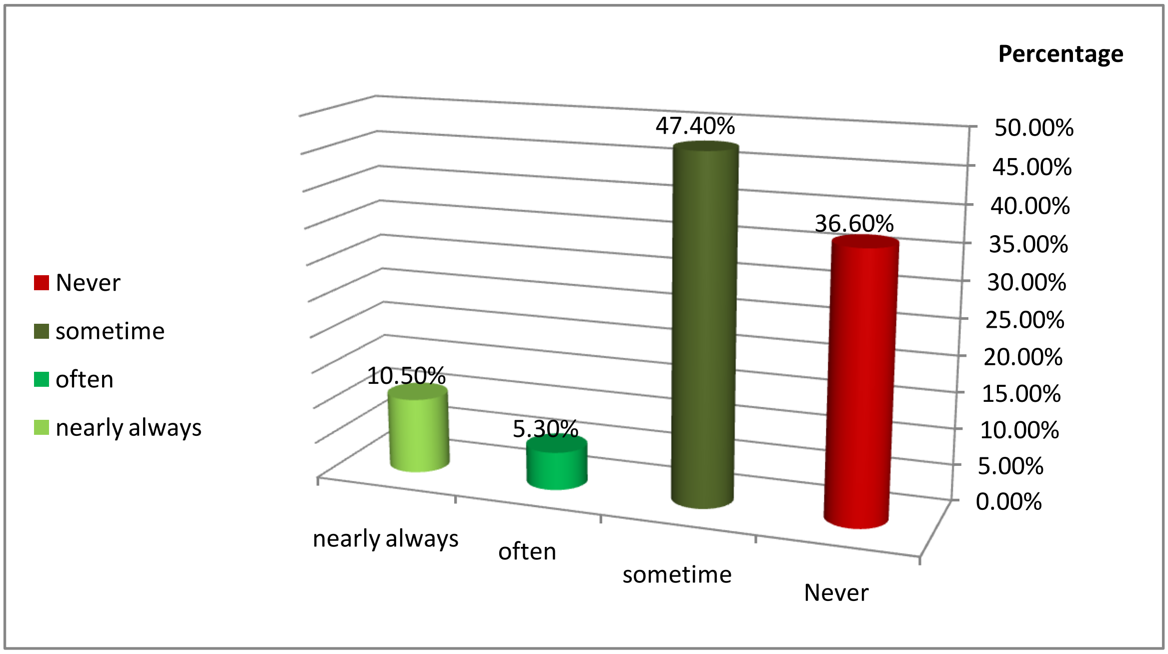

Figure 5. Frequency of synthetic based fluid usage

4.1.4 Usage of Gaseous Drilling in Drilling Operations

Gaseous drilling or gas fluids is a very effective drilling technique for drilling in dry formations. The advantages of air drilling are that it is usually much faster than drilling with liquids and it may eliminate lost circulation problems. The disadvantages are the inability to control the influx of formation fluid into the wellbore and the destabilization of the borehole wall in the absence of the wellbore pressure typically provided by liquids (Schlumberger,2012).

High volume gas or other flows may present a well control problem. This can become even more hazardous when H_2S or CO_2 are present. It expected that the reasons of not using this kind the of drilling fluids is the high cost of technology, another reasons could be the well control problem, thus, many Saudi Arabia oil and gas wells has high H_2S, so Gaseous drilling can be hazardous and not safe. The results in this study show that all of the respondents "never" used gaseous fluid in their drilling operations.

4.1.5Comparison between Different Types of Drilling Fluids Used

Factors have to considered for the effectively operated drilling. Thus it could be environmental friendly, economical favorable, provides safety measures and convenience. Table 1shows a summary of the usage of all types of drilling fluids in drilling operations.

From the responses obtained, 63.2% of the drilling contractors nearly always use WBF, while 36.8% of them often use it. It was seen that 31.6% of the respondents use OBF whereas more than 50% of the drilling contractors use SBF. All of the respondents never use gaseous fluids.

The comparison has found generally that highest percentage for its nearly always used is the WBF which is (63.2%), the (36.8 %) of respondents answered Often used (WBF), (31.6 %) of the respondents companies used the Oil Based Fluids (OBF), It was also shown that a total of more than 50% respondents companies used synthetic based fluids (SBF), finally (100 %)of the respondents answered with "never" used gaseous fluids.

The percentage of oil based fluids used to bring an environmental concern due to the effects of diesel, hydrocarbon, chemicals and other additives. It was also shown that a total of more than (50%) respondents companies used synthetic based fluids (SBF), which is less toxic than (OBF) and causes less environmental impacts, but also need proper handling and effective wastes management.

Table 1. A comparison between the different types of drilling fluids used

Drilling Fluids types	Frequency	Frequency	Percentage
Water Based Fluids(WBF)	Never	--	--
	Sometimes	--	--
	Often	7	36.8%
	Nearly always	12	63.2%
Oil Based Fluids(OBF)	Never	13	68.4%
	Sometimes	4	21.1%
	Often	2	10.5%
	Nearly always	--	--
Synthetic Based Fluids(SBF)	Never	7	36.8%
	Sometimes	9	47.4%
	Often	1	5.3%
	Nearly always	2	10.5%
Gaseous or PreimaticFluids	Never	19	100%
	Sometimes	--	--
	Often	--	--
	Nearly always	--	--

4.1.6Factors Considered While Selecting Drilling Fluids for Operations

In order to understand the reasons behind the usage of different types of drilling fluids, the study included one question about the factors considered by the drilling contractors when selecting the drilling fluid type. Figure 6 below compares the factors considered while selecting fluids for drilling operations with percentages. The factors listed as answers as following: Lowest environmental effects, the drilling directions, Availability and Lowest cost.

It can be clearly seen that the factors correlate with the kinds of drilling fluids to be used in the operation .The greatest factor to be considered is the geological formation to be drilled with 22%respondents, then the lowest environmental effects with 21% respondents. Interestingly, availability and The drilling directions and the lost cost have the same rate.

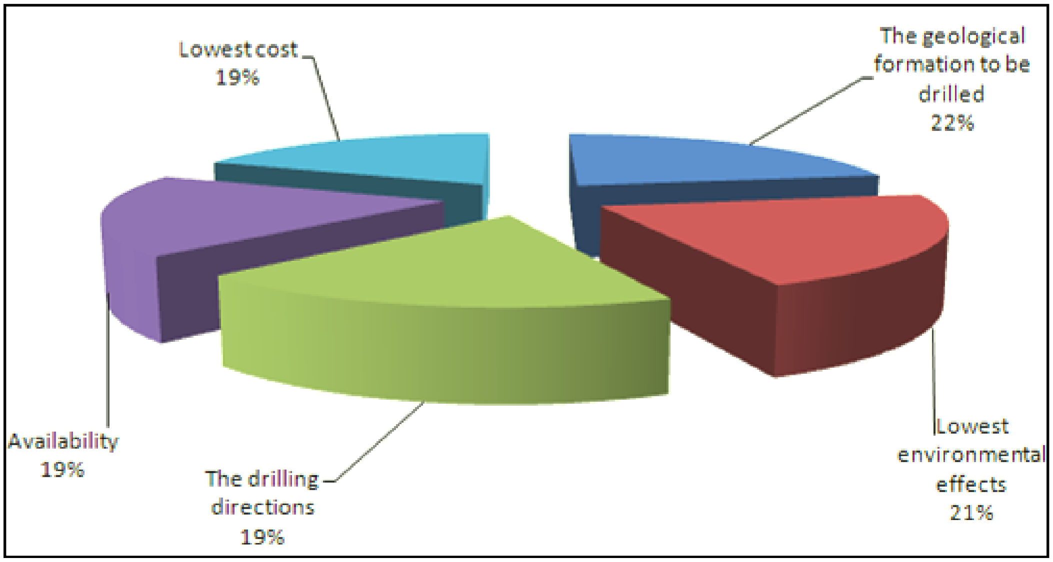

Figure 6.Factors considered while selecting fluids

4.1.7Composition of the Drilling Fluids

The composition of the drilling wastes reflects the characteristics of the formation being drilled as well as the composition of the drilling fluid utilized. Drilling waste often appears as sludge, with an aqueous layer floating on the surface. The composition of the drilling fluid itself might vary, depending on the circumstances of drilling. Typically a mixture of water and clay, drilling fluids may contain other additives. A common additive is barite, a weighing agent, used to improve the viscosity of the fluid and its ability to counterbalance the formation pressure and to float soil material to the surface. Oil-based and synthetic fluids are used in special circumstances, such as drilling to great depth or through high-pressure formations.

A question was asked on how often is the usage of the following chemicals and additives in drilling fluids. The fluids were listed as follows; montmorillonite, Bentonites, Attapulgites, Sepidites, Filtrate Reducers, Starch, Derivatives of Cellulose, Polyanionic Polymers, Natural Polymer-Bioplolymer, thinners, Phosphates, Tannins, Calcium Carbonate, Barite, Specific Products for Lost, Caustic Soda, Sodium Carbonate, Bicarbonate of Soda and Rheological parameters. The results obtained are shown in Table 2 below.Bentonites, Barite and Specific Products for Lost circulation are among the highest chemicals and additives used with fluids.Bentonites and barite have interesting properties in the drilling operations and can be sources of contaminants.

Commonly used lost-circulation materials include are fibrous (cedar bark, shredded cane stalks, mineral fiber and hair), flaky (mica flakes and pieces of plastic or cellophane sheeting) or granular (ground and sized limestone or marble, wood, nut hulls, Formica, (corncobs and cotton hulls). Schlumberger ,2012)

The environmental risk of the drilling additives include chemical composition , chemical-physical properties (such as pH, solids content, emulsive properties, solubility in water) environmental fate and transport , ecotoxicity (including chronic and acute) , biodegradation (under anaerobic and aerobic conditions) , consideration of the risk of any metabolites , potential for bioaccumulation , potential pathway to sensitive receptors and the receiving environment.

Field observations by Miller et al revealed that the soil around drilling sites after drilling operations do not adequately support plant life in such areas. It has also been established that a discharge of bentonite and barite on land will prevent plant growth until other natural processes develop new topsoil, which are not themselves toxic. In water these materials disperse or sink and may become locally bottom-living creatures by burying them. In fresh water, bentonite clays form a viscous gel, which kills fish by inhibiting their gill action.(Miller et al 1974). It is important that each chemicals and additives used to prepare the drilling fluids must be tested to avoid the environmental effects, the proper disposal of drilling fluids also should carefully consider.

Table 2.List of chemicals and additives used for preparing the drilling fluids

Chemicalsor Additives	**Never**		**Sometimes**		**Usually used**		**Missing***	**Total**
	Frequency	Percent	Frequency	Percent	Frequency	Percent		
Montmorillonite	4	21.1	8	42.1	1	5.3	6	13
Bentonites	0	0	6	31.6	13	68.4	0	19
Attapulgites	4	21.1	7	36.8	2	10.5	6	13
Sepiolites	6	31.6	4	21.1	2	10.5	7	12
Filtrate Reducers	0	0	9	47.4	5	26.3	5	14
Starch	1	5.3	9	47.4	1	5.3	8	11
Derivatives of Cellulose	1	5.3	7	36.8	1	5.3	10	9
Polyanionic Polymers	1	5.3	7	36.8	4	21.1	7	12
Natural Polymer-Biopolymer	2	10.5	6	31.6	2	10.5	9	10
Thinners	1	5.3	11	57.9	2	10.5	5	14
Phosphates	4	21.1	9	47.4	1	5.3	5	14
Tannins	2	10.5	10	52.6	3	15.8	4	15
Calcium Carbonate	0	0	11	57.9	3	15.8	5	14
Barite	0	0	5	26.3	12	63.2	2	17
Specific Products for Lost circulation	0	0	7	36.8	11	57.9	1	18
Anti-foam	1	5.3	10	52.6	2	10.5	6	13
Caustic Soda	0	0	9	47.4	1	5.3	9	10
Sodium Carbonate (Soda Ash	2	105	11	57.9	1	5.3	5	14
Bicarbonate of Soda	3	15.8	9	47.4	1	5.3	6	19
Rheological parameters	2	10.5	9	47.4	0	0	8	11

* There are no answers

4.2 Estimation of Quantities of Drilling Wastes Generated

4.2.1 Average Volume of Drilling Fluids Generated

Knowing the quantity of the drilling fluids wastes generated is relevant for all drilling contractors , subsequently incorporating a proper environmental wastes management for such . In this part a question was asked to know the average volumes of drilling fluids generated by one well.

Table 3 shows the drilling fluids generated per well (tons). Generally, the volumes of drilling wastes produced are not consistent. Most of the drilling contractors produced a range between (500 -4000) tons of fluids wastes.

The quantities of drilling wastes produced depends of several factors, the depth of the well, as well as the technique used for solids control. The Recycle-Reduce-Reuse (R3) programs are also important and can affect the total volume of the wastes generated.

As can be seen from Table 3, more than 120,000 tons of drilling fluids are generated. There are thousands of tons of drilling fluids generated by drilling companies in Saudi Arabia. In recent years, these volumes have been increased due to the expansion of the drilling operations in the Kingdom. For this reason, a drilling waste management plans needed and also a monitoring program to insure that the wastes do not pollute the environment.

According to API, 361 million barrels of drilling waste were produced in 1985. Due to a reduction in the number of wells drilled, for 1995 API preliminary findings indicate an estimated 146 million barrels of drilling waste (API, 1997). Drilling fluids (fluids and rock cuttings) are the largest sources of drilling wastes. For offshore Gulf of Mexico, EPA estimates from 1993 assumed that 7,861 barrels of drilling fluids and 2,681 barrels of cuttings are discharged overboard per exploratory well, and 5,808 barrels of drilling fluids and 1,628 barrels of cuttings are discharged per development well.

Table 3.Estimation Quantities of Drilling Fluids Generated

Company	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C14	C15	C16	C17	C18	C19
Drilling (Fluids) tons per well	**1200**	**600**	**900**	**600**	**300**	**300**	**4300**	**2000**	**950**	**1000**	**4000**	**3000**	**100**	**400**	**2100**	**700**	**650**	**900**
Number of Wells Drilled per Year	**2**	**1**	**2**	**2**	**10**	**3**	**3**	**1**	**3**	**2**	**13**	**4**	**8**	**3**	**2**	**2**	**2**	**20**
No. of Tonnes	2400	600	1800	1200	3000	900	12900	2000	2850	2000	52000	12000	800	1200	4200	1400	1300	18000

Total fluids wastes generated = 120, 550 Tonnes

4.2.2 The Average Volume of Drilling Solid Cuttings

In order to know the average volumes of drilling cuttings generated by one well, an open ended question was asked. It is known that the amount of the drilling cuttings generated depends on depth of well.

Table 4 shows the drilling solid cuttings generated by one well (tons). Most of the drilling contractors produced a range between (300-3000) tons of solid cuttings per well. Most drilling cuttings are managed through disposal, although some are treated and beneficially reused. Before the cuttings can be reused, it is necessary to ensure that the hydrocarbon content, moisture content, salinity and clay content of the cuttings are suitable for the intended use of the material.

Table 4.Drilling cuttings generated from drilling companies by one well (tons)

Company	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C14	C15	C16	C17	C18	C19	
Drilling Wastes (Cuttings) tons per well	1300	700	1350	700	700	500	2600	1500	1575	2000	3000	2500	300	800	1100	566	500	1900	
Number of Wells Drilled per Year	2	1	2	2	10	3	3	1	3	2	13	4	8	3	2	2	2	20	
Tons	2600	700	2700	1400	7000	1500	7800	1500	4725	4000	39000	10000	2400	2400	2200	1132	1000	38000	130057

4.2.3 Estimation of the Total Volumes of Drilling Wastes Generated Per Year

In order to estimate the total volume of both drilling wastes, a survey is made to companies to determine the average number of drilled well per year.

From the (19) companies respondents the survey was classified from the drilling wastes for fluid per well and drilling wastes for cuttings per well, as a sum the number of wells drilled per year was also determined.

In a year the average of (20) wells is drilled by a company as the highest and (1) is the lowest, It is known that the sum of drilling wastes for fluids from the respondents is (120,550)tons while for the cuttings is (130,084) tons, with 85 wells drilled in a year as total. The estimated total volume both of the wastes in a year is (250,634)tons, It is worth mentioning that there are exploratory wells drilled and are not found productive and this might double the amount of drilling waste generated in this part of the world only. Thus, this is a very big responsibility for managing these wastes, Table 5shows an estimation of total volumes of drilling wastes generated per year..

The successful drilling wastes management starts with full environmental regulations and standards, setting a good wastes management plan, as each drilling company should set plan in their environmental impacts assessment before actual drilling is very important step in any wastes management program, this include an estimation of drilling that will be garneted and the way of handling and managing, additionally, applying the reduce, recycle, reuse when possible to minimize the waste generated, also treating the wastes with the efficient methods to insure that ways does not have a high level of toxic chemicals, heavy metals or additives that could contaminate the environment, finally choosing the right disposal and mentoring program taking in account the natural of the disposal area and sensitive environment that could be effected.

According to API, 361 million barrels of drilling waste were produced in 1985. Due to a reduction in the number of wells drilled, for 1995 API preliminary findings indicate an estimated 146 million barrels of drilling waste (API, 1997). Drilling fluids (fluids and rock cuttings) are the largest sources of drilling wastes. For offshore Gulf of Mexico, EPA estimates from 1993 assumed that 7,861 barrels of drilling fluids and 2,681 barrels of cuttings are discharged overboard per exploratory well, and 5,808 barrels of drilling fluids and 1,628 barrels of cuttings are discharged per development well.

Table 5.Estimation the total volumes of drilling wastes generated per year

Company	Total wells drilled per year	Total Drilling wastes (fluids) tons per company	Drilling wastes (cuttings) tons per company
C1	2	2400	**2600**
C2	1	600	**700**
C3	2	1800	**2700**
C4	2	1200	**1400**
C5	10	3000	**7000**
C6	3	900	**1500**
C7	3	12900	**7800**
C8	1	2000	**1500**
C9	3	2850	**4752**
C10	2	2000	**4000**
C11	13	52000	**39000**
C12	4	12000	**10000**
C13	2	**N/A**	N/A
C14	8	800	**2400**
C15	3	1200	**2400**
C16	2	4200	**2200**
C17	2	1400	**1132**
C18	2	1300	**1000**
C19	20	18000	**38000**
Total (tons)	85	120550	**130084**

Total Drilling Wastes = 250,000 tonnes per year

4.3 Drilling Wastes Management

The drilling contractors can use a variety of technologies and practices to manage the wastes. Generally the management technologies and practices can be grouped into three major categories: waste minimization, recycle/reuse, and disposal. In this part several wastes management practices will be discussed.

4.3.1 Reduce drilling wastes

Reducing wastes is one of the techniques used to waste management and practices. Globally recognized as a part of modern processes, drilling companies were asked about the measures they were applying to reduce the drilling waste.

From Figure 7, it is clear that most of the drilling companies are resorting to the use of drilling techniques that use less drilling fluid (42% of them) and also drilling fluid systems that generate less waste (42% of them). The remaining 16% rely on drilling smaller diameter holes.

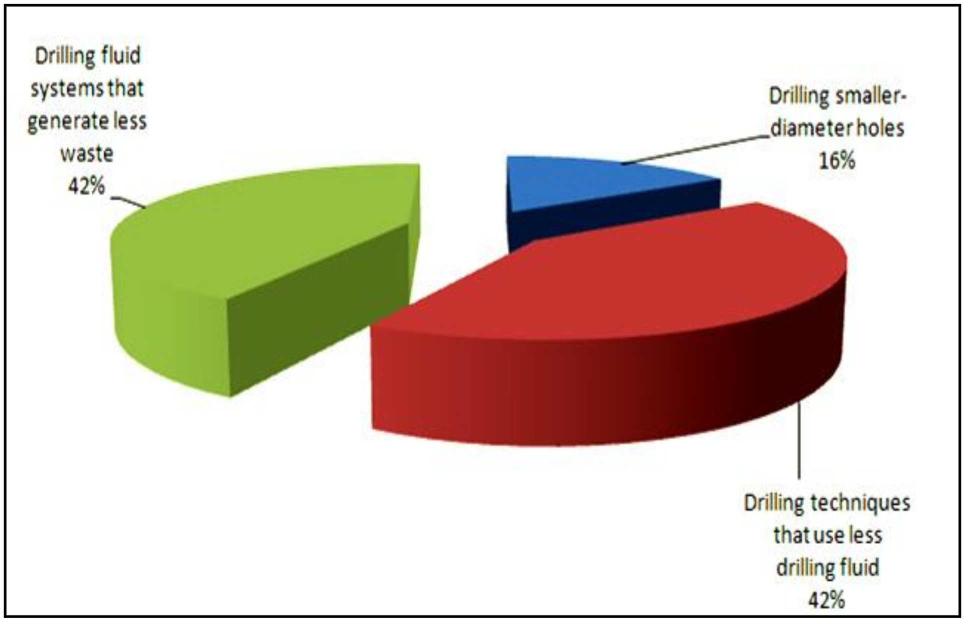

Figure 7.Measures that applied to reduce the drilling waste by drilling companies

The best way to reduce pollution is to prevent it in the first place. Some companies have creatively implemented pollution prevention techniques that improve efficiency and increase profits while at the same time minimizing environmental impacts. This can be done in many ways such as reducing material inputs, re-engineering processes to reuse by-products, improving management practices, and employing substitution of toxic chemicals. Some smaller facilities are able to actually get below regulatory thresholds just by reducing pollutant releases through aggressive pollution prevention policies, (Figure 8) .

Waste minimization can be looked at strictly from the perspective of solid waste volume. A more comprehensive view of "minimization" looks at the overall environmental impacts associated with a process or technology. There are many relatively simple processes that can be used on drilling rigs to reduce the amount of fluids that is discarded or spilled.

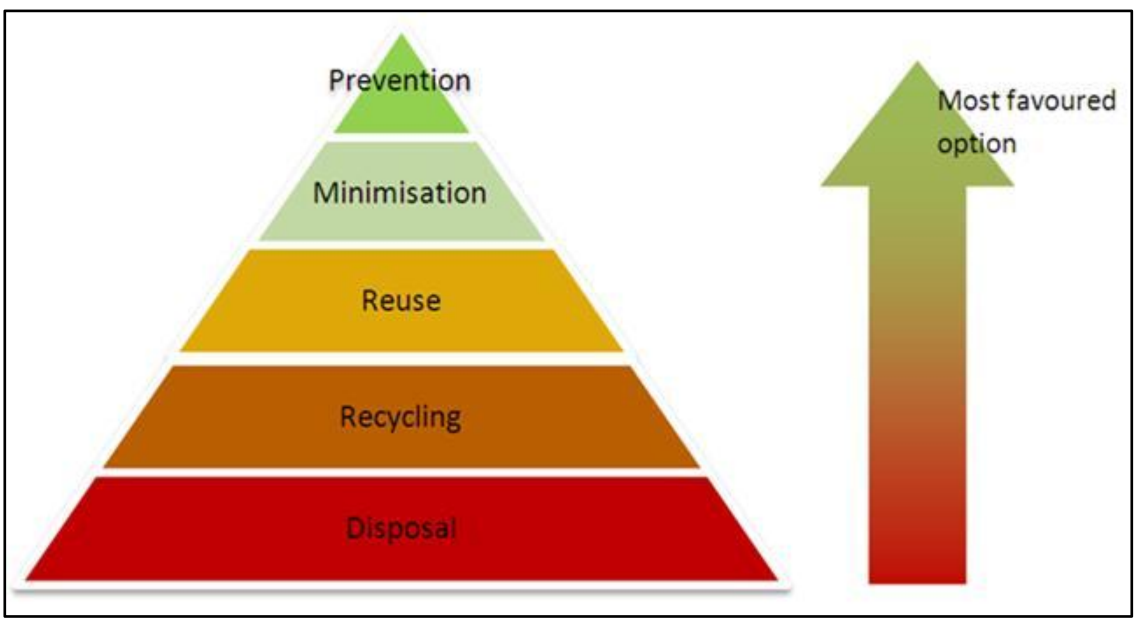

Figure 8. The Waste Hierarchy diagram , Source: university of London

Examples include pipe wipers, fluids buckets, and vacuuming of spills on the rig floor. These devices allow clean fluids to be returned to the fluids system and not treated as waste.

Drilling fluid is often disposed of when a well is completed, and fresh fluid used for any adjacent wells. Filtration processes have allowed drilling fluid to be reconditioned, so that it can be used for multiple wells before being discarded. Other possible uses for used drilling fluids are to plug un productive wells or to spud in new wells. Reuse of oil-based and synthetic-based drilling fluids to drill additional wells is common because of the high cost of the base fluids. Pollution prevention opportunities are most effective when they are coordinated in a facility-wide waste management plan. The American Petroleum Institute (API) has published guidelines for waste management plans, in which pollution prevention is an integral part (API, 1991). The ten-step plan involves the following:

1. Company management approval: Management should establish goals for the waste management plan, identify key personnel and resources that are committed to the plan, and develop a mission statement for its environmental policies.
2. Area Definition: The waste management plan should be designed for a specific area to account for differing regulations and conditions; in most cases, the area would be limited to within one state.
3. Regulatory Analysis: Federal, state and local laws, and landowner and lease agreements, should be evaluated. Based on these evaluations, operating conditions and requirements should be defined.

4. Waste Identification: The source, nature, and quantity of generated wastes within the plan's area should be identified, and a brief description of each type of waste should be written.
5. Waste Classification: Each waste stream should be classified according to its regulatory status, including whether it is a hazardous waste subject to regulation under the Resource Conservation and Recovery Act (RCRA).
6. List and Evaluate Waste Management and Disposal Options: List all waste management practices and determine the environmental acceptability of each option. Consider regulatory restrictions, engineering limitations, economics, and intangible benefits when determining their feasibility.
7. Waste Minimization: Analyse each waste-generating process for opportunities to reduce the volume generated or ways to reuse or recycle wastes. Note that the waste minimization or pollution prevention opportunities that are presented in this section can be used for this step.
8. Select Preferred Waste Management Practices: Choose the preferred management practices identified in Step 6 and incorporate waste minimization options from Step 7 wherever feasible. Specific instructions for implementation should be developed.
9. Prepare and Implement an Area Waste Management Plan: Compile all preferred waste management and minimization practices and write waste management summaries for each waste. Implement the plan on a field level.
10. Review and Update Waste Management Plan: Establish a procedure to periodically review and revise the plan.

4.3.2 Reuse of drilling wastes

Measures that applied to reuse of the drilling waste by drilling companies were analyzed. Methods had been used in drilling wastes, contiguous numbers made a gumption for such to be analyzed which is better used by the most companies. Figure 9shows the methods most commonly used in the reuse of drilling waste. Road spreadingis most commonly employed (31.6%), while 15.8% of them utilized land farming.26.3%of the respondents used other measures not mentioned in the questionnaire while another 26.3% skipped the answer.

Road spreading of some exploration and production (E&P)wastes is one method of on-site management that is commonly allowed. This technique is typically limited to the application of drilling wastes such as fluids and tank bottoms; which are primarily sand but can contain up to 19% oil by volume. Solid cuttings cannot be spread on public dirt roads. Operators should make sure that cuttings are not spread close to stream crossings or on steep slopes. Application rates should be controlled so that no free oil appears on the road surface. The objective of applying drilling wastes to the land is to allow the soil's naturally occurring microbial population to metabolize, transform, and assimilate waste constituents in place, the land farming is also consider as treatment method.

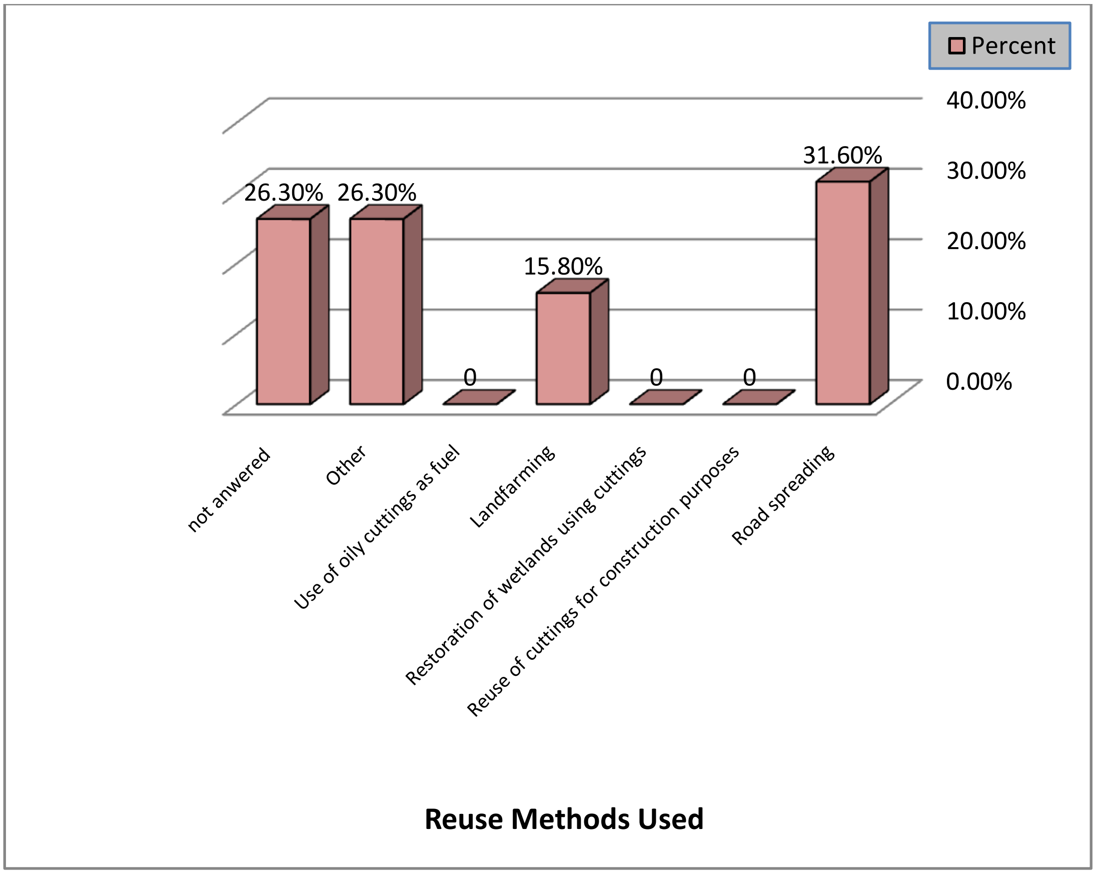

Figure 9.Methods used by drilling companies to reuse waste drilling

According to API, The monitoring of soil constituents (e.g., pH, chlorides, and total hydrocarbons) is required by state agencies and once certain levels are reached, no more wastes may be applied on that site. In either one-time or multiple application operations, fertilizer may be added to enhance biodegradation of hydrocarbons. Land farming operations must be controlled to ensure that the hydrocarbons, salts and metals do not present a threat to groundwater or surface water, and that the hydrocarbon concentration does not inhibit biological activity. Approximately 10 percent of drilling waste solids are disposed of in-landfarming operations (API 1997,Smith 1999).

4.3.3 Transferring drilling wastes

In early offshore oil and gas development, drilling wastes were generally discharged from the platforms directly to the ocean. Until several decades ago, the oceans were perceived to be limitless dumping grounds. Evidence mounted that some types of drilling waste discharges could have undesirable effects on local ecology, particularly in shallow water. When water-based fluids (WBMs) were used, only limited environmental harm was likely to occur, but when operators employed oil-based fluids (OBMs) on deeper sections of wells, the resulting cuttings piles created impaired zones beneath and adjacent to the platforms.. Piles of oil-based cuttings can affect the local ecosystem in three ways: by smothering organisms, by direct toxic effect of the drilling waste, and by anoxic conditions caused by microbial degradation of the organic components in the waste. Current regulatory controls minimize the impacts of permitted discharges of cuttings (Minton, R., and J. McGlaughlin, 2003).

The means of transferring the drilling wastes are determined in the frequency of usage of the drilling contractors, giving responses from different companies. The responses obtained are shown in Figure 10.Most of the respondents (57%) "only transferred the drilling fluids on shore " , while 29% of them "only transferred the cuttings on shore". On the other hand, 14% of respondents do not transfer any drilling wastes ".

Saudi Arabia has many offshore oil and gas operations located in the eastern province, including; Safaniya, Zuluf, Manifa, Abu Sa'fa, and joint operations in KHAFJI area, Safaniya is the largest offshore oilfield in the world. As the results indicated that some drilling companies used drilling fluids that could be harmful to the marine organisms, including the (OBF) and the (SBF) especially, thus, it is important to make sure that drilling waste transfer program in the offshore operations is effective and monitor and not harmful drilling wastes are discharged.

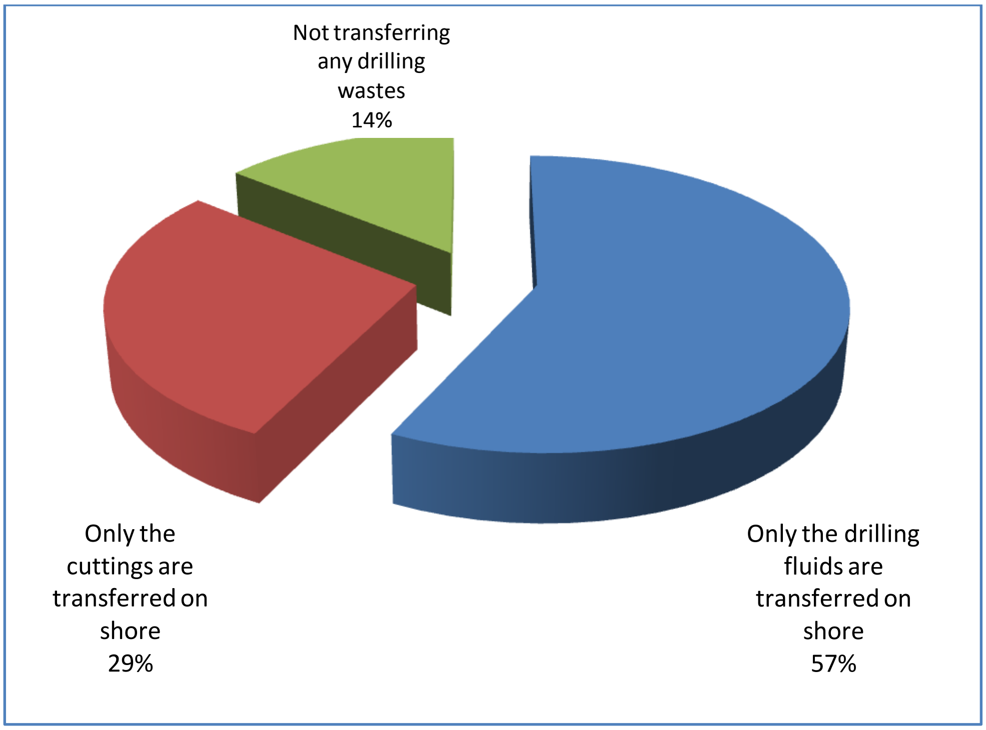

Figure 10. Transfer drilling wastes in (off-shore) drilling operations

4.3.4Challenges Faced by the Companies in Transferring Drilling Wastes

Many drilling companies face several difficulties in transferring drilling wastes. The two main challenges are: cost of the transfer and engineering difficulties. The cost of transfer involving money as its prices of transferring, while the engineering difficulties are the machinery needed for such operation and location factors.

Figure11and Figure 12show significant differences in the levels of the challenges faced by the company in transferring the drilling wastes. Most respondents (73%) agreed that cost of transferring the waste is a challenge, while about (68%) of the respondents disagreed that engineering difficulties is a challenge.

Several companies reported onshore disposal costs, which ranged from $7.50/bbl to $350/bbl. It is highly probable that the operator costs included the cost of additional waste handling equipment, transportation. Another important consideration in the transportation cost. Large volumes and weights of drilling wastes are generated at each well that is drilled. For onshore wells, disposal facilities must generally be located within a 50- to 75-mile radius of the wells in order for transportation costs to be manageable.

It can be said that most drilling operations in Saudi Arabia located in remote areas, some are located in the offshore, this can add more cost to the drilling companies specially if the deposal areas are far from the drilling operations.

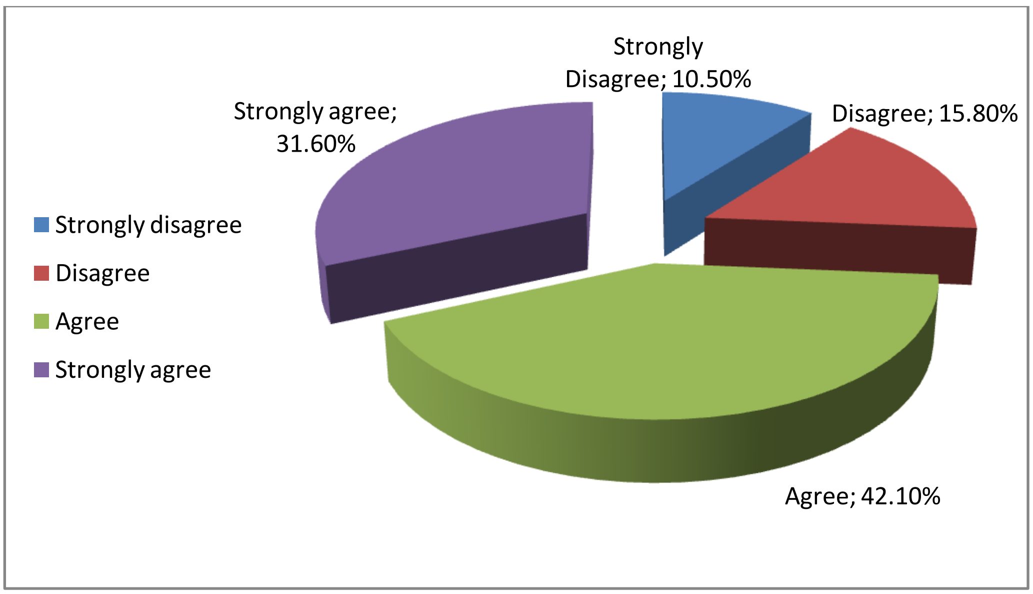

Figure 11. Cost of transfers as challenge faced by the companies in transferring drilling wastes

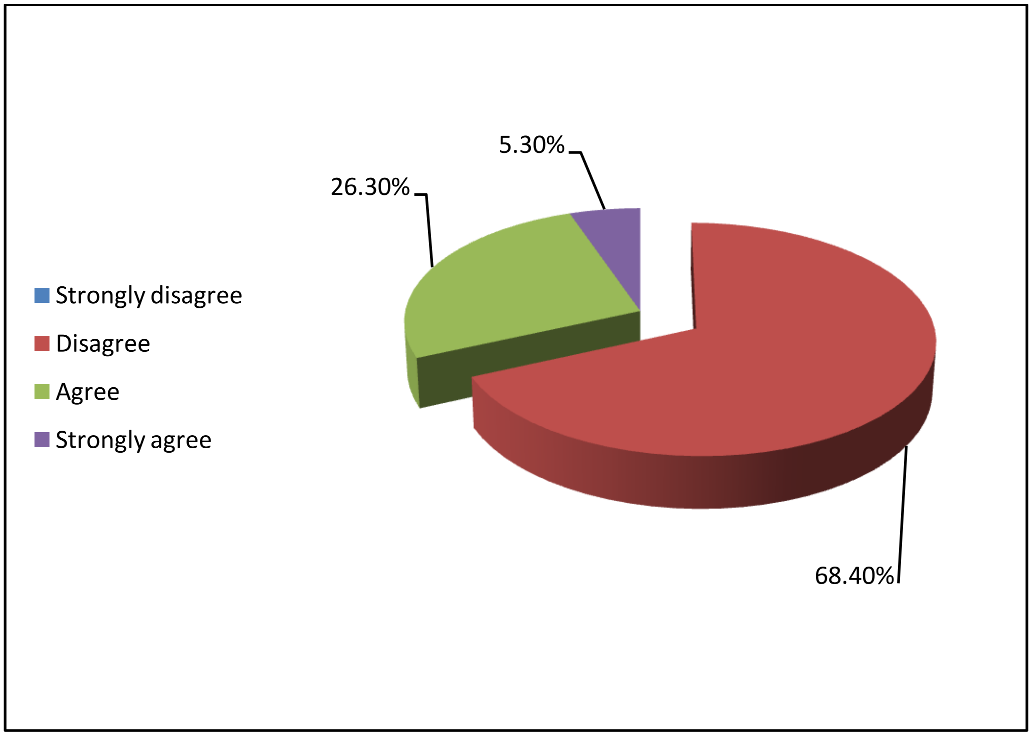

Figure 12. Engineering difficulties as challenge faced by the companies in transferring drilling wastes

4.4 Treatment Methods Used for Drilling Wastes

Treatment method is one of the most crucial phase for the drilling wastes. It could be done in different ways and processes, thus this section is done to acknowledge the frequency of the usage.

Table 6 shows methods of treatment used to treat drilling wastes and how it is rated. It can be clearly seen that there are four types of treatment for the drilling wastes such as Chemical Treatment; Biological Treatment; Physical Treatment and Thermal Treatment. These are subdivided into Never, Sometime, Often and Always. Furthermore, most respondents drilling companies in their operations sometimes uses these treatment as 31.6%;10.5;10;5 and 15.8% respectively. As for the other aspect it is oftentimes used 10.5%, 0%, 15.8% and 0% respectively. As the study shows the least used treatment methods are biological treatment (57.9%), followed by thermal treatment (42.1%), then chemical treatment (36.2%) and physical treatment (10.5%).

On the other hand the most always used methods are physical Treatment (63.2%), then thermal treatment for (5.2%). Chemical and biological treatments are not always used.

Table 6. Applied treatment methods by the companies

Treatment Methods	Answers	Frequency	Percentage
Chemical Treatment	Never	7	36.2%
	Sometimes	6	31.6%
	Often	2	10.5%
	Always	--	--
	Not answered	4	21.1%
Biological Treatment	Never	11	57.9%
	Sometimes	2	10.5%
	Often	--	
	Always	--	
	Not answered	6	31.6%
Physical Treatment	Never	2	10.5%
	Sometimes	2	10.5%
	Often	3	15.8%
	Always	12	63.2%
	Not answered	--	--
Thermal Treatment	Never	8	42.1%
	Sometimes	3	15.8%
	Often	--	--
	Always	1	5.3%
	Not answered	7	36.8%

Potential treatment steps to minimize waste volume or toxicity considered after examining source reduction, reuse, recycling, and recovery options. Treatment methods may include: biological methods (i.e., land spreading, composting, tank based reactors), thermal methods (i.e., thermal desorption, detoxification), chemical methods (precipitation, extraction, neutralization) and physical methods (i.e., gravity separation, filtration, centrifugation).

Drilling wastes are placed on a series of vibrating screens called shale shakers. Each successive shale shaker uses finer mesh screen, so the collected particles are smaller in size. The liquid fluids passes through the screens and is sent back to fluids pits to be reused. If the recycled fluids contains fine particles that would interfere with drilling performance, the fluids are treated using fluids cleaners or centrifuges to remove very fine particles. The solid cuttings coated with a film of fluids remain on top of the shale shakers and are collected at the opposite end of the shakers. If the cuttings are able to meet the discharge standards at this point, they are generally discharged. If they are unable to meet the discharge standards (particularly relevant when SBMs are being used), the cuttings must be treated further by vertical or horizontal cuttings dryers, squeeze presses, or centrifuges. The cuttings dryers recover additional fluids and produce dry, powdery cuttings (Sumrow, M., 2002).

In conclusion, Physical Treatment is very common in treating drilling wastes, in fact,it is easy and less expensive comparing with other treatments methods. on other hand , the physical treatment could be not an effective way when treating some oil and synthetic fluids and cuttings.

4.4.1 Treatment Methodology and Technologies

Technology is known to be a developing subject, as well as the advancement of processes. Subsequently, technology is a way of making methods more eloquent and relevant. Figure 13 shows the treatment methodology and technologies used to treat drilling wastes, the methods were listed as following: Composting, Bioreactors,Vermiculture, Incineration, thermal, desorption Solidification, Stabilization, Other, please specify. As in Figure 12 shows that most of the respondents working in the drilling companies agreed that the (Stabilization with 33%) is the most methodology using to treat and manage drilling wastes, followed by Solidification with 29 % respondents.

The cuttings separated from the fluids at the shale shakers may be coated with so much fluids that they are unsuitable for the next reuse or disposal step or are difficult to handle or transport. Constituents of the cuttings or the fluids coating them (e.g., oil, metals) may leach from the waste, making them unsuitable for land application or burial approaches. Various materials can be added to cuttings to solidify and stabilize them.(BMT Cordah Limited, 2002).

Not all drilling wastes are amenable to chemical fixation and stabilization treatments. Solidification/stabilization should be adapted for site-specific applications depending on the end-use of the treated material and the chemical characteristics of the waste. Conducting laboratory tests to determine the proper blend of additives to achieve the desired material properties is recommended.

Some companies have used solidification/stabilization for drilling wastes. The resulting materials have been used for road foundations, backfill for earthworks, and as building materials (Morillon et al. 2002) and may be used for other purposes (BMT Cordah Limited 2002).

There are limitations on the applicability of stabilization/solidification systems. For example, cement-based systems do not work when:

- the organics content is above 45% by weight,
- the wastes have less than 15% solids,
- excessive quantities of fine soil particles are present, or
- too many large particles are present.

As noted above, the most commonly used additive materials have a high pH, which can pose a problem if the stabilized wastes are subsequently land-applied or used as a soil supplement. In a series of studies to test the suitability of using treated cuttings to grow wetlands vegetation, researchers at Southeast Louisiana University discovered that cuttings stabilized in a silica matrix had a pH higher than 11. The stabilized cuttings did not support plant growth as well as un stabilized cuttings (Shaffer et al. 1998).In API's 1995 survey, less than 1 percent of drilling waste volumes were disposed of in this manner (API, 1997).

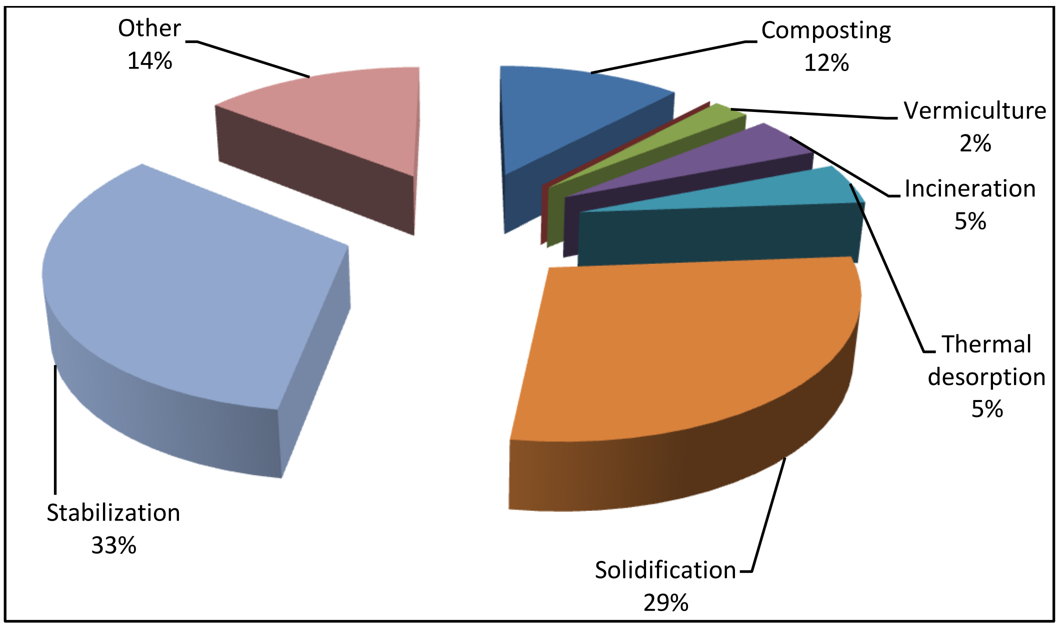

Figure 13.Treatment methodology and technologies used to treat drilling wastes

4.5 Disposal of the Drilling Wastes

4.5.1 Applied methods used for disposal of drilling wastes

The methods applied for the disposal of drilling wastes by the drilling companies were determined as subject of significance. The drilling contractors were asked to select from the following options: Onsite pit, Disposal in landfill, Slurry injection, Salt caverns, Onsite evaporation, and Other.

Figure 14 shows the methods applied to disposal of drilling wastes by the drilling contractors covered in the study. It can be clearly seen that most of the respondents drilling companies agreed that the (Onsite pit) is the most methodology applying to disposal of drilling wastes, followed by Onsite evaporation.

Pit may be the most misunderstood or misapplied disposal technique. Simply pushing the walls of the reserve pit over the drilled cuttings is generally not acceptable. The depth or placement of the burial cell is important. A moisture content limit should be established on the buried cuttings, and the chemical composition should be determined. Onsite pit burial may not be a good choice for wastes that contain high concentrations of oil, salt, biologically available metals, industrial chemicals, and other materials with harmful components that could migrate from the pit and contaminate usable water resources.

According to the (USEPA) Land Disposal Restrictions or (LDRs) (40 CFR Part 268) the regulations prohibiting the disposal of hazardous waste on land without prior treatment. Under the LDRs program, materials must meet treatment standards prior to placement in a RCRA land disposal unit (landfill, land treatment unit, waste pile, or surface impoundment). Generators of waste subject to the LDRs must provide notification of such to the designated TSD facility to ensure proper treatment prior to disposal.

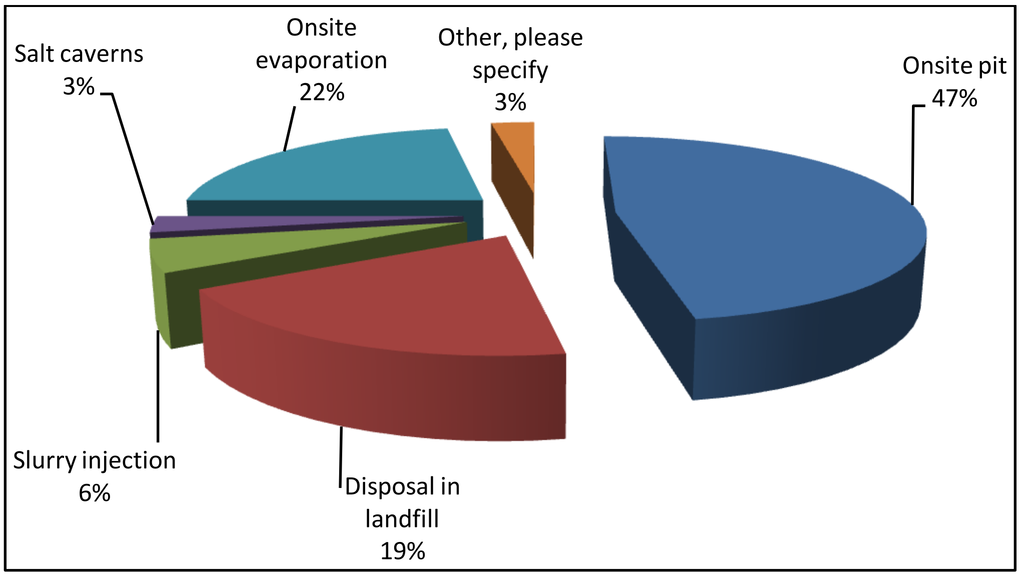

Figure 14.Applied methods used for disposalof drilling wastes by the companies

4.5.2 Materials Used as Landfill Bottom Liner

Landfill Bottom Liner upon its usage, how could it affect the milieu for disposing drilling wastes. Thus, Figure15shows that different materials such as clay, plastic, composite are used as landfill bottom liner used for disposing drilling wastes in the Kingdom of Saudi Arabia. Most respondents drilling companies with (50%) agreed that they used clay as bottom line, while (27%)of the respondents used the plastic bottom liner and (23%) used composite liner bottom liner.

Clay is widely used as the landfill bottom line for the flowing materials amongst others, the length of the line should be carefully consider, engineering precautions incorporated into the design will help to ensure pit integrity. Precautions should be taken to prevent disposal of chemicals, or other additives materials not intended for pit disposal, this will help protecting the groundwater aquifers from being contaminated.

The containment of fluids within a pit is the most critical element in the prevention of shallow ground water contamination. Depending upon the fluids being placed in the pit, the duration of the storage and the soil conditions, pit lining may be necessary to prevent infiltration of fluids into the subsurface. In twenty-three states, pits of a certain type or in a particular location must have a natural or artificial liner designed to prevent the downward movement of pit fluids into the subsurface. Typically, pit liners are constructed of compacted clay or synthetic materials like polyethylene.

According to US EPA, In California, for example, pits may not be placed in areas considered “natural drainage channels”. Twelve states also explicitly either prohibit or restrict the use of pits that intersect the water table. Further, sixteen states require fluids in pits remain a certain level below the top of the pit wall. This distance, referred to as the “freeboard” provides for a safety margin to prevent pit overflows in the event of significant rainfall. A landfill should not be constructed in areas where water table is less than 2m below ground surface. Special design measures be adopted. The depth above and below pit. Areas with shallow groundwater are not appropriate; a pit location of at least five feet above any groundwater is recommended to prevent migration to the groundwater. The top of the burial cell should be below the rooting zone of any plants likely to grow in that area in the future (normally about three feet).

In conclusion, it is important to know that significant threat to water resources can occur if the pit or landfill does not contain a well-designed liner, liners are generally required.

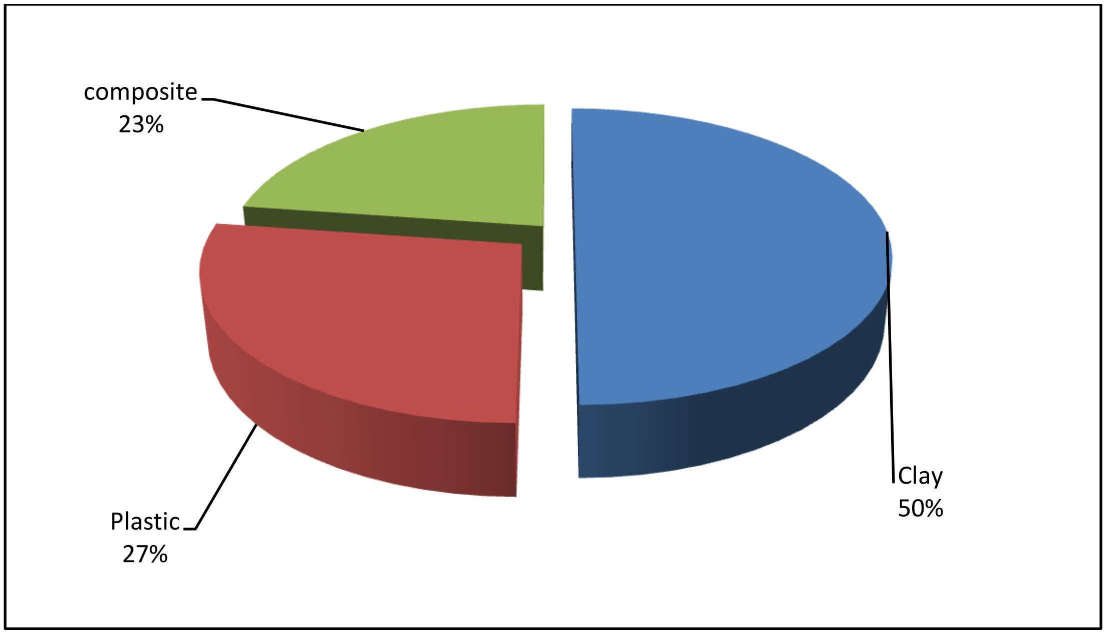

Figure 15.Materials used as landfill or pit bottom liner

4.6 Regulations and Standards

4.6.1 International regulations & standards

Regulations are needed to set boundaries, limitations and policies in legal basis. Drilling and wastes management are simple matters but indeed the coherency of standards and regulations should be implicated or implemented. Companies have its own prerogative deciding its matter within the company. Thus, Figure 16 shows that the international environmental regulations that are followed by drilling companies covered in this study. The following environmental regulations and standards are named with their corresponding percentages. USA regulations/standards 78.9%; Europe regulations/standards 5.3%; Canadian regulations/standards 0% and other standards 15.8%. Interestingly, there are more companies using the American regulation and standards.

The two major policy tools for protecting the environment in the US environmental regulations are rules and inducements. The United States has chosen to use rules, primarily through regulation. Such regulation can come in the form of design standards and performance standards. Performance standards specify emission levels and let those covered by the rules decide how those levels will be met. Design standards specify exactly how performance standards will be met.

Some US environmental laws require you to obtain an environmental permit before you can emit or discharge a pollutant into the air or water, dispose of hazardous waste, or engage in certain regulated activities. Permits are also used by federal, state and local government agencies to implement environmental laws intended to protect specific types of resources

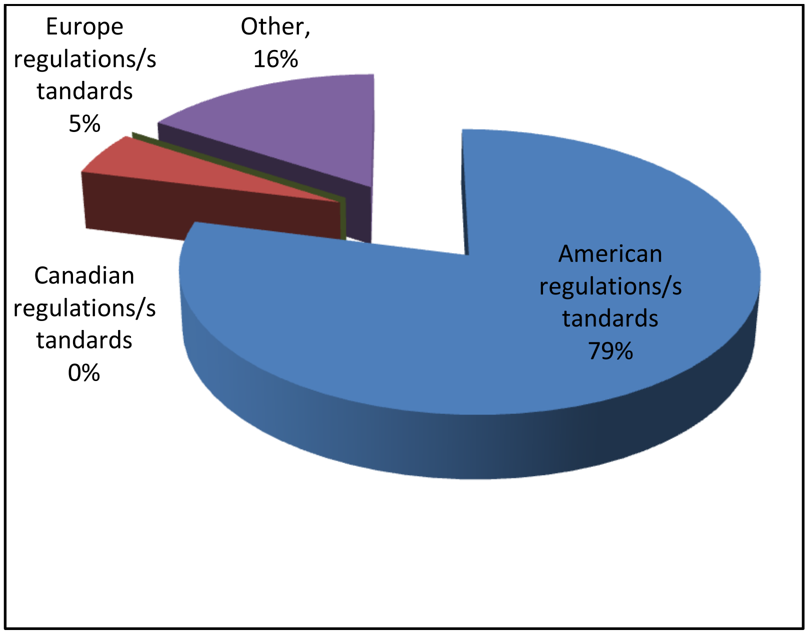

Figure 16. International environmental regulations or standards followed by drilling companies

The three laws that govern the disposal of drilling waste in the USA are (i) Resource Conservation and Recovery Act (RCRA), (ii) Safe Drinking Water Act (SDWA), and (iii) Clean Water Act (CWA).The US-EPA (1988) exempted oil and gas wastes from the hazardous waste requirements of RCRA Subtitle C but not the Subtitle D solid waste regulations. E&P wastes are not subject to federal hazardous waste regulations, however, most States include them in hazardous waste requirements (depending on the characteristics of the wastes). This does not mean that these wastes could not pose a hazard to human health and the environment if managed improperly [US-EPA, 2002]. The RCRA Subtitle C exemption only applies to wastes generated from the exploration, development, and production (i.e., primary field operations) of crude oil or natural gas. Hence, wastes generated from the transportation of crude oil or natural gas are not Subtitle C exempt. Lists of exempt and non-exempt E&P wastes [US-EPA, 1988 and 2002].

The US-EPA also regulates the Underground Injection Control (UIC) program that is established under SDWA. The purpose of the UIC is to protect current and future underground sources of drinking water through proper site location, construction, and operation of injection wells.

4.6.2 Local Regulations and Standards

The drilling companies were asked about knowledge on any specific governmental regulations/standards in managing drilling wastes. As drillings occurred in different localities provisions are needed specifically in a certain areas.

Most respondents were not aware of any such regulations or standards (68%), while31% claimed to be aware. (Figure 17).Therefore, recently there is none of any governmental regulation /standards applied for managing drilling wastes , The governmental environmental agencies should establish the drilling wastes regulations to minimize its impact on the environment, there is an urgent and necessary need for the environmental governmental agencies to start managing and regulating this important wastes.

A review of the Presidency of Meteorology Environment’s regulations revealed that the regulations do not address drilling wastes specifically. The regulations addressed waste management in general terms.

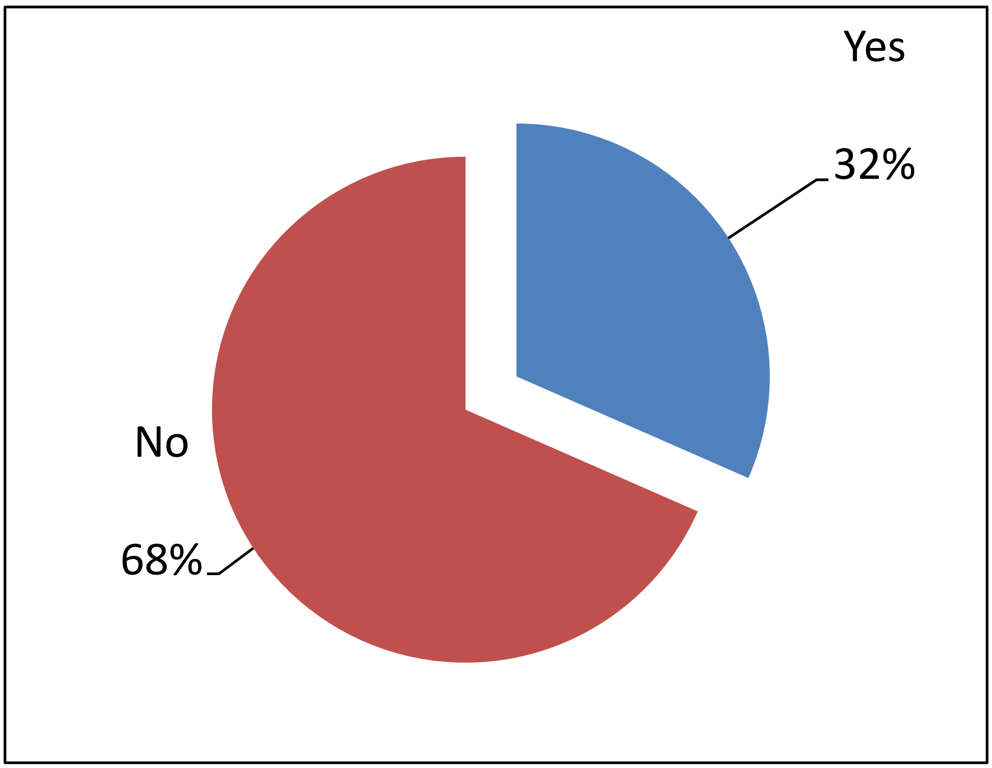

Figure 17.Companies knowledge on any local specific governmental regulations/standards in managing drilling wastes

According to (PME)Article Thirteen of 'The General Regulations on the Environment' of the Presidency of Meteorology and Environment (PME), all persons engaging in production, service, or other activities shall take the necessary actions to achieve the following:

(i) Prevent direct or indirect contamination of surface, ground, and coastal waters with solid or liquid wastes;

(ii) Prevent the discharge, in any quantity, of any type of solid or liquid wastes, substance, organic or inorganic compound that may be classified as hazardous into surface, ground or coastal waters; and

(iii) Preserve soil and land and control their degradation and contamination.

Therefore, recently there is none of any governmental regulation /standards applied for managing drilling wastes, on other hand, some oil companies has strong corporate standards containing guidelines applicable to environmental protection policy. Saudi Aramco as a good example has some regulations pertaining to: (1) discharge to marine environment from drilling operation, (2) waste water treatment re-use and disposal, (3) protection of marine life, (4) pollution control and environment protection, (5) waste management for fluids, cuttings and rubbish.

As explained by (Abu Khamsin, 1997) that in Saudi Aramco regulations all oil-based drilling fluids, toxic fluids, and cuttings from toxic drilling fluids must be hauled back to an approved onshore disposal site. For alternative oil based fluids, LC-50 toxicity tests shall be run to determine toxicity of the cuttings. If fluids are toxic then fluids and cuttings should be disposed in an approved disposal site.

4.6.3 Evaluating the local regulations

Regulations are not placed and implemented at once. In ample time, provisions are legally analyzed, comprehended and synthesized whether it is right to be depicted or not. Either of the results may negative or not evaluation is highly demanded.

Figure 18depicts how the drilling companies evaluated the local regulations. The question asked was “The local regulations are old that need to be developed and updated ?.The high number of the respondents(79%) agreed that the local regulations are old and need to be developed and updated, while 21% of respondents disagreed with that.

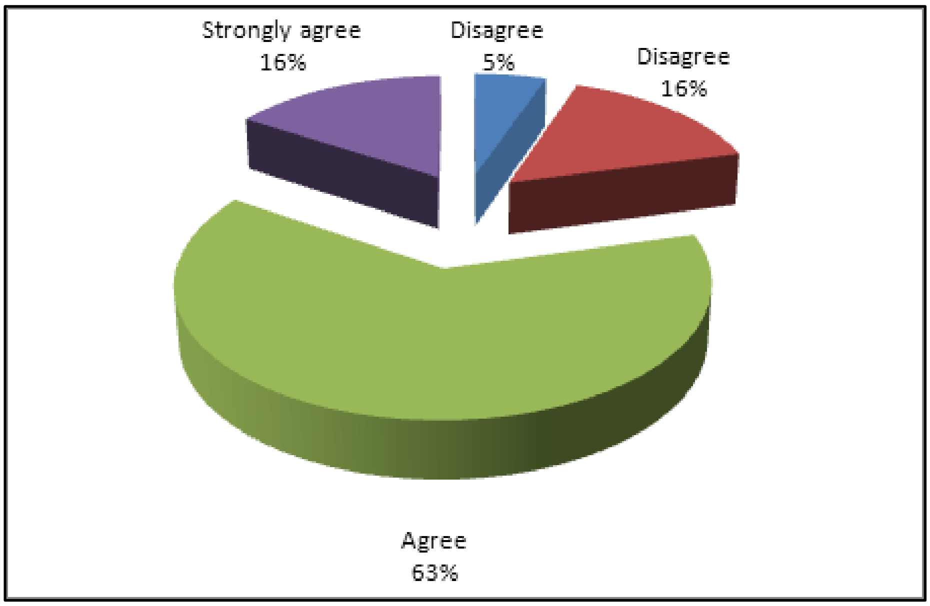

Figure 18. Evaluation of the local regulations by drilling companies

CHAPTER 5

CONNCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The main aim of this work is to assess the practices of managing drilling wastes in the Eastern Province of Saudi Arabia. This was accomplished by collecting data through distributing questionnaires to the drilling companies then conducting data analysis and assessing the current wastes management practices followed by the drilling companies operating in the study area.

The study found out that most of the respondent companies (63.2%) generally always used water based fluids (WBF), 36.8% of them often used WBF while 31.6 % of the respondent companies used oil based fluids (OBF). It was also shown that more than 50% of respondent companies used synthetic based fluids (SBF) while none of the companies used gaseous fluids for their operations.

The compositions of drilling fluids as the results indicated that percentages are varies, respectively, the Bentonites, Barite , and Specific Products for Lost circulation are among the highest chemicals and additives used with fluids.

The total volume of drilling wastes produced is about 250,000 tonnes per year. The study also found that the volume of drilling wastes produced in not consistent, most respondent companies produced a range between (500 - 4000) tons of fluids wastes and (300-3000) tons of the solids cuttings. The wastes volumes depends on several factors such as the depth of the well, as well as the technique used for solids control, the 3Rs , all these factors are important and can minimize the total volume of the wastes. The study depicts that most companies faced challenges when transferring the drilling wastes, more than 73% of the responses agreed that the transferring is costly.

The results of this investigation showed that high percentage of respondents companies applied common measures to reduce the drilling wastes, it was also shown that (64.6%) from responses companies reuse the drilling wastes in tow main applications ; the road spreading and land farming. the responses companies used physical treatment methods with (80%),while the(62%) used solidification and stabilization techniques to manage the drilling wastes, this indicated that these companies minimizing their wastes in the beneficial ways. it can be clearly noticed that most of the responses companies deposal of the drilling wastes in Pit using mainly clay as a bottom liner. The study found, that 87.9% of the respondent companies agreed that they followed American standards/regulations to deal with drilling wastes. The most interesting results shown that Saudi Arabia does not have specific governmental regulations/standards in managing drilling wastes, 68.4 % of the respondent companies admitted that in their answers. It can be clearly figured out that high number of respondent companies with (79%)agreed that the local environmental regulations are weak and old that need to be developed and updated.

Our findings in this research are subject to at least three limitations, this important limitations need to be considered. First, the sensitivity of such scientific research, which look in Environmental problem, lead difficulty of obtaining information especially when some considered it as “confidential" information, this need long time to complete it, as the researcher have to get some approvals to start distributing the questionnaire to the oil and gas companies and drilling contractors. Second, some individuals refused to answer the questionnaire either because they were busy or they were NOT confident enough about the questionnaire or also others did not complete the questionnaire with the full answers as needed. Thirdly, although, the researcher in this study tried to cover every aspects related to drilling wastes management, the study did not evaluate each topic in deep details.

5.2 Recommendations

It is recommended that further research be undertaken in the following areas:

- A further study could assess the discharge of Oil based fluids and synthetic based fluids in offshore operations and its impacts in ecological systems.
- Research is also needed to determine and evaluate the environmental designing of drilling wastes onsite pit and landfill.
- Further research in the field “groundwater aquifers evaluation "near the drilling pits and landfill.
- It would be interesting to assess the effects of heavy metals concentrations associated with drilling wastes and its impacts on the soil and marine environment.

Finally, the findings of this study have a number of important implications for future practice of drilling companies:

- Minimizing all drilling waste as a first priority of drilling companies then segregated and, where possible, reuse or recycle. Appropriate treatment prior to disposal will be carried out.
- Preparing the drilling Waste Management Plan (WMP) for each drilling company that contains measures to prevent contamination of soils , marine and groundwater during the drilling operations by specifying measures for refueling and on site storage of waste.

- Accounting for all waste generated (type and volumes).
- Workforces of all drilling contractors and educated them to minimize and properly dispose of waste and set targets in order to understand the volume and type of waste being generated, and actively reduce the volumes.
- Handling all wastes according to applicable international industry standards, as appropriate.
- Dispose the non-hazardous wastes of in accordance with the requirements of local conditions and the Environmental Management Report.
- Dispose the drilling fluids and cuttings according to the international Waste Management Procedure.
- Insulating drainage and cutting pits with polyethylene film to store the drilling fluids and drilling cuttings.
- Minimizing drilling cuttings using the High G shale shaker.
- Reducing drilling fluids by its reuse in the other wells, where possible.
- Preparing A quarterly report on waste generation, reuse, recycling, and disposal to submit it to government environmental agencies.

Another important practical implication for the government environmental agencies is to make a firm database with quantity and classifications of the wastes products inclusions, also promoting and motivating drilling companies to minimize and reuse drilling wastes when possible then applying treatment measures in an effective and innovative means with the help of the advanced technology.

Nomenclature

IEA	=	International Energy Agency
OPEC	=	Organization of Petroleum Exporting Countries
ROP	=	Rate of Penetration
WBF	=	Water Based Fluids
WBM	=	Water Based Fluids
OBF	=	Oil-Based Fluid
SBF	=	Synthetic Based Fluids
SBDF	=	Synthetic Based Drilling Fluids
PAO	=	Polyalpha Olefins
EIA	=	Environmental Impact Assessment
OBM	=	Oil based fluids
TFM	=	Total fluid management
EIR	=	Environmental impact reduction
NAF	=	Non-aqueous fluids
IEA	=	International Energy Agency
OPEC	=	Organization of Petroleum Exporting Countries
ROP	=	Rate of Penetration

APPENDICES

Appendix-1

The Questionnaire

KING FAHD UNIVERSITY OF PETROLEUM AND MINERALS

EARTH SCIENCE DEPARTMENT

ACADEMIC RESEARCH FOR M.SC ENVIRONMENTAL SCIENCES PROGRAM

Dear Respondent thanks for taking time to answer my questionnaire

This research questionnaire is aimed at collecting data for an M.Sc. thesis in Environmental Sciences at KFUPM entitled "Management of the Drilling Wastes in the Eastern Province of Saudi Arabia".

As the exploration and drilling activities have increased in the eastern part of Saudi Arabia, unfortunately, some drilling activities have been associated with several impacts on the surrounding environment which need to be studied.

The exercise is purely academic and the researcher is aware that information obtained is absolutely confidential and will be treated as such. Comments and feedbacks offered shall enhance the success of the research. Your kind support of the exercise shall be greatly appreciated.

Kindly, answer the following questions by ticking where appropriate (/) or by filling the blank spaces.

Thank you again for your anticipated cooperation.

Ali Al-Zahrani
Researcher

Background information about the company

1) **Company Name (**Optional**)**

***2)** **Years of services in drilling operations :**

☐ ≤ 5 years ☐ 6-10 years ☐ 10-20 yeas ☐ More than 20 years

***3)** **Approximate number of employees related to drilling activities ;**

☐ ≤ 10 ☐ 11-50 ☐ 50- 00 ☐ More than 100

4) **Percentage of employees at following education levels ;**

PhD %

Masters degree %

Bachelors degree %

Diploma %

High school and below %

***5)** **Your company :**

☐ Does actual drilling activities

☐ Monitors and supervises the drilling contractors

☐ Carries out some drilling activities and leave other activities to contractors

☐ Other, please specify:

***6)** Company areas of operations :

☐ On shore ☐ Off shore ☐ Both

***7)** **The drilling technologies employed in the operations of the company:**

☐ Directional well ☐ Horizontal well ☐ Both types

***8)** **Average number of drilled wells your company complete per year;**

*

Types , volume and composition of drilling fluids and cuttings

***9) How o often do you use the following drilling fluids in your drilling operations?**

	Never 1	Sometimes 2	Often 3	Nearly always 4
Water Based Fluids(WBF)	☐	☐	☐	☐
Oil Based Fluids (OBF)	☐	☐	☐	☐
Synthetic Based Fluids(SBF)	☐	☐	☐	☐
Gaseous or PreimaticFluids	☐	☐	☐	☐

***10) Which of these following factors do you consider when selecting drilling fluids for your operations (please rate the factors according to importance) ?**

	Not very important 1	2	3	4	Extremely important 5
The geological formation to be drilled	☐	☐	☐	☐	☐
The drilling directions	☐	☐	☐	☐	☐
Lowest environmental effects	☐	☐	☐	☐	☐
Lowest cost	☐	☐	☐	☐	☐

Availability	☐	☐	☐	☐	☐

11) How often do you use the following chemicals in drilling fluids :

	Never 1	Sometimes 2	Usually used 3
Montmorillonite	☐	☐	☐
Bentonites	☐	☐	☐
Attapulgites	☐	☐	☐
Sepiolites	☐	☐	☐
Filtrate Reducers	☐	☐	☐
Starch	☐	☐	☐
Derivatives of Cellulose	☐	☐	☐
Polyanionic Polymers	☐	☐	☐
Natural Polymer-Biopolymer	☐	☐	☐
Thinners	☐	☐	☐
Phosphates	☐	☐	☐
Tannins	☐	☐	☐
Calcium Carbonate	☐	☐	☐
Barite	☐	☐	☐
Specific Products for Lost circulation	☐	☐	☐
Anti-foam	☐	☐	☐
Caustic Soda	☐	☐	☐
Sodium Carbonate (Soda Ash)	☐	☐	☐

Bicarbonate of Soda	☐	☐	☐
Rheological parameters	☐	☐	☐

***12) What is the average volume of off-spec fluids generated by one well?**

*** Water Based Fluids (WBM)**
*

*** Oil Based Fluids (OBM)**
*

*** Synthetic Based Fluids(SBM)**
*

***13) What is the average volume of solid cuttings wastes generated by one well ?**

*

14) Do you test / analysis the heavy metals contents on the drilling cuttings ?

☐ Yes ☐ No

15) If the answer is yes , what is the average concentrations of following heavy metals in the drilling waste (mg/kg)

Cadmium	
Mercury	
Lead	
Chromium	
Arsenic	

Drilling wastes management

***16) Which of following onsite measures you are taking to reduce drilling wastes ?**

- ☐ Drilling smaller-diameter holes
- ☐ Drilling techniques that use less drilling fluid
- ☐ Drilling fluid systems that generate less waste
- ☐ Other, please specify:

***17) Which of these methods are you applying to reuse drilling wastes in beneficial ways?**

- ☐ Road spreading
- ☐ Reuse of cuttings for construction purposes
- ☐ Restoration of wetlands using cuttings
- ☐ Landfarming
- ☐ Use of oily cuttings as fuel
- ☐ Other, please specify:

***18) How do you temporarily store the drilling fluids wastes and cuttings at the drilling site ?**

☐ In special tanks for each type of waste
☐ In pits
☐ Other, please specify:

***19) Do you mix drilling wastes (fluids and cuttings) with any other wastes ?**

☐ Yes ☐ No

***20) Do you use any technique to separate solid cuttings waste from drilling fluids before the final disposal?**

☐ Yes ☐ No

***21) Do you transfer the drilling wastes from the drilling site ?**

☐ Yes ☐ NO

***22) If the answer is Yes , when do you usually transfer them ?**

☐ During the drilling operation ☐ After finishing drilling operation

***23) How do you transfer drilling wastes in (off-shore) drilling operations ?**

☐ Only the drilling fluids are transferred on shore
☐ Only the cuttings are transferred on shore
☐ Not transferring any drilling wastes

***24) Please rate the following challenges faced by the company in transferring the drilling wastes;**

	Strongly disagree 1	Disagree 2	Agree 3	Strongly agree 4
The transfer is very expensive	☐	☐	☐	☐
Engineering difficulties	☐	☐	☐	☐

***25) When do you usually treat the drilling wastes before disposal?**

☐ When Oil Based Fluids is used
☐ When Water based fluids is used
☐ When Synthetic Based Fluids is used
☐ When cuttings contain heavy metals
☐ When salt water is used to prepare drilling Fluids
☐ Not making any treatment
☐ Other, please specify:

***26) Please rate the following treatment methods you use to treat drilling wastes ?**

	Never 1	Sometimes 2	Often 3	Always 4
Chemical Treatment	☐	☐	☐	☐
Biological Treatment	☐	☐	☐	☐
Physical Treatment	☐	☐	☐	☐
Thermal Treatment	☐	☐	☐	☐

***27) Which of the following treatment methodology do you use to treat and manage drilling wastes ? (please chick all that apply)**

☐ Composting
☐ Bioreactors

☐ Vermiculture
☐ Incineration
☐ Thermal desorption
☐ Solidification
☐ Stabilization

☐ Other, please specify:

---

28) Where does the company dispose off its (offshore) drilling wastes?

☐ Close to drilling sites (less than 500m)
☐ In specific areas outside drilling operations
☐ Not disposing any drilling wastes in the sea
☐ Other, please specify:

***29) Do you dispose off both drilling wastes (fluids and cuttings) in one site?**

☐ Yes ☐ NO

---

30) How do you dispose/discharge drilling wastes in off-shore operations ?

☐ Discharge all wastes directly into the sea near the drilling site.
☐ Transfer it and dispose of in specific location in the sea
☐ Dispose the cuttings only
☐ Dispose the fluids only
☐ Treat and dispose of in seawater
☐ Other, please specify:

---

31) When using oil based fluids in your off-shore drilling operations ;

☐ Both drilling wastes can be discharged into sea. ☐ The drilling cuttings can be discharged into sea ☐ Not discharging any drilling wastes

*32) **Which of these methods are you applying to disposal of drilling wastes(please check all that apply) ?**

☐ Onsite pit
☐ Disposal in landfill
☐ Slurry injection
☐ Salt caverns
☐ Onsite evaporation
☐ Other, please specify:

*33) **The final disposal site of drilling wastes is categorized as ;**

☐ Single well disposal area (Onsite)
☐ Multi-well disposal area (Gathering area)

*34) **Does the landfill or pits contains a bottom and cover layer ?**

☐ Yes ☐ No

35) **What is the average thickness of landfill bottomliner?(m)**

*36) **Which of the flowing materials do you use as landfill bottom liner ?**

☐ Clay
☐ Plastic
☐ composite
☐ Does not contain any liner

*37) **Do you install landfill monitoring wells to check groundwater contamination?**

☐ Yes ☐ NO

38) **Describe design standards for constructions landfill or disposal sump , If any ?**

*39) **When using landfill and pits ,The base of the final subsoil above the water table is at least ;**

☐ 0.5 meter
☐ 1.0 meter
☐ 1.5 meter
☐ More than 1.5 meter

40) **Describe requirements of groundwater protection , if any ?**

41) **How often do you take samples from marine environment ?**

☐ Never ☐ Sometime ☐ Often ☐ Nearly always

42) **What kinds of samples do you take from the marine environment?**

☐ Fish
☐ Sea water
☐ Sediment

☐ Other, please specify:

43) **Have you ever noticed any contamination resulting from drilling wastes in the marine environment ?**

☐ Yes ☐ No

44) **What was the source of this contamination ?**

45) **How did you treat it ?**

Environmental Regulations & Standards

*46) **Please rate the following environmental regulations that followed in the company?**

	Never 1	Sometimes 2	Often 3	Always 4
Local regulations	☐	☐	☐	☐
International regulations	☐	☐	☐	☐
The company has its own standards	☐	☐	☐	☐
Mixed	☐	☐	☐	☐

*47) **Which governmental agency is responsible for supervising and monitoring the drilling wastes management in the company?**

☐ Presidency of Meteorology and Environment
☐ Ministry Of Petroleum and Minerals Resources
☐ Both agencies above
☐ Other, please specify:

*48) **What international environmental regulations or standards are you following to deal with drilling waste in your company ?**

☐ American regulations/standards
☐ Europe regulations/standards
☐ Canadian regulations/standards

☐ Other, please specify:

*49) **Is there any specific governmental regulations/standards you are following in managing drilling wastes ?**

☐ Yes ☐ No

50) **If the answer is yes, please indicate which specific regulations/standards?**

51) **Do you have an arrangement with an environmental company to conduct and manage the drilling wastes ?**

☐ Yes ☐ NO

*52) **How often does the governmental environmental agencies carry out inspection visits to monitor the drilling wastes management ?**

☐ Never

☐ Sometime
☐ Often
☐ Always

*53) **Do you usually prepare Environmental Impacts Assessment (EIA) before drilling ?**

☐ Yes ☐ No

*54) **If the answer is yes , does it contain full report about drilling wastes management plan ?**

☐ Yes ☐ NO

*55) **How do you evaluate the local environmental regulations and standards ?**

	Strongly disagree 1	Disagree 2	Agree 3	Strongly agree 4
Strong enough in dealing with wastes management	☐	☐	☐	☐
Weak and old regulations that need to be developed and updated	☐	☐	☐	☐
The regulations and standards are strong but not applied	☐	☐	☐	☐

…………………Thank you ………………..

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Appendix 2

Questionnaire Evaluation

EARTH SCIENCE DEPARTMENT
KING FAHD UNIVERSITY OF PETROLEUM AND MINERALS
ACADEMIC RESEARCH FOR M.SC ENVIRONMENTAL SCIENCES PROGRAMME
SAMPLE SURVEY QUESTIONNAIRE
INTRODUCTION

Dear Sir,
You have been chosen to evaluate a sample questionnaire for an environmental study. I am designing a questionnaire to collect data for a M.Sc. thesis in Environmental Sciences at KFUPM titled "**Management of the Drilling Wastes in the Eastern Province of Saudi Arabia**"
The questionnaire is divided to four parts;
(Part 1) Background information about the company
(Part 2) Types, volume and composition of drilling fluids and cuttings
(Part 3) Drilling wastes management
(Part 4) Environmental Regulations & Standards
As important step before distributing the questionnaire, it is necessary to pre-test and evaluate the questionnaire to determine whether or not the quality of questions are effective and understandable, this will improve the questionnaire and make it more applicable.
Kindly check the items in the questionnaire and provide your candid opinion read by ticking where appropriate (•) or by writing your comments on the below table.
Thank you for your anticipated cooperation.

Researcher
Ali Al-Zahrani

		Understanding the Question		To what extent is the question related to the study?		Using the Language correctly	
		☐Understandable	☐Not Understandable	☐Related	☐Unrelated	☐correct	☐Not correct
Question number	(Part 1) Background information about the company						
1		☐	☐	☐	☐	☐	☐
2		☐	☐	☐	☐	☐	☐
3		☐	☐	☐	☐	☐	☐
4		☐	☐	☐	☐	☐	☐
5		☐	☐	☐	☐	☐	☐
6		☐	☐	☐	☐	☐	☐
7		☐	☐	☐	☐	☐	☐
8		☐	☐	☐	☐	☐	☐
9		☐	☐	☐	☐	☐	☐
10		☐	☐	☐	☐	☐	☐
(Part 2) Types , volume and composition of drillings fluids and cuttings							
11		☐	☐	☐	☐	☐	☐
12		☐	☐	☐	☐	☐	☐
13		☐	☐	☐	☐	☐	☐
14		☐	☐	☐	☐	☐	☐
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(Part 3) Drilling wastes management							
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(Part 4) Environmental Regulations & Standards							
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Does the questionnaire include (Title , the goal of the study , clear instructions to answer) ?☐ Yes ☐ No							
Time taken to answer the questionnaire☐ Normal ☐ long ☐ too long							
Accessing questionnaire web link☐ Easy to access ☐ difficult to access							

Your Education level ;

☐ **PhD**

☐**Masters degree**

☐**Bachelors degree**

☐ **Diploma**

Years of experiences ;

☐ ≤ 5 years

☐ 6-10 years

☐ 10-20 yeas

Your General Evaluation	**☐The questionnaire is acceptable**	**☐The questionnaire is not acceptable**
Comments , Advices and		
Your Name	…………………………………………………………………..	
Your specialization or major	…………………………………………………………………..	
Your position	…………………………………………………………………..	
Department		
Phone number		
Signature/ Date		

REFERENCES

Ajaj, Ahmad. Economics of oil and natural gas, Al-Resalafor publication and distribution, Amman, Jordan,(2010).

Al-Maghrbi, Mohamed Kamel."Methods of Scientific Research", 1st edition. Amman, AldarAlelmeah for publication and distribution,2002.

ASME."Drilling Fluids Processing Handbook", ASME shale shaker committee. Elsevier Inc.,2005.

API, "Specification 13A",American Petroleum Institute,1983.

Abu Khamsin, S.A."Environmental Regulations for Drilling Operations in Saudi Arabia", SPE/IADC Middle East Drilling Technology Conference, 23-25 November, Bahrain,1997.

Bradford, D. W., Growcock, F. B., Malachosky, E., and Fleming, C. N., "Evaluation of Centrifugal Drying for Recovery of Synthetic-Based and Oil-Based Drilling Fluids,'' SPE 56566, SPE Annual Technical Conference and Exhibition, Houston, Oct. 3–6.

Candiand, Douglas, K.,"The Experimental & Descriptive Approach", New York: McGraw Hill Book Co., 1990.

Candler, J.E., A.J.J. Leuterman, and J.H. Rushing. "SyntheticBased Fluids Systems Offer EnvironmentalBenefits over Traditional Fluids Systems," SPE 25993 presented at SPE/EPA Exploration & Production Environmental Conference held in San Antonio, TX, March 710, 1993.

Candler, John and Leuterman.Art. "Drill Fluids and Offshore Environmental Protection", Foro international,2008.

Carmody, G., Letter to Heinz J. Mueller, USEPA from G. Carmody, USDOI, FWS, regarding FWS Log No. 4P93065, National Pollutant Discharge Elimination System

(NPDES) Permits EPA Region 4: Eastern Gulf of Mexico Offshore MS, AL, FL. February 19, 1999.

Clave, James Dietrich, Frank,“Statistics”, 2nd edition. San Francisco: Dellen Publishing Co.,1982.

Collins, A., Joseph, D., &Bielaczyc, K. “Design research: Theoretical and methodological issues”, Journal of the Learning Sciences, 13(1),2004.

Conklin, P.J., D.G. Doughtie and K.R. Rao,Effects of barite and used drilling fluids on crustaceans, with particular reference to the grass shrimp,Palaemonetespugio. In: Symposium on research on environmental fate and effects of drilling fluids and cuttings. Lake Buena Vista, FL, January 1999. API, Washington, DC.pp. 723738,1999.

Deis, P. 2005, ‘‘Infill Drilling in the Mississippian Midale Beds of the Weyburn Field Using Underbalanced Horizontal Drilling Techniques,’’ Paper No. 93-1105, CADE/CAODC Spring Drilling Conference, Calgary, Alberta, Canada, April 14–16.

Duel, L. L., Jr. and Holliday, G. H.,“Soil Remediation for the Petroleum Extraction Industry”, Pennwell Publishing,1994.

Ebel, H. F., Bliefert, C., Russey, W. E., 2003, “The Art of Scientific Writing”, 2nd edition. Wiley: New Jersey. ISBN 3-527-29829-0

Elírio E. Toldo Jr., Ricardo N. AyupZouain,“Environmental monitoring of offshore drilling for petroleum exploration (MAPEM): A brief overview,” Deep Sea Research Part II: Topical Studies in Oceanography, Volume 56,2008.

Friedheim, J., Toups, B., and van Oort, E., ‘‘Drilling Faster with Water-Based Fluidss,’’ AADE Ann. Tech. Forum, Houston, March 30–3,1999.

MINISTRY OF ENVIRONMENT , INDIA –"Guidelines for Disposal of Solid Waste" ,

Protection Rules, 1986

Gonzalez Manny, Wayne Crawley, U. Dennis Patton.. New Reduce, Reuse, Recycle Drilling Waste Treatment Technologies And Programs, presented at the Integrated Petroleum Environmental Consortium (IPEC).2010.

Gundilji, Amer,“Scientific research and the use of traditional and electronic information sources”. I-1, Amman: Dar Yazouri,2002.

Hollier, C., Reddoch, J., and Hollier, G. ‘‘Successful Optimization of Advances in Disposal and Treatment Technologies, to Cost Effectively Meet New Oil- Based Cuttings Environmental Regulations,’’ AADE 01-NC-HO-13, AADE National Drilling Conference, Houston, March 27–29,2001.

Jerry M. Neff and Duxbury, MA.,“Composition, Environmental Fates, and Biological Effects of Water Based Drilling Fluidss and Cuttings Discharged to the Marine Environment: A Synthesis and Annotated Bibliography”, Petroleum Environmental Research Forum (PERF) and American Petroleum Institute,2005.

Kinigoma, BS.,“Effect of Drilling Fluid Additives on the Niger Delta Environment: -A Case Study of the Soku Oil Fields”, J. Appl. Sci. Environ. Mgt. Vol, 5 (1), 57-61,2001.

Kokelj S.V, D. Riseborough, R. Coutts and J.C.N. Kanigan,“Permafrost and terrain conditions at northern drilling-fluids sumps: Impacts of vegetation and climate change and the management implications”, Cold Regions Science and Technology, Volume 64,2010.

Labat, C. P., Benoit, D. J., and Vining, P. R.,“Underbalance Drilling at Its Limits Brings Life to Old Field”. SPE 62896.Dallas, Texas, October,2000.

M. EnamulHossain, “Development of a Sustainable Diagnostic Test for Drilling Fluid”, King Fahd University of Petroleum & Minerals,2011.

Minton, R., and J. McGlaughlin, "Rising Drilling-Waste Costs Promote Novel Technologies, Approaches," Oil & Gas Journal, August 11, 2003.

Melton H. R., Smith1, J. P., C. R. Martin1, T. J. Nedwed, H.L. Mairs, D. L. Raught. “Offshore Discharge of Drilling Fluids and Cuttings –A Scientific Perspective on Public Policy”, Brazilian Petroleum Institute – IBP,2000.

Morillon, A., J.F. Vidalie, U. Syahnudi, S. Suripno, and E.K. Hadinoto, 2002, "Drilling and Waste Management," SPE 73931, presented at the SPE International Conference on Health, Safety, and Environment in Oil and Gas Exploration and Production, Kuala Lumpur, Malaysia, March 20-22.

Moore, P.L. "Drilling Practices Manual".SecondEdition.PennWell Books, Tulsa, OK.586pp.Moore, W.S., S. Krishmaswami and S.G. Bhat. 1973. Radiometric determination of coral growth rates. *Bull. Mar. Sci*. 23:157176,1986.

Muhereil M.A and R. Junin, "Potential Of Surfactant Washing To Solve Drilling Waste Environmental Problems Offshore", Emirates Journal for Engineering Research, 12 (2), 1-10,2007.

Ministry of Petroleum and Mineral Resources - Saudi Arabia ,http://www.mopm.gov.sa

Ministry of environment , India–"Guidelines for Disposal of Solid Waste" , Protection

Rules, 1986

Nilsen C., SPE, K. McCosh, SPE and M. Kapila, SPE, M-I SWACO,"Tar Sands Drilling Waste Management,: A Clean Solution IADC/SPE Drilling Conference, Orlando, Florida, USA,2008.

Nweke C. O. and Okpokwasili G. C.,"Drilling fluid base oil biodegradation potential of a soil staphylococcus species", African Journal of Biotechnology, Vol. 2 (9), pp. 293-295, September,2003.

Oort, E. V., Friedhim, J. E. and Toups, B.,"Drilling Faster with Water-Based Fluidss", Proceedings of the AADE Annual Technical Forum. March 30-3,1999.

Perricone, C.,"Major Drilling Fluid Additives1979". In: Symposium on Research on Environmental Fate and Effects of Drilling Fluids and Cuttings. Lake Buena Vista, FL. January, 1980.

Pivel M.A.G., C.M.D.S. Freitas, J.L.D. Comba,"Modeling the discharge of cuttings and drilling fluids in a deep-water environment" , Deep Sea Research Part II: Topical Studies in Oceanography, Volume 56, 2008.

Richard C. Haut, John D. Rogers, Bruce W. McDole, David B. Burnett, Thomas E. Williams and OluwaseunOlatubi,"Collaborative Team Researches Best Management Practices For Drilling Wastes", the American Oil and Gas Reporter,2007.

Robinson, Leon. "Historical Perspective And Introduction, Drilling Fluids Processing Handbook"2005.

Robinson J.P., S.W. Kingman, C.E. Snape,R. Barranco, H. Shang, M.S.A. Bradley, S.M. Bradshaw,"Remediation of oil-contaminated drill cuttings using continuous microwave heating", Chemical Engineering Journal, Volume 152,2009.

Rojas N.G. Avelizapa, T. Roldán-Carrillo, H. Zegarra-Martínez, A.M. Muñoz-Colunga, L.C. Fernández-Linares,"A field trial for an ex-situ bioremediation of a drilling fluids-polluted site", Chemosphere, Volume 66,2007.

SAIC,"Descriptive Statistics and distributional Analysis of Cadmium and Mercury Concentrations in Barite, Drilling Fluids, and Drill Cuttings from the API/USEPA Metals Database". Prepared for Industrial Technology Division, U.S. Environmental Protection Agency, February. 1980. API, Washington, DC. pp. 1529,1991.

Santos M.F.L, P.C. Lana, J. Silva, J.G. Fachel and F.H. Pulgati,"Effects of non-aqueous fluids cuttings discharge from exploratory drilling activities on the deep-sea macrobenthiccommunities", Deep Sea Research Part II: Topical Studies in Oceanography, Volume 56,2008.

Schmidt, J.H., W.L. Friar, M.L. Bill, and G.D. Cooper, "Large-Scale Injection of North Slope Drilling Cuttings," SPE 52738, presented at the 1999 SPE/EPA Exploration and Production Environmental Conference, Austin, TX, February 28 March 3,1999,

Sengupta.B.,Oil& Gas Drilling and Extraction Industry", Central Pollution Control Board,2006.

Soegianto, A.; B. Irawan and M. Affandi, "Toxicity of Drilling Waste and Its Impact on Gill Structure of Post Larvae of Tiger Prawn (Penaeusmonodon)", Global Journal of Environmental Research 2 (1): 2008.

Sumrow, M., "Synthetic-Based Fluidss Reduce Pollution Discharge, Improve Drilling," *Oil & Gas Journal*, December 23,2002.

Sadiq, R.; Husain, T.; Veitch, B.; Bose, N., "Risk management of drilling waste discharges in the marine environment:AHolistic Approach",2003.

Shaffer, G.P., M.W. Hester, S. Miller, D. J. DesRoches, R.F. Souther, G.W. Childers, and F.M. Campo, "Restored Drill Cuttings for Wetlands Creation: Results of a Two-Year Mesocosm Approach to Emulate Field Conditions under Varying Hydrologic Regimes," DOE/BC/14849-3, prepared by Southeastern Louisiana University Wetlands Restoration Laboratory, Hammond, LA, for U.S. Department of Energy, National Petroleum Technology Office, November.1998.

Schlumberger Limited , http://www.glossary.oilfield.slb.com , 2012

TawabiniS.Bassam, "Environmental Management of Drilling Wastes: An Overview", 2010.

Tawfiq Abdul-Jabbar, "Statistical Analysis", Second edition, Kuwait Foundation for the Advancement of Science, Kuwait,1985.

Teitelbaum, H.,"How to Write a Thesis: A Guide to the Research Paper", 1st edition, Arco Publishing Inc, New York, 2007.

The International Energy Agency Annul Report,"Conditions of the world's energy". The International Energy Agency report,2009.

US Environmental Protection Agency, "2000Guidance document for the system of solid waste in Egypt", 2001.

Veil, John A.,"Offshore Waste Management – Discharge, Inject, or Haul To Shore"? Argonne National Laboratory, Washington, DC.,2004.

Zhang Li D, Y, Quan X, Zhao Y.,"Microwave thermal remediation of crude oil contaminated soil enhanced by carbon fiber", Journal of Environmental Sciences, Volume 21,2009.

Zikmond, W. G.,"BusinessResearch Methods". 4th edition, TheDryent Press, Orlando, Florida,1992.

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Mr. Ali A. Al-Zahrani was born in Al-Baha, south-west direction of Saudi Arabia in 1977. He started his elementary study from AL-Fadeal school in1991, then he finished his high school study in 1997 and joined King Abdul Aziz University for Bachelors Science Degree in Petroleum Geology in the same year (1997) and the Degree was awarded to him in 2002.

After obtaining his Degree in B.Sc Petroleum Geology, he joined the Ministry of Petroleum and Mineral Resources, Dhahran in 2005 in the Department of Engineering as a Geologist and since then he has been working there till now. He gained a lot of experience during the tenure of his employment and contributed a lot to his department as well. As a result very soon, he started supervising oil and gas companies' explorations and drilling operations. Apart from this, a quest of higher education and upgrdation of his career was always observed in him.

In pursuant to this, he joined King Fahd University of Petroleum and Minerals (KFUPM), Dhahran in 2009 as a part-time student in seeking the Master Degree in the Environmental Sciences Program of the Earth Sciences. During the course of his Master Degree in KFUPM, he was involved in the following several activities: attended three environmental conferences, made two visits to the leading environmental companies, attended two workshops in environmental issues, attended five courses in environmental wastes management and risk assessment and became the member of two active environmental societies.

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