CHARACTERIZATION, ANALYSIS AND REVIEW OF HAZARDOUS WASTE MANAGEMENT IN OIL DRILLING FIELDS IN TURKANA, KENYA

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DECLARATION

I understand that plagiarism is an offence and I therefore declare that this thesis report is my original work and has not been presented to any other institution for any other award.

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DEDICATION

I would like to dedicate this research thesis to my dear wife, Millicent Akinyi and lovely daughter Paula Praise Avy. To my late parents, Mr. & Mrs. Nyateng, we started this together and wished we could complete it together. In pain, you have stood the test of time, till we meet again. You are so dear to me.

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ABBREVIATIONS AND ACRONYMS

AC	**:**	Air Conditioner
CR-I	**:**	Cuttings Re-Injection
EMCA	**:**	Environmental Management and Coordination Act
EPA	**:**	Environmental Planning Agency
ESHS	**:**	Environmental, Social, Health and Safety
EU	**:**	European Union
GHS	**:**	Globally Harmonized System of Classification and Labelling of Chemicals
NEMA	**:**	National Environmental Management Authority
OBM	**:**	Oil Based Mugs
PCBs	**:**	Polychlorinated biphenyl
SBM	**:**	Synthetic Based Mud
TKBV	**:**	Tullow Kenya BV
UN	**:**	United Nations
UNEP	**:**	United Nations Environment Program
UNFCC	**:**	United Nations Framework Convention on Climate Change
UOG	**:**	Unconventional Oil and Gas

ABSTRACT

This research was carried out with the main aim of identifying the major waste streams and respective impacts from the oil drilling and exploration fields in Lokichar basin, Turkana County, Kenya. The area of study, known as Block 10BB and 13T covers Central Lokichar, from Twiga, all the way to Ngamia_1. The study physically examined the types of waste generated by the activities in the study area and characterized them into different streams and classes, where the major focus was on hazardous waste. General waste was also investigated with the interest of the point of contamination and relevant volumes produced. Kenya's National Environment Management Authority's (NEMA) Waste Management Regulation (2006), fourth schedule was used to benchmark the existing practices against the requirements to determine the compliance level. Primary data was obtained using questionnaires and schedules as the main tools. These were administered to the environmental department of the oil drilling company, as the key respondent in this study. The approach used in this research is majorly a case study. One questionnaire and direct interviews were administered on the environmental monitor of the oil drilling company. This study discovered that the major class of waste from the oil drilling activities is the produced water, which also carries the highest health risk. This is followed by cuttings that contain higher amounts of hydrocarbons and indeterminate chemical compounds. It was also observed that general waste was being contaminated with certain chemicals, rendering them hazardous. Other waste streams identified were effluent from the kitchen and lavatories. The risk factor, mitigation and improvement initiatives have been recommended after an informed discussion against the available literature from similar studies. This is expected to help in reduction of the impacts related to poor waste management at the rig on the local population and ecosystem.

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the study

Oil and gas exploration exert pressure on the natural resources and ecosystems in areas where such activities are done. These can be long term liabilities and acute short-term critical impacts that have expensive inter-generational impacts and must be dealt with at the onset of the activities. One of the greatest impacts comes from inappropriate disposal and management of waste from drilling activities. This research considers the case in Kenyan Oil and gas exploration to identify various waste disposal strategies, the impacts of improper disposal and the legal framework to govern the practices. The study strives to investigate the legal framework gaps as far as implementation is concerned.

Kenya began oil and gas exploration in the year 2012, having successfully tendered its potential oil producing blocks to some international oil drilling companies. The regions with potential to produce hydrocarbons in Kenya were classified into blocks in the tendering process and the Lokichar basin with the confirmed highest potential was falling under the blocks 10BB and 13T. These two blocks are the study area of this research. Tullow Oil PLC announced its success in Kenyan Oil and gas exploration in the very year, 2012, and thus the genesis of active and successful oil exploration and drilling in Kenya. (Tullow Oil PLC, 2017).

During any oil exploration and drilling, a lot of environmental liabilities would be anticipated. Among the problems is hazardous waste which facilitates pollution and degradation of natural resources. This is even a threat to natural flora and fauna and depletes the natural heritage for the wildlife which is found in these habitats (NEMA, 2006). Hazardous waste introduces foreign substances and chemicals which may be dangerous to the natural environment if not well managed. Some of the impacts may be long term and may extend among many generations of the habitats (Carson & Murmford, 2005).

Such critical impacts have triggered a closer situational analysis of the hazardous waste management in the oil drilling fields of Block 13T and 10BB in the Lokichar Basin, Northern Kenya. It is intended that through this study, best practices both technologically and institutionally will contribute to the options in the country to deal with the hazardous waste related with oil and gas exploration and drilling. The impacts, their magnitude and the existing controls to mitigate the prevailing issues have been analyzed through interviews of key informants in the project. Mitigation measures have been formulated to the challenges identified and appropriate recommendations thus issued. These have been deemed helpful to both the drilling contractors and the government at large.

The legal measures and controls have also been analyzed with various case studies with similar operations to come up with scenario modeling solutions for Kenya, with a main objective of turning this problem into opportunity for the immediate potentially affected parties.

There is a strong relationship between the health of the ecosystem and the health of the human system. Waste generation is moderated by drivers that can be manipulated through a wide variety of responses by policy actors and decision-makers to ensure the mitigation of negative impacts of wastes and the adoption/adaptation measures. There are many people who have fallen victims of poor waste management in the world and specifically waste derived from mining works. Environmental degradation is one key issue associated with poor waste management as well as degrading the aesthetic value provided by nature of the ecosystems.

"In other countries where oil drilling and production have been taking place the following strategies have been used to manage the waste from the rigs; Bioremediation/land farming, Cuttings slurrification and re-injection (CRI), Dewatering and water treatment, Stabilization, Thermal processing, Cuttings drying, Vacuum collection and Pneumatic cuttings transport" (Shariff & al, 2017). This specific research work has investigated the existing methods and recommended more cost-effective methods of managing the waste from the drilling operations.

The High-Density Polyethylene (HDPE) liners are sometimes discarded by the drillers and scavenged by the local community. These are used to construct the *Manyattas (Turkana's traditional huts)* and shield the communities from rain during such seasons. Nevertheless, the communities at times raise complains concerning the impacts of these waste and some of the impacts may be directly or indirectly related the waste issues. The drilling company has contracted a hazardous waste management company that deals with all the hazardous waste, there is a reduced interaction by the local community with the hazardous waste. A good percentage (To be determined by the research) of the hazardous wastes from the operations are removed from the sites for safe disposal at the authorized hazardous waste. Moreover, the drilling muds that could be contaminated with oil are processed in the Thermal Desorption Unit (TDU) which extracts the oils and reused in the drilling cycle (Environment Agency, 2008).

1.1.1 Toxicity levels of the waste

Various waste materials have varying impacts, and these have been classified by EU, EPA and UN differently as shall be seen in chapter2 of this study. The Waste Management Regulation of Kenya from the EMCA ,2006 has also provided methodologies of dealing with all the hazardous waste with certain chemical components and impacts. These have also been illustrated in Chapter 2. These classifications aid in identification and characterizing the drilling waste into respective categories therefore recommending the best handling methodologies that can be used to adequately dispose the waste. The highest level of toxicity has been considered to be carcinogenic, cytotoxic and ecotoxic impacts. In so doing, the research has been able to conscientiously arrive at an empirical conclusion that meets the objectives of the study.

1.2 Statement of the Problem

The unending conflict between the residents and the Oil and gas drilling operations attracted an interest to study the mode of waste management as a potential trigger to the conflicts. The local population that is majorly nomadic pastoralists, raised complains about livestock being poisoned after consuming hazardous chemicals from drilling processes. Other social and environmental conflicts were also at play, and thus the need to demystify such claims through a structured study to identify the challenges. This study therefore closely investigates these allegations for confirmation or to demystify the claims with scientific methodologies described hereafter. Potential Environmental, Social, Health and Safety issues caused by these activities need to be investigated for control and mitigation, since environmental issues are built-in, as opposed to add-on. (Kibwage, 2002).

The impacts of the oil and gas industry on the natural environment can be heinous in the natural habitats and conservation areas of flora and fauna. EMCA 2016 vitiates that it is the responsibility of the polluter to carry out restoration and/or remediation of contaminated grounds on well-pads. Environmental risks reduction/elimination, sustainable wastes management and waste reduction/reuse are some of the best practices as envisaged in the Waste Management Regulation, 2006 of the EMCA 1999.

Without proper means of ensuring further treatment and disposal of drill cuttings and spent drilling mud into the environment these would have detrimental effects on the ecosystem in the study area. Some of the management strategies may not be applicable to Kenyan situation due to lack of installed technology and regulations. However, they are necessary for the sake of environmental sustainability.

This research study proposes to identify and characterize the various hazardous waste streams associated with oil and gas exploration operations, review technological systems for waste treatment and assess existing regulatory framework for waste control, treatment, and disposal methodologies with the aim to review their adequacy to mitigate the relevant environmental liabilities.

1.3 General Objectives of the Study

1.3.1 General Objective

The General objective of this research was to Analyse the status of hazardous waste management in the oil drilling fields in the Lokichar basin of the Turkana County of Kenya.

1.3.2 Specific Objectives

i. To classify (characterize) the hazardous waste produced from the oil field.
ii. To analyze the existing hazardous waste management systems and technologies used by the oil drilling company.
iii. To review the existing legal framework that governs hazardous waste management in Kenya in relevance to oil and gas waste management.

1.4 Research Questions

i. What are the waste streams/classes from the oil field drilling operations (generated either directly or indirectly)?
ii. What are the existing waste management systems and technologies for the hazardous waste generated in the oil and gas drilling fields?
iii. Which legislative frameworks are there in Kenya to govern oil drilling waste management?

1.5 Justification for the study

Resource extraction activities, including oil and gas exploration, generate Environmental, Social, Health and Safety (ESHS) impacts, many of which have the potential to endure beyond the conclusion of commercial exploitation. In the absence of adequate planning and mitigation measures, the impacts of resource extraction activities can present persistent and adverse ESHS effects with significant potential legal and financial consequences to the operator(s), the local population, and the host communities in which these projects are conducted.

The problems related to hazardous waste in the oil drilling sector are not unique to Kenya. Other countries have developed technology to mitigate the problems, while socio-cultural factors have also been considered to realize a compromise, to achieve sustainable development. There is need to closely analyze Kenya's readiness for the environmental impacts associated with oil and gas drilling activities, and the sufficiency in legal framework in the country to help in safeguarding the environment and enable sustainability.

The adequacy of the systems put by the contractors to ensure sound environmental management, as far as hazardous waste is concerned and the robustness of the national and county regulatory frameworks on environmental management, are vital to unlocking the potential benefits of oil and gas to the economy. Therefore, the results of this study will contribute scientific information on existing hazardous waste management systems in relation to oil and gas drilling operations and the status of environmental regulatory framework to support safe and environmentally friendly waste management in the country. The Constitution of Kenya 2010 is the overarching law that governs natural resources in Kenya. Article 69 (1) (a) of the Constitution bestows on the State the responsibility to ensure sustainable exploitation, utilization, management and conservation of the environment and natural resources, and ensure the equitable sharing of the accruing benefits. The State is required to utilize the environment and natural resources for the benefit of the people of Kenya.

The article 42 of the constitution of Kenya states that every Kenyan has a right to a clean and healthy environment which includes: To have the environment protected for the benefit of present and future generations through legislation and other measure, particularly that contemplated in article 69 and to have obligation relating to the environment fulfilled under article 70.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Hazardous waste

Hazardous wastes are those that have potential to pose health risks, high environmental risks, and liabilities. They may contain toxic substances generated from industry, hospitals, and some types of household wastes. These wastes could be corrosive, inflammable, explosive, or react when exposed to other materials. Some hazardous wastes are highly toxic to environment including humans, animals, and plants (Hosam & al, 2016).

2.1.1 Nature of Hazardous waste

The hazardous wastes in the oil and gas exploration activities are majorly in three states, namely, solids, liquids, and gases. These could be generated from leaks, releases, and spills. Moreover, chemicals used in the exploration activities could be sources of greenhouse gases and thus pose critical climatic challenges. The hazards of 'chemicals' stem from their inherent flammable, explosive, toxic, carcinogenic, corrosive, radioactive or chemical-reactive properties (Carson & Murmford, 2005). The effect of exposure on personnel may be acute, e.g., in a flashfire or due to inhalation of a high concentration of an irritant vapor. Alternatively, prolonged, or intermittent exposure may result in an occupational disease or systemic poisoning. Generally acute effects are readily attributable; chronic effects, especially if they follow a long latency period or involve some type of allergic reaction to a chemical, may be less easy to assign to particular occupational exposures (Carson & Murmford, 2005)

2.1.2 The Impacts of the drilling waste

The impacts of these wastes can be either positive or negative regarding the environment and human health. The drilling muds or the cuttings when properly managed and treated can be useful in farming as they contain important minerals such as sodium, calcium and phosphorous that is useful to plants. On flipside, the cuttings may contain heavy metals such as lead, cadmium, mercury and arsenic (UNEP, 2022) and other pollutants that are harmful to the soil fauna and flora (Smith & Scott, 2005). Similarly, the produced water is also rich is phosphates of ammonia and calcium and carbonates of ammonia. The carbonates of ammonia when heated, readily decomposes to carbon dioxide and ammonia gases, which are fixed by legumes back to soil. These are essential nutrients that are required in vegetative growth of plants. However, the produced water may also contain harmful pollutants and soil poisoning substances from the greater depths of drilling (Ellis, 2016). This makes them unusable in the aspect of irrigation.

2.1.3 Type and Sources of Waste from the Drilling Activities

Oil exploration activities involve several processes, ranging from seismic work to exploration/drilling to production level. These generate wastes of different types, both hazardous and non-hazardous. The wastes fall into larger categories of produced water, drilling wastes and associated wastes (Reiss, 1996).

2.1.4 Produced Water

Produced water is the waste stream generated in the largest amounts by the oil production industry, at a ratio of 9:1 water to oil. (Bashat, 2002). Globally, it is approximately 77 billion barrels of water are produced per annum. The conventional methods to handle waste stream are reinjection into the well, direct discharge or reuse in case of thermal loop (Durasaimy & al, 2013). Produced water waste usually contains impurities that can adversely impact the environment if available in sufficient amounts. These impurities include dissolved solids (primarily salts and heavy metals), suspended and dissolved organic materials, formation solids, sulphur dioxide, and carbon dioxide and have deficiency in oxygen (Reiss, 1996). The physical and chemical properties of produced water depend on the geographic location of the field, the geological formation with which the produced water has been in contact for thousands of years, and the type of hydrocarbon product being produced. The main constituents of produced water are dissolved and dispersed oil compounds, dissolved formation minerals, production chemical compounds, production solids (formation, corrosion, scale, bacteria, waxes, and asphaltenes) and dissolved gases (Durasaimy & al, 2013).

Produced waters discharged from gas/condensate platforms are about 10 times more toxic than the produced waters discharged from oil wells, but the volumes from gas production are much lower; hence the total impact may be less (Durasaimy & al, 2013).

Based on the above arguments, it is evident that produced water fall into the category of hazardous waste according to the Kenyan Waste Management regulation, 2016 (GoK, 2016).

2.1.5 The drilling wastes

Another category of waste associated with oil and gas drilling operations is drilling waste. These wastes consist mainly of formation materials displaced during drilling and coated with drilling fluid. Soil and rock cuttings are lifted to the surface by the fluid circulated through the drilling pipe and collected into a nearby earthen pit, called drilling pit. This is illustrated in Figure 2.1:

Figure 1. Drilling waste muds: (Nagy, 2002)

Specifically, the process of drilling oil and gas wells generates two primary types of wastes; spent drilling fluids and drill cuttings. Drilling fluids (known as drilling mud in the oil and gas industry) are very important in the drilling process as they serve to balance formation pressures and to transport drill cuttings to the surface. The fluid phase of the drilling mud can be water, synthetic or natural oils, air, gas, or a mixture of these components. Drilling mud is circulated through the drill bit to lubricate and cool the bit, control the formation fluid pressures and to aid in carrying the drill cuttings to the surface, where the mud and cuttings are separated by mechanical means. The drilling muds may be categorized into: Synthetic based Muds (SBM); Water based Muds (WBM) and Oil Based Muds (OBMs) (Amoasah, 2010).

When circulated out of the well during drilling, the drilling mud is mixed with drill cuttings and hydrocarbons from the formations (Shariff & al, 2017). Despite on-site treatment, drill cuttings still contain significant number of hydrocarbons typically in the range of 5-10%, which is above the legal limits (Nwakaudu, 2012).

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 such as Barium Sulphate (commonly known as Barite). Barite is a common additive, which is a weighting 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. (Reiss, 1996).

From this knowledge, it is evident that the chemical composition of the drilling waste qualifies the waste to be hazardous. It is therefore necessary that proper methods of disposal are assimilated into the process of drilling.

2.2 The associated wastes

The last broader category of waste from the drilling process is the associated waste. These are generated from the related activities of oil exploration and drilling. Other waste waters routinely generated at onshore oil and gas facilities include sewage waters, drainage waters, tank bottom water, fire water, equipment and vehicle wash waters and general oily water (World Bank, 2007). According to Californian Environmental Protection Agency, these waste streams have been classified as; Oily sludge's; Work over wastes; well completion and well abandonment wastes (such as left-over cement and drilling fluid) and other small volume wastes associated with oil production (Adipepe, 1991). This indicates that the associated wastes from the drilling operations maybe of the smallest quantities as compared to other streams. Oil filters, and used oils from machines and vehicles repairs also form part of this stream.

Table 1. Wastes Components and Environmentally Significant Constituents from Drilling Activities

Type of Waste	Main components	Possible Environmentally Significant Constituents
Waste lubricants	Lube oil, grease	Heavy metals, organic compounds
Spacers	Mineral oil, detergents, Surfactants	Synthetic minerals and persistent pollutants
Spent/contaminated. water based muds. (include brine)	Whole mud, mineral oil, biodegradable, Matters	Heavy metals, inorganic salts, biocides, hydrocarbons, solids/cutting, BOD,
Water based muds Cutting	Formation solids, water-based muds, mineral oil	Heavy metals, inorganic salts, biocides, hydrocarbons, solid/cutting
Spent/contaminated oil, based muds	Whole mud mineral, Oil	Hydrocarbons, heavy metals, inorganic salts, solids, BOD, organics, Surfactants
Oil based muds Cuttings	Formation solids, oil based muds	Heavy metals, inorganic salts, hydrocarbons, solid/cutting
Spent bulk chemical	Cement, bentonite, barites, viscosities, thinners, fluid loss reducers, specialty Product	Heavy metals, hydrocarbon,
Spent special products	H_2S scavengers, defoamers, tracers	Zinc carbonates, Iron oxides, hydrocarbons, silicon oils, potassium salts, radioactive materials

Source: (Bashat, 2002)

2.3 Environmental Impacts of Oil Drilling Waste

Like all other wastes the hazardous waste related or generated from the oil drilling operations have several impacts. Some may be negative, whilst others may be positive. It is important that the oil and gas industries give sustainability a priority. Sustainable development is vital in ensuring inter and intra-generational equity in terms of resources use.

A study to investigate environmental impacts of drilling activities in Ghana reveals three orders of impacts of oil and gas exploration as described by (Amoasah, 2010).

The first order of impact in oil and gas industry comprises the activities with immediate effects or consequences on the surrounding environment. Each phase presents its peculiar primary impacts, and these impacts are driven by the release of emissions, discharges, collisions and physical destruction of the parent rock. These impacts with time, give rise to the second and third orders of impact.

The second order of impacts in oil and gas industry collectively includes those indirect effects that result from the project. For instance, the enormous job opportunities that comes with the oil and gas exploration. This coupled with differences in salary levels are enough to serve as incentive for the inhabitants of the surrounding communities to abandon farming, fishing, and other related economic activities for oil related jobs. Such a shift may result in other sectors of the economy particularly, the agricultural sector suffering.

These impacts are also referred to as accumulated impacts and they become manifested over a prolonged period. The impact may result from a continuous accumulation of the first and/or the second impact (Amoasah, 2010). From this statement it can be deduced that these impacts can be realized long after the activities are closed. They could include effects such as chronic illnesses and changed ecosystem set-up.

2.4 Health Impacts of the Wastes

In Unconventional Oil and Gas (UOG) industry, over 1000 different types of chemicals, most of these poses various known and unknown health and environmental impacts (APHA, 2018). The drilling fluids, including surfactants, biocides, proppants, viscosity modifiers have been known to have varying toxicity effects. Some are believed to be safe, while others are known or suspected to be carcinogens, endocrine disruptors, or otherwise toxic to humans. Among the toxic chemicals include silica, benzene, lead, ethylene glycol, methanol, boric acid, and gamma-emitting isotopes (APHA, 2018). The toxicities severity depends much on concentration, exposure level and duration. Often, the precise identity, quantity, and mixture of the fluids used to fracture each well are not disclosed which is quite significant is vitiating the health impacts of these chemicals.

According to (Holdway, 2002), the health impacts of oil drilling waste can be categorized into **acute** impacts and **chronic** impacts. The acute impacts are those that have short and reversible effects whilst the chronic impacts are those with long term and terminal health impacts.

In relevance to waste management, the same impacts may be almost similar in hierarchy. The Basal Convention on Dangerous Goods classifies waste in order of hazard nature (UNEP, 2000). This forms the basis upon which various toxicity levels of the waste materials and chemicals are classified. The Globally Harmonized System of Classification and Labelling of Chemicals (GHS) provide a framework for such harmonization in terms of the first step of classification, or hazard identification (EPA, 2013). While GHS itself does not address risk assessment or management, beyond hazard identification and communication, the GHS framework can be used as the foundation of a waste classification system *(UNEP, 2005)*. The drilling waste may also contain heavy metals such as chromium, lead, mercury in levels of public concern. These have been associated with cancer and could have long term impacts. The results discussed in this research reveals the levels from the samples collected in the field and tested in lab.

2.4.1 Pollutants from Oil and Gas drilling and the associated health impacts

During oil and gas drilling process, pollutants are generated with the drilling mud or fluids. The hazard codes of the specific pollutants have been classified by respective bodies as per the table 2.2-1 and the impacts have been illustrated in the table 2.2-2.

Table 2. Hazard Codes for the USA DOT, the UN and the EU.

Chemical Property/Toxicity level	USA DOT	UN	EU
Explosive	1	1	H1
Flammable gas	2.1	2	H3-A
Non-flammable gas	2	2	2
Poisonous/toxic gas	2.3	2	H6
Flammable liquid flash point _18 °C 3	3	3.1	H3-A
Flammable liquid flash point 18 to 21 °C	3	3.2	H3-A
Flammable liquid flash point 21 to 23 °C	3	3.2	H3-B
Flammable liquid flash point 23to 55 °C	3	3.3	H3-B
Flammable liquid flash point 55 to 61 °	3	3.3	-
Flammable solid	4.1	4.1	H3-A
Spontaneously combustible	4.2	-	H3-A
Oxidizer	5.1	5.1	H2
Organic peroxide	5.2	5.2	-
Poison/toxic	6.1	6.1	H6
Infectious material	6.2	-	H9
Radioactive	7	-	7
Corrosive	8	8	H8
Miscellaneous	9	9	-
Non- regulated	-	NR	-

Source: (Smith & Scott, 2005)

Table 3. Examples of the Impacts from Toxins and Other Pollutants in the Oil Production Process

Chemical	***Aspect of Oil Production Process***	***Health/Environmental Impacts***
Benzene	Produced water	Carcinogen, reproductive toxicant, developmental toxicant
Toluene	Produced water	Developmental toxicant, suspected blood toxicant, neurotoxicant, liver toxicant, and kidney toxicant
Mercury	Produced water and drilling fluids (Mud)	Developmental toxicant, suspected blood toxicant, endocrine toxicant, neurotoxicant, reproductive toxicant, immunotoxicity
Zinc	Produced water and drilling fluids (Mud)	Suspected blood toxicant developmental toxicant, and reproductive toxicant
Lead	Produced water and drilling fluids (Mud)	Carcinogen, reproductive toxicant, developmental toxicant
Sodium (salinity)	Produced water	Contaminates soil, making it unfit for vegetation
Hydrogen Sulfide	Natural gas extraction	Suspected blood toxicant, neurotoxicant, and reproductive toxicant
Sulfur dioxide	Natural gas flaring	Major contributor to acid rain

Source: (Carson & Murmford, 2005)

2.5 Waste Management Technologies in Oil and Gas

The waste management practices have three wide approaches (Bashat, 2002). The methodology used to dispose of the waste is highly dependent on the drilling fluid used. For the waste derived synthetic and oil-based muds, the cuttings are spread on the road or could be used on the farmlands. This approach is however used in areas where the chemical components have been ascertained to be of negligible health impacts.

Some of the cuttings may be cleaned using soil washing technologies to remove high toxicant elements. The resulting waste is then used to grade roads. Some wastes have been dispersed to the ocean where offshore drilling is being done. This however pose high risks to the aquatic life and as such this practice has been abandoned.

Some of the approaches above may have been abandoned as technologies keep changing in the oil and gas exploration works. Various new technologies available have been documented by various researchers and authors as discussed in this section.

The new technologies currently used broadly include thermal desorption, incineration and soil washing techniques.

2.5.1 Thermal desorption Unit (TDU)

Thermal desorption/treatment is an environmental remediation process that uses heat to increase the volatility of contaminants using a series of equipment (desorber and oxidizer) such that the hydrocarbons and water are separated or removed from the solid matrix. It is normally carried out between the temperature range of 250-650^{o}C. At these temperatures both the lighter and heavier hydrocarbons are removed and collected or thermally oxidized by further heating to a temperature of over 850^{o}C. The resulting solid residue has essentially no residual hydrocarbons (having been oxidized) but does concentrate salts and heavy metal (Okeke & Obi, 2013). The flow chart below shows the thermal desorption unit process.

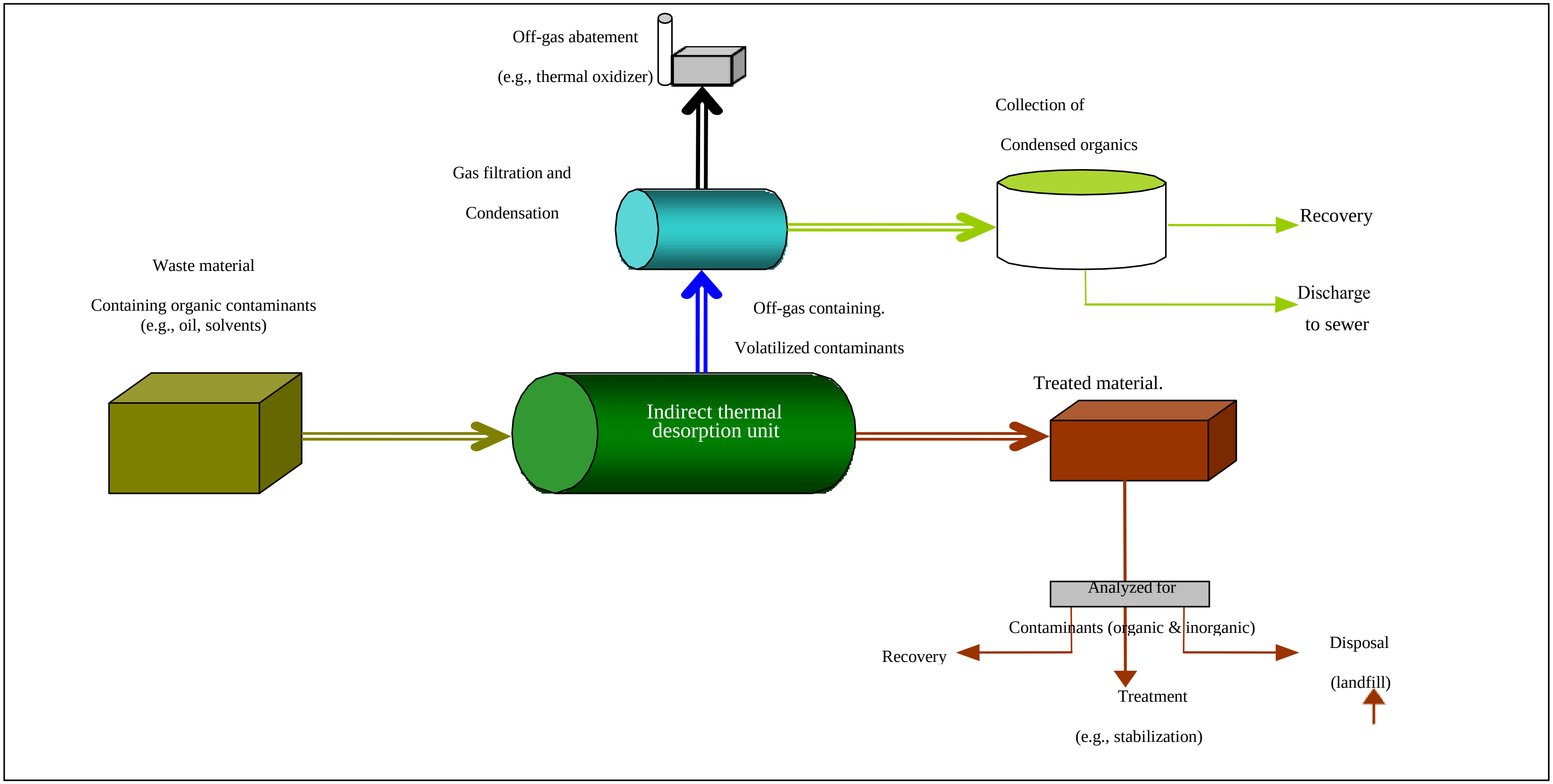

Figure 2. Example of a TDU. Off-gas abatement system (Enviromental Agency, 2006)

2.5.2 Incineration

Hazardous waste incineration uses controlled flame combustion to treat organic contaminants mainly in rotary kilns. Typically, this process for treatment involves heating to a temperature above 850 °C. This ensures most of the hydrocarbons, dangerous compounds that include PCBs are destroyed or dissociated to less harmful compounds. Good practice requires that if the chlorine content of the waste material is above 1%, then temperatures greater than 1,100 °C, must be attained with a residence time greater than 2 seconds (GoK, 2016). Such conditions ensure appropriate mixing and high combustion efficiency. Dedicated hazardous waste incinerators are available in several configurations including rotary kiln incinerators, static ovens (for liquids only). High-efficiency boilers and light-weight aggregate kilns are also used for the co-incineration of hazardous wastes (Bashat, 2002).

2.6 Legal and Regulatory Framework

These are both local and internationally adopted treaties and pacts that govern waste management regulation. The local regulations tend to streamline operationalization and protection of the natural resources and environmental resources within the land. The international treaties majorly control the transboundary pollutants from impacting other nations and also shared resources. The area of study has other countries within the borders, including Ethiopia, Uganda and Somali. L.Turkana is also a transboundary water resources that must be protected by both countries sharing it to avoid over dilapidation.

2.6.1 Local Legal and Regulatory frameworks associated with waste management of oil drilling activities

Section 69 part of the Kenyan constitution states that every person has a duty to cooperate with State organs and other persons to protect and conserve the environment and ensure ecologically sustainable development and use of natural resources (GoK, 2010). This mandates the Oil drillers to put in place measures that would ensure sustainable exploration of the oil and gas by ensuring environmentally sound management of the waste materials.

The Kenya waste Management Regulation 2006 was revised in 2016 and forms the main yardstick against which compliance was measured. The fourth schedule of this regulations provides description of the hazardous waste materials. Amongst these materials as described in the regulation include compounds copper, arsenic, and all the heavy metals (GoK, 2016). PCBs are also included in this regulation and have been investigated within the research scope.

The Oil and gas exploration leads to grievous impacts to ecosystems if the streams of waste are not well managed and taken care of. These include flora and fauna within the research area. The Wildlife Conservation Act and the Forest Act are very crucial in protecting these ecosystems' flora and fauna.

2.6.2 Compliance to the multilateral regulatory frameworks

These are treaties and pacts signed by nations to govern the cross-boundary pollution that may be experienced during the drilling and exploration exercise. In the Oil and gas exploration exercise, there are resources that the country shares with other nations and these must be safeguarded to avoid regional conflicts.

For Instance, the United Framework on Climate Change (UNFCC) governs the emissions of pollutants, and especially the greenhouse gases into the atmosphere. It protects the environment against further pollution by the development goals and initiatives. In the Oil and gas exploration, it is expected that hydrocarbons and chlorinated carbon pollutants may be emitted into the atmosphere. These have far-reaching impacts and needs to be safely managed to protect the regional interest as far the environmental concerns are concerned (UNEP, 2000).

The Montreal Protocol on Substances that deplete the ozone protects the atmosphere against pollution with the atmospheric pollutants which depletes the ozone later (UNEP, 2000). Some of these ozone depleting pollutants emanate from the hazardous wastes produced from the oil and gas extraction that have been discovered during this study.

The Basal Convention on the control of trans-boundary movements of hazardous wastes and their disposal provides the guidelines for the movement of trans-boundary pollutants, which are very common in the drilling operations. The drilling chemicals are usually transported across many borders and may spill, resulting to serious trans-boundary pollution during shipment (UNEP, 2022).

As much as these multilateral pacts may not have direct impacts and control upon the waste management at the drilling level, they still give supportive function to the local laws where gaps may exist, since Kenya is venturing into active Oil and gas exploration for the first time with these Turkana discoveries.

CHAPTER THREE

3.0 METHODOLOGY

Analysis and assessment of drilling waste and the associated streams in this context involved use of primary and secondary data collection. Various online resources were key in obtaining the qualitative and quantitative data. The principal source of primary data was from the environmental department of the oil drilling company.

3.1 Area of Study

The research was done in the block 10BB and 13T region of the oil and gas exploration in Kenya, which is situated in Turkana County, majorly in the South Eastern region of the County. The GPS Coordinates for the area of study is approximately 2.3519349,35.608875. The area is known as the South Lokichar basin that forms the home of rich hydrocarbons, proved to be economically viable for exploration in the production of oil and gas. It is noteworthy that Turkana County is the second largest County in Kenya and has always been in the marginalized areas of Kenya. The land is partially arable due to unfavorable weather conditions, specifically characterized by scanty rains experienced annually. It receives on average of 373mm of precipitation per annum and an average temperature of 39.7^{0}C per year (Climate-Data.Org, 2022). The figure below shows the climate outlook for Turkana per month:

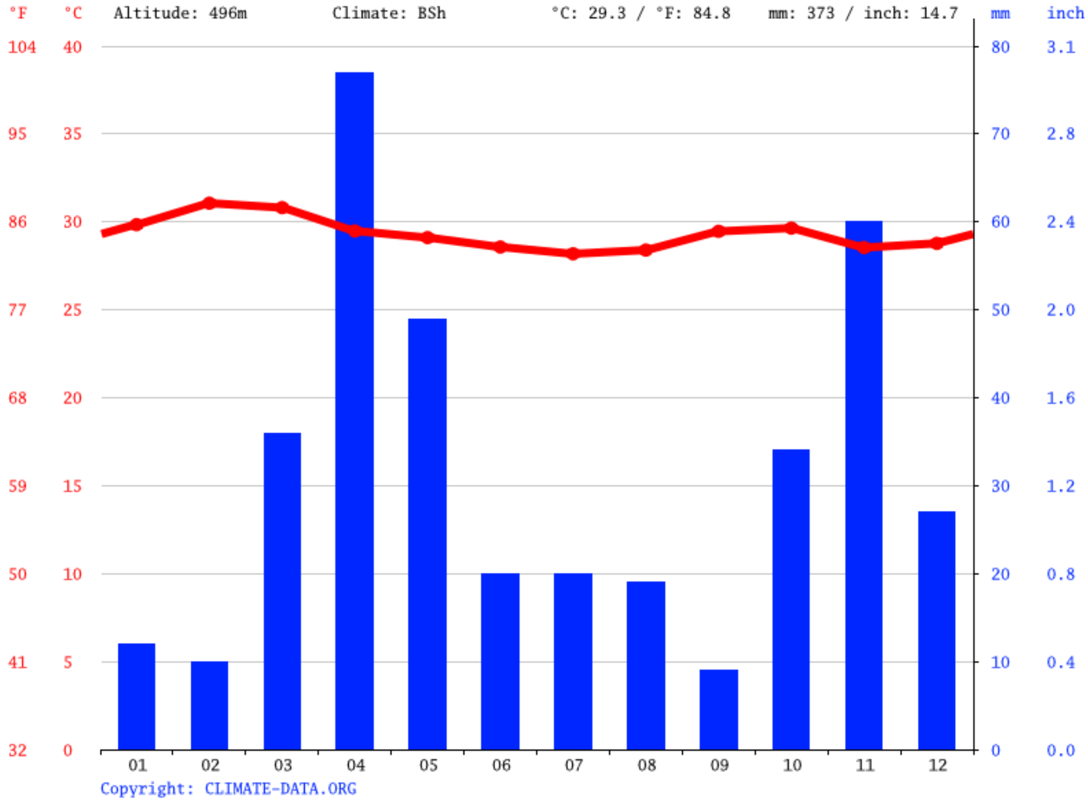

Figure 3. Climate Graph /Weather by month in Turkana, Kenya. Source: (Climate-Data.Org, 2022)

The community in this area is majorly nomadic pastoralists who rely entirely on livestock for their beef and milk. Some small-scale subsistence crop farming is done along the river shores on the west of the study area. Vegetables, maize, sorghum and watermelon are some of the crops grown in such areas.

This study was done in Turkana County in the South Lokichar basin where oil exploration and drilling has taken an active course, carried out by Tullow Oil Company. The South Lokichar covers approximately 1,085ha in the Turkana County, in north-west Kenya, approximately 450km north of Nairobi.

Figure 4. Map of Turkana County. Source: (Tullow Oil PLC, 2017)

The Amosing, Ngamia and Twiga fields forms the part of sampled well sites within 10BB and 13T of the South Lokichar Basin. The Ngamia-1 wildcat well was the first site that encountered oil in 2012. Twenty-eight wells have been successfully drilled and ready for extraction of crude oils within the area of study. The following is a map in figure 3.3 is showing the specific sites in block 10BB and 13T, where the research was being done.

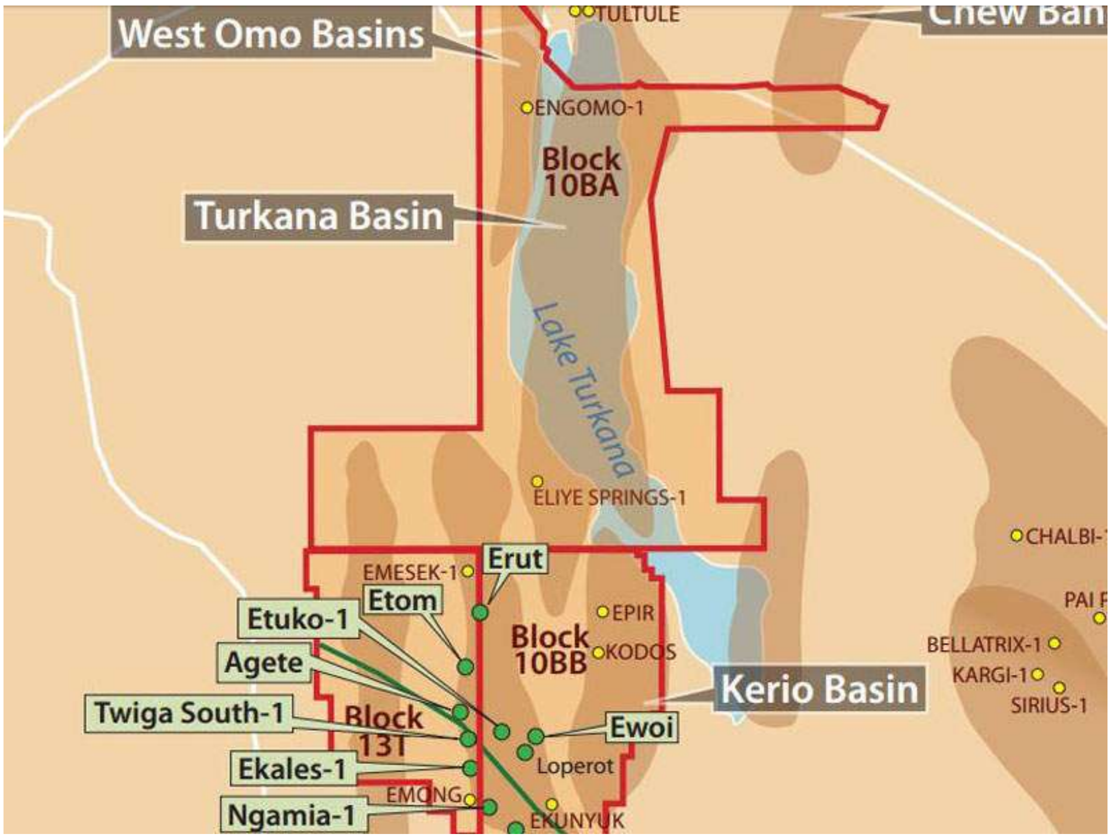

Figure 5. Map showing the research location area (Oil wells in Turkana County)
Source: (Verdict Media Ltd, 2022)

According to 2019 census, Lodwar County has a population density of 13 persons per square km. Lokichar Ward has a total population of 21,791 as per USAID and KNBS, 2019/20.

3.2 General Approach and Scope

This research was based on waste characterization approach. This is where waste is tracked from the cradle to the grave to analyze the characteristics in both nature and methods of handling. The legislative frameworks were also closely assessed to find out the relevance and compliance. Secondary sources of data have been widely used to enable the research to realize most of the objectives. Each of the objectives has been given a unique approach and has been handled in separate context. The research scope covered one rig site for primary data, which has been extrapolated to estimate the values and characteristics of the wastes from other rig sites and within a given period.

Drilling waste forms the focal point around which this research revolves, and this has been given close and informed study, by use of both secondary and the primary sources of data. The main objective was realized by drawing conclusions from the specific objectives of the study.

This research used both primary and secondary sources of data to gather information and compile the final deductions. Interviews by use of questionnaires were conducted among the key persons in the drilling field and the NEMA experts. Stakeholders of the project were also probed for their knowledge and opinion. The methodology is specific for each research question and the details are as follows:

3.2.1 Analysis of the hazardous waste

To attain this objective, the data of the waste collected from the rig site was sampled and studied against the set standards and description of hazardous waste as per the Kenyan waste management regulation, (GoK, 2016). The data obtained provided a window for classifying the waste and determining the proportions thereof. The data was obtained from the disposers of the said waste, by the authority of the key informant in charge of environment. Different types of waste were categorized into different classes depending on the source and way in which they have been derived. This was done using the schedule in Table 5.

Table 4. Waste streams at the drilling sites

Waste Stream	Quantity (Kgs/Ltrs)	% Quantity by mass
Wastewater		
Drilling Muds		
Used Chemicals and chemical containers		
Other field operations related waste		

3.2.2 Analysis of existing waste management systems used by the oil drilling company and identification of any operational gaps in meeting the legislated requirements

This was achieved using questionnaire (Appendix 2) administered on the drillers environmental department. Site visits and surveys also revealed the systems put in place in managing the hazardous waste in the exploration fields. The field-based results were closely analyzed against the existing regulations in Kenya that governs waste management in Kenya (GoK, 2016). A screen method was done to investigate the existing waste management methodology put in place by the drillers. This was done majorly through observation of the waste handling strategies from the generation to final disposal, for each identifiable category of waste as envisaged on this research proposal. The degree of performance was determined by the pre-set legal requirements. And scored to find out the level of compliance.

3.2.3 Reviewing the adequacy of the existing legal framework that governs hazardous waste management

A checklist was used to probe the adequacy of the existing regulations from the authority in governing the guidelines for hazardous waste management, especially with regards to oil and gas exploration. Similarly, a questionnaire was also administered upon the drilling company at the rig site. The secondary data obtained was also key in finding out the existing regulations, both local and multilateral and their adequacy in monitoring the waste management strategies. Daily practices with verifiable evidence were investigated alongside some major articles of the relevant legislations to find out the level of compliance by the oil explorers to such regulations. As such it was possible to gauge the impending impacts of the activities and identifying the existing gaps thereof, for making accurate recommendations. In this case, observation was used as the major tool for data collection and recorded as per Table 5.

Table 5. Screening tool for observation

S/No	Observable incumbent practices	Best practice required by the regulation	Performance scored in a scale of 10

The observable practices were screened against the legal requirements to determine the compliance level as per the Table 4 above.

3.3 Research Design and data collection

Purposive sampling was used where one active rig, Amosing_1 site was sampled to generate the data requirements, and then extrapolated with the number of rigs to obtain the overhaul impacts. These have been obtained from the key informants of the drilling company. Such data are used to obtain the direct and indirect impacts of the hazardous waste in the study area. Moreover, the regulatory framework to which oil and gas explorers are bound to, have been closely investigated. NEMA Kenya was also approached for data concerning the regulations and measures put in place to ensure sound management of the hazardous waste in the study area, and especially the waste from the rigs, to avoid future environmental liability.

The research used primary data heavily to achieve objectives 1, 2 and 3. One rig site (Amosing_1) was purposively sampled for the case study. This is following the assumption that the waste streams from the rigs are almost the same as activities and processes are identical. The Company man at study rigs was approached, who gave the required technical data to achieve the intended objectives. From the data, it was possible to identify direct, indirect, positive, and negative impacts of the waste from the drilling operations. The direct environmental impacts of the drilling waste are perceived to be manifested on the immediate ecosphere.

To achieve the third objective of this study, a checklist was used to ascertain the level of legal compliance and identify the gaps in the legal framework. The checklist was used to obtain data from the Contractor and from NEMA's website. Some multilateral agreements screened against the existing policies and practices to find out the level of compliance. The research structure can therefore be summarized as shown in table 3.0.3.

Table 6. Research structure data collection tool

Respondent	**Type of Data**	**Sample Size**	**Data Collection Tool**
Oil drilling company	Primary and Secondary data	1 Purposively sampled rig camps (Key Informant – EHS Rep)	**Interview/Questionnaire** **Checklist** Journals, publications and EIA reports for well site

At least two samples of the hazardous waste from the rig camps were also taken and classified using the waste management regulation 2016, to ascertain the risk level and thus the hazard identification of the said chemical waste.

3.4 Secondary Data

Secondary data have been obtained from the libraries in SEKU, UNEP, World Bank UoN and other e-resources such as journals and use of www.*googlescholar*.com Knowledge expansion was mostly possible by extensive reading on the rig waste from the available online resources. Technical data and case studies were purely done online, and the main focus remains the African cases.

CHAPTER FOUR

4.0 RESULTS

4.1 Characterization of the hazardous waste produced in the study area.

From the data collection methods discussed in Chapter three, it was possible to characterize the wastes into various classes, starting from the two broad categories that were further characterized to other smaller categories. This is shown below;

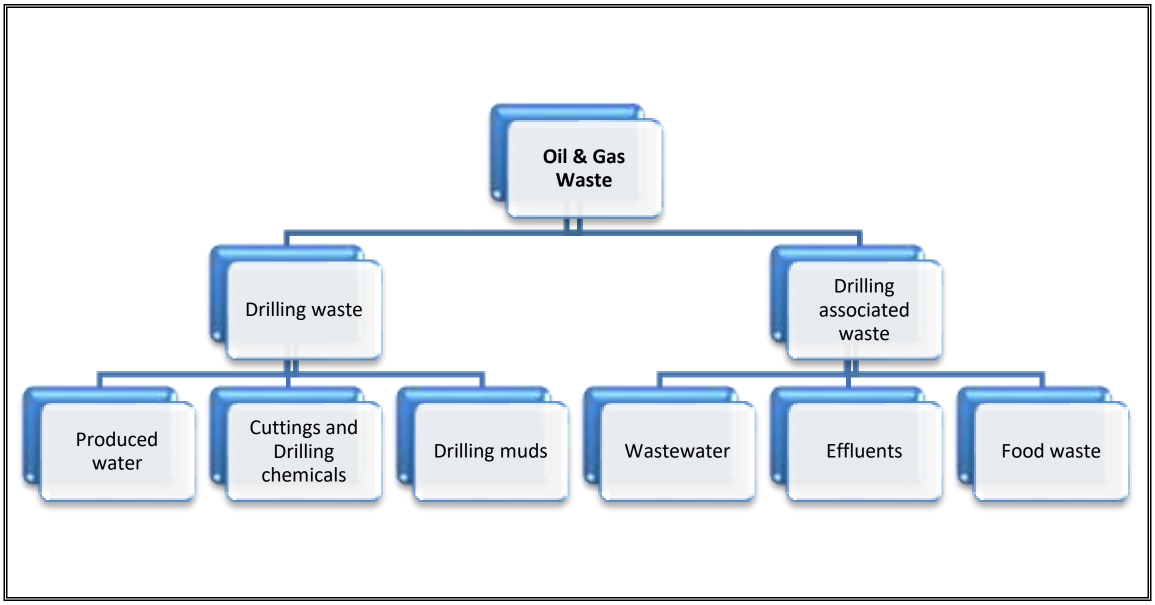

Figure 6. Waste Categories Characterised

4.1.1 Drilling waste

From the analysis of the waste produced by the oil drilling activities, it was possible to obtain the waste quantities and characteristics. The major areas of hazardous waste that were found include produced water, commonly known as silicate water, drilling muds, commonly known as cuttings and chemical waste from spills and used chemicals. Table 4.0.1 shows the proportions of these wastes as they are produced from the oil drilling activities.

Table 7. Waste Streams Proportions, Disposed, the Residuals and the Methods of Disposal

Waste Stream	Chemical Composition	Amount Produced in Kgs/Lts per week	% By Volume	Amount Disposed (Kg/Lts)	Residual Amount (Kg/Lts)	% Disposed	Disposal Method
Produced water (silicate water)	Na_2O_3Si	610,000	71.30	580,000	30,000	72.29	Evaporation
Drilling mud produced Oil (OBM)	Linear Apha Olefin (LAO), Polyalpha Olefin (PAO) and Internal Olefin (IO).	147, 000	17.18	132,000	15,500	16.45	Incineration / TDU
Drilling chemical waste	$C_{12}H_{24}$ $C_{14}H_{24}$ $C_{16}H_{32}$	24,000	2.80	19,500	4,500	2.43	Incineration
Produced oil	Carbon, Nitrogen, Oxygen & Sulphur	58,000	6.78	56,250	1,750	7.01	TDU
Others	Barite ($BaSO_4$	16500	1.93	14,600	1,900	1.81	Incineration

4.1.2 Other Drilling-Related Waste

Other functions of oil drilling also include camp operations and management, transport and other extramural activities. These functions also generate waste and may be associated with drilling operations, though indirectly. Such categories of waste include, grey and black water, sewerage/effluents, used oil from vehicles and machineries, and contaminated wood, construction waste (rubbles and cement), clinical waste. All these are under hazardous and/or biohazardous waste.

It is noteworthy that rig camps are usually very temporary and hardly last for more than 45days. During such periods, domestic and utility wastes are usually generated and must be properly managed to avoid epidemics of waterborne diseases. To begin with, there must be sufficient water to cater for the huge workforce in the rigs. Therefore, grey water, black water, food waste and clinical wastes emanate from the camps' activities. All these falls under the category of related waste and are still hazardous. The Table 8 below shows the amounts of different related wastes produced in one rig site having operated for four weeks:

Table 8. Amounts of associated wastes and disposal methods

Waste Stream	**Amount Generated in Kgs/Lts**	**% Proportions**	**Method of Disposal**	**Period of Generation (weeks)**
Black/Grey water	110,000	42	Bio-treatment	4
Sewerage/Effluents	81,000	31	Bio-treatment	4
General Non-hazardous solid waste	(Segregated)	N/A	Landfill	4
Used oil from vehicles and generators servicing	24,000	9	Incineration	4
Wood waste	8400	3	Charcoal/fuel	4
Plastics	6250	2	Recycling	4
E-waste	600	0.1	Incineration	4
Construction waste (Concrete, rubbles etc.)	35250	13	Landfills	4
Clinical waste	450	0.1	Incineration	4

4.1.3 Impacts of the waste

Different streams of hazardous waste have varied hazard levels. This is dependent on their rates of toxicity to human health, livestock, and wild animals, including the general environmental ecospheres. The EU classification hierarchy in Table 3 has been used to draw an analysis of the hazard levels of the different streams of wastes from the rigs. The following table shows the data received as far as the waste toxicity levels are concerned.

Table 9. Waste hazard levels analysis and Pollutants

4 – Carcinogenic 3. – Chronic 2. - Greenhouse effect 1. – Soil/ vegetation toxicity

Waste Stream	Hazard level (1-4 as above)	Pollutants present e.g. PCBs, heavy metals
Produced water (Silicate water)	2	Hydrocarbons
Drilling mud produced (OBM)	4	Hydrocarbons, heavy metals
Drilling Chemical Wastes	3	Barites, hydrocarbons
Produced oil	4	Hydrocarbons, metals

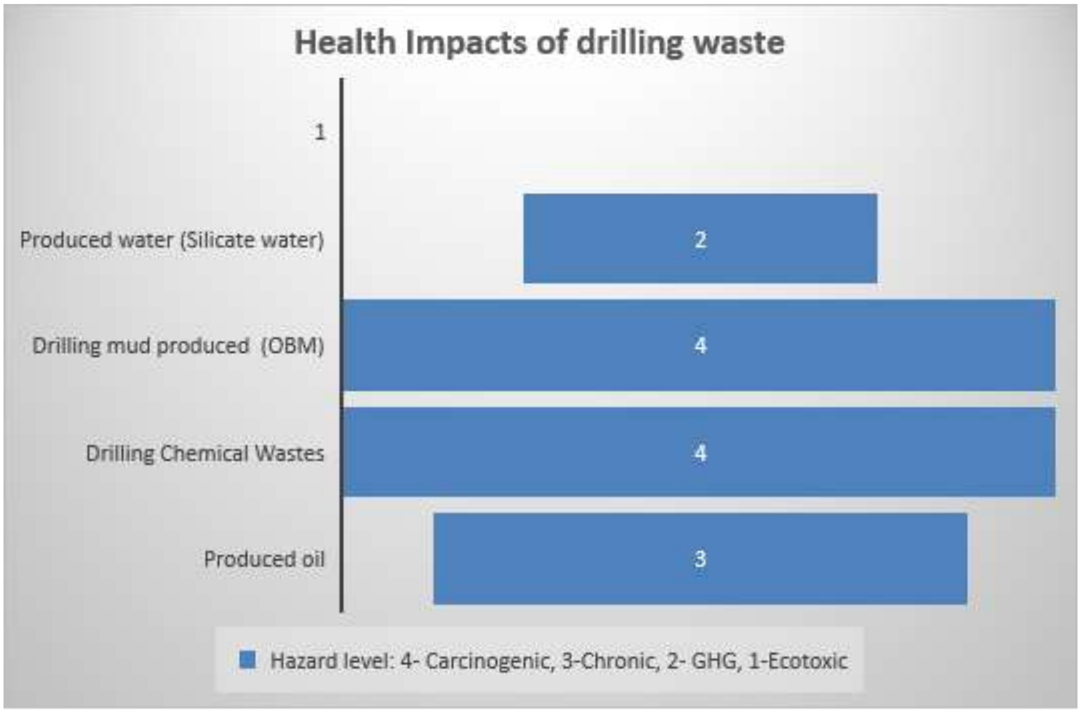

Figure 7. Health impacts of drilling waste

The classification above considers the highest impact of the specific waste stream, being carcinogenic, followed by chronic (waste that can lead to chronic diseases), then Greenhouse gases, followed by ecotoxic impacts. This classification considers the ease with which these impacts can be reversible or mitigated.

4.2 Legal and Regulatory Compliance

The main waste management regulation in Kenya, EMCA (NEMA, 2016) was used as a yard stick to measure the level of compliance. This was done through a rating checklist. The checklist was graded in a scorecard of 1-10, where 1 was the least compliance and 10 most compliance. The summation was converted into percentage. Other related regulations were also compared alongside this Waste Management Regulation, 2016. The scores produced the following results highlighting the major legal requirements met or otherwise as shown in Figure 8 below;

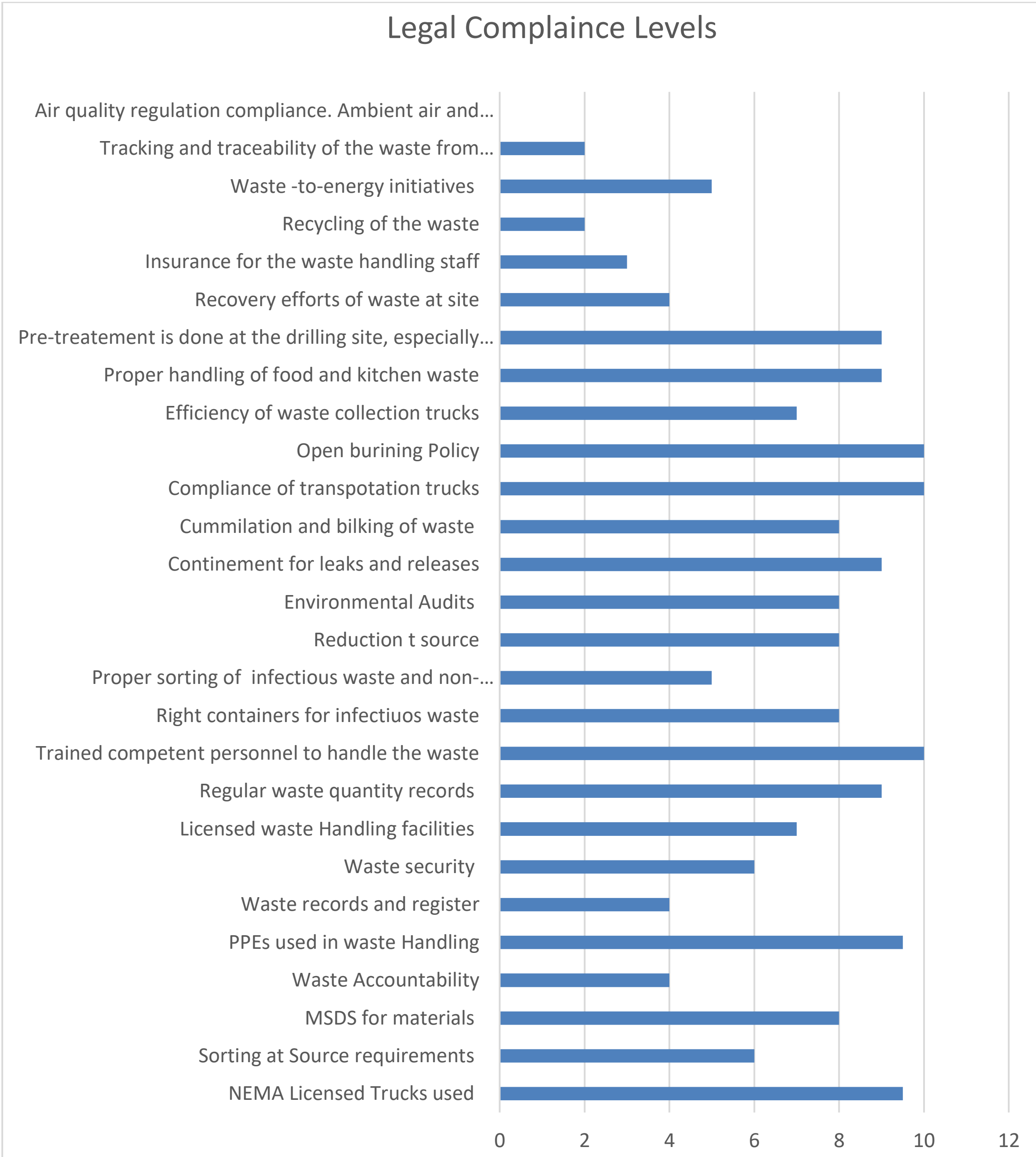

Figure 8. Level of Legal Compliance

CHAPTER FIVE

5.0 DISCUSSIONS

5.1 Discussion on proportions of waste generated from the rig sites

Table 1 illustrates that produced water forms the bulk of the hazardous waste produced. Every week, about 61,000 liters of produced water is discharged from the drilling process and translates to about 71% of the total waste produced during drilling process per rig site. The drilling operations at the site from which this data was obtained took four weeks to complete active drilling to a final depth of 1813meters (Tullow Oil PLC, 2017). This means that the total amount of produced water for the entire well is 2,440,000litres and contains sodium silicate as the active ingredient.

The mud produced from the drilling operations forms the second largest by volume. This is basically Synthetic Based Mud (SBM) as the preferred drilling mud used by the drillers. The study shows that the drilling mud constitutes 17% of the total hazardous waste in the drilling operations. This amounted to 147,000kgs by volume per week. This waste contains various chemical components with varying proportions, depending on the formulation of the drilling mud. This formulation is however dictated by the permanent rock structures at the well site. Nonetheless, the chemicals used tend to be similar in almost all the drilling fluids. These chemical components have been enlisted in the Table 7.

The next category of the drilling waste in the operations is the produced oil. This is generated from flaring and extends well tests processes. It formed 7% of the total hazardous waste produced in the processes. The 7% as per the chart is 58,000lts. The variations may be high, depending on the hydrocarbons in the deposits and the depth of the well at final drilling process.

The chemical waste forms 3%, while other chemical contaminated items and waste from chemical ills form 2% of the volume. Chemical wastes are majorly chemical spills, expired chemicals, and used chemical containers. The volumes are 24000kgs and 16500kgs respectively. The chart below shows the amounts of waste produced verses the amounts disposed as was observed and analyzed during field study work.

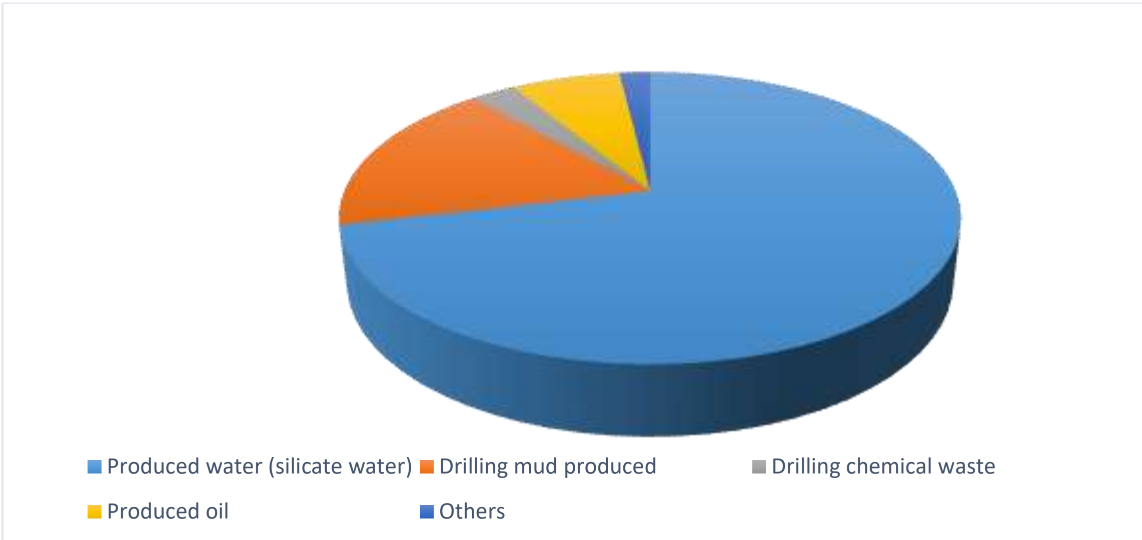

Figure 9. Proportions of Waste Generated

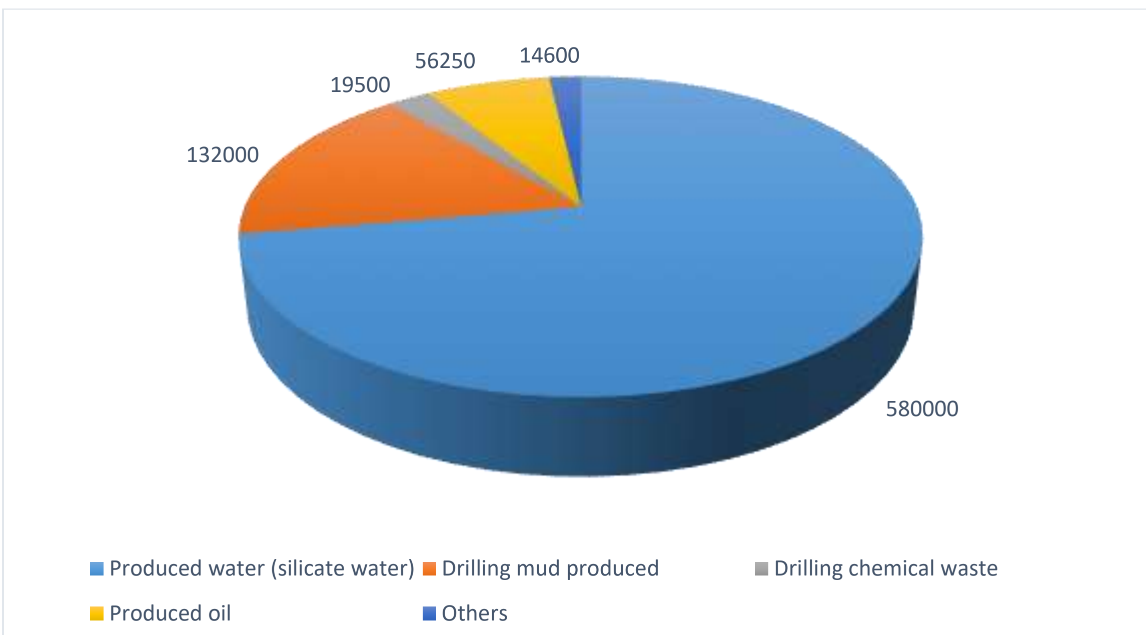

Figure 10. Proportions of waste disposed

5.2 Waste Disposed from the rig sites

The figure shows the proportions of waste disposed from the rig sites. The non-drilling wastes from the camp sites generated within a month, their methods of disposal and the respective amounts have been found out. It indicates that 6.27% of the total waste generated had not been disposed as at the end of the drilling process. These waste streams range from offices, which generate mainly E-waste like printing cartridges, electronic parts, cables, and A/C parts. The e-waste forms a fraction of the percentage of the total waste in this section. From vehicles and equipment maintenance emanates the used oils and filters. This forms 9% in the category of other related wastes. Wastewater can be seen to form the largest by volume in this category. This includes water from washrooms and cleaning activities. The amounts usually vary with the number of people staying in each camp per drilling session. The more the number of personnel, the more the amount of used water. Closely related to this is the sewerage/effluent from the toilets. These are considered as bio-hazardous waste. They can pose serious infection if not well managed in such scenarios.

Another category of hazardous waste is the construction waste or rubbles recovered from the construction concrete works. These are usually emanating from camp constructions and well pads. As much as they are not generated quite often, their volumes are usually high during camp decommissioning. They comprise 13% of the category of drilling-related wastes from table 4.2.

Contaminated plastics and wood wastes form 3% and 2% respectively by volume. These are mostly from items delivered in pallets, which include chemicals and engineering parts. Wooden pallets are used for loading of such goods on transit and are mostly discarded upon delivery, thus forming part of hazardous waste when contaminated with chemicals.

5.3 Toxicity of Waste

From figure 4.3, it is evident that the drilling chemicals and muds have the highest toxicity levels, followed by produced oil and water respectively. The waste at the top of the hierarchy has been denoted as 4 and has the greatest or most detrimental health impacts, with 1 denoting the least of the impacts. The greatest impacts are those with the potential to cause cancer, known as carcinogenic. Those with mild impacts may only intoxicate the soil, leading to nutrients toxicities and thus less soil productivity. Even though it was not tested, it was evident that some of the plants near well pads where leaks were experienced did not have very good stature.

5.4 Other Drilling-Related Waste

Other functions of oil drilling also include camp operations and management, transport and other extramural activities. These functions also generate waste and may be associated with drilling operations, though indirectly. Such categories of waste include, grey and black water, sewerage/effluents, used oil from vehicles and machinery, and contaminated wood, construction waste (rubbles and cement), clinical waste. All these are under hazardous and/or biohazardous waste.

It is noteworthy that rig camps are usually very temporary and hardly last for more than 45days. During such periods, domestic and utility waste is usually generated and must be properly managed to avoid epidemics. To begin with, there must be sufficient water to cater for the huge workforce in the rigs. Therefore, grey water, black water, food waste and clinical wastes emanate from the camps' activities. All these falls under the category of related waste and are still hazardous.

These waste ranges from offices, which produces mainly E-waste like printing cartridges, electronic parts, cables, and A/C parts. The e-waste forms a fraction of the percentage of the total waste in this section. From vehicles and equipment maintenance emanates the used oils and filters. This forms 9% in the category of other related wastes. Wastewater can be seen to form the largest by volume in this category. This includes water from washrooms and cleaning activities. The amounts usually vary with the number of people staying in each camp per drilling session. The greater the number of personnel, the more the amount of used water. Closely related to this is the sewerage/effluent from the toilets. These are considered as bio-hazardous waste. They can pose serious infection if not well managed in such scenarios.

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5.5 Existing Hazardous Waste Management Strategies

During the time of research, various strategies of waste handling and management were seen to be in place. The following section describes how various streams of waste were being managed and handled in the study area.

5.5.1 Drilling Mud

The strategies for managing this waste category in the area under study include Incineration, Thermal Desorption Unit (TDU) and Block making. During the drilling process these wastes are generated in terms of oil mixed with mud and drill cuttings. They may also contain spills of drilling chemicals and are usually deposited in the waste pit that is constructed next to the well bore. The entire process of cuttings and drilling waste production from the drilling line is illustrated in the Figure 11.

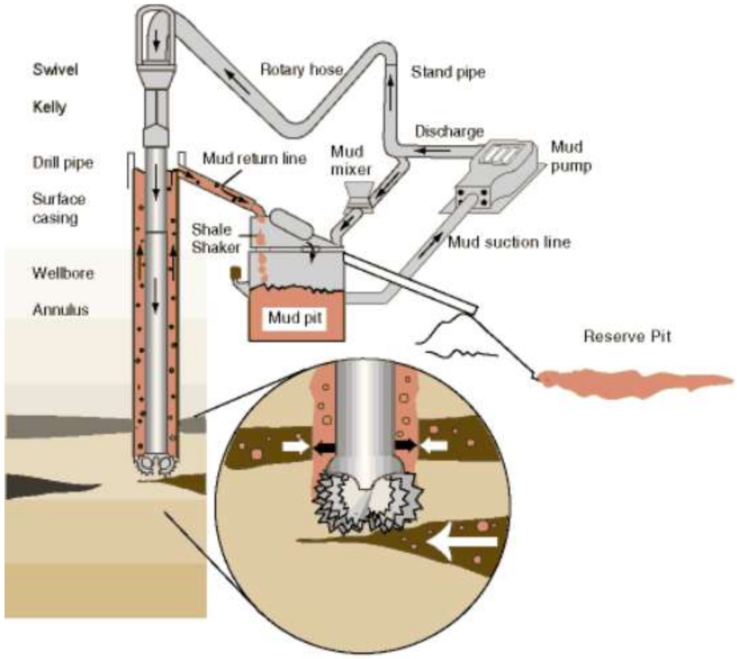


Figure 11. Production of mud waste. Source: (Tullow Oil PLC, 2017)

The pit is bunded with a High-Density Polyethylene (HDPE) liner. Therefore, it contains the sludge during the period within which the well drilling is on course. Cuttings that emanate directly from the well bore is collected in a containment next to this pit and transported daily to an accumulation site for processing and decontamination.

The cuttings are passed through a thermal desorption unit (TDU) which recovers the Oil Based Mud and dries up the cuttings to form a dry soil. Thermal desorption is the separation and recovery process resulting in three streams: water, oil and solid. The heating volatilizes liquid, and the vapor is cooled and separated into water-oil phases (Okeke & Obi, 2013). TDU technology is whereby the wet cuttings are heated indirectly to raise its temperature to around 400°C. This will vaporize the hydrocarbon components of the cuttings which can then be condensed in coolants to recover the oil. The oil is taken back for use in the drilling process. In other words, it is a way of recycling the oil-based drilling muds. The process lowers the cost of drilling and at the same time leaves the soil clean and free from hydrocarbons. The by-product soil can then be used for spreading on the roads, in farms and making building blocks.

As much as Thermal Desorption Unit (TDU) technology has not been fully incorporated in Kenya as a waste management technique, it could be one of the best options to use for treating the drill cuttings. Nevertheless, there are no regulations that govern the use of this technology in the country now.

The next step with the processed cuttings has not been established yet by the drillers. The drillers have engaged the services of a waste management company who have established a TDU to carry out this process to recover the drilling fluid and clean the cuttings. It is noteworthy that these cuttings can be rich in minerals such as calcium, ammonium and phosphorous and thus ideal for farming. They, however, may contain heavy metals such as cadmium, mercury and lead that may need to be tested and verified in thus absence. Therefore, until the specific contents of the cuttings are established through lab tests and approved by NEMA Kenya, they are not authorized for third party use.

The highly contaminated sludge and mud is usually taken up for incineration in a NEMA licensed facility. This ensures that all the hydrocarbons are destroyed, and major pollutants are broken down to less harmful states. This also includes the residual products of the TDU process. The drillers have obtained the services of a licensed company that deals with hazardous waste. This usually safeguards and removes such contaminated waste from the various sites for incineration and/or further safe treatment as deemed fit by the authority. Wider specs of waste are usually treated through this method to ensure proper disposal.

5.6 Produced Water (Silicate Water)

This is usually collected in silicate water pit during the drilling period. Large volumes of this water are left to evaporate in the air, leaving sediments to settle down. In cases where the produced water supersedes the pit capacity, which is often the case, then this water is transported in tankers made and labeled as ‘silicate water’ and transfer to specially made evaporation pits at waste management site designated for handling the drilling waste. The evaporation pits are wider and shallow depressions sunken slightly below the surface and lined with HDPE sheets, with sand berms circumference. With the high temperatures in the region, it is possible to evaporate thousands of liters of silicate water in these evaporation ponds each day. It is a cost-effective way of disposal and environmentally friendly, since the evaporating water is UV treated. This method, however, can have various disadvantages, as some harmful chemicals maybe volatilized into the atmosphere. These may pose various risks to the local community. This process is illustrated in Figure 12

Figure 12. Evaporation ponds filled with silicate water (left), and After evaporation of the silicate water (right)

The sediments that remain in the silicate pits and the evaporation pits are safeguarded and removed from the sites for incineration. The pits are then restored, whereby the liners are recovered, and the pits backfilled once the site is abandoned.

5.6.1 Chemical waste

These are harmful and not exceptional in this area of study. Thousands of tons of chemicals are used in the drilling process, and these have a lot of detrimental effects if not dealt with properly. During the study, it was noticed that all the spilt chemicals and their remnants of drilling were being clustered together in one segment and collected whenever the quantities were enough for a truck load. These were then collected and taken to a licensed site for waste disposal. The contracted disposer operates a high temperature incinerator that is licensed by NEMA to dispose of hazardous waste. Therefore, the wastes are collected and transported all the way to Nairobi, about 600Km for final disposal. The transporting vehicles were also licensed to transport hazardous waste from countrywide to the disposal facility. The process of safeguarding and loading these chemical and chemical containers waste is illustrated in Figure 13.

Figure 13. Chemical waste and the transporting truck

There were occasional chemical spills experienced. The spills were usually contained, and emerging wastes safeguarded for collection and disposal. The greatest here is that these spills could find their way to the pastures and consumed by the livestock. These could be harmful to both fauna and flora in the surrounding areas.

The other classes of waste are also disposed alongside these chemical wastes are the e-waste and clinical/biohazard wastes. The biohazard wastes are normally collected on regular basis from the clinics at the sites.

5.7 Drilling Associated wastes Management Strategies (Table 4.4)

Bulk of the related wastes is basically the effluents and waste waters. These are usually pre-treated through biological digesters. They are fabricated bio-boxes with cultured micro-organisms that help in breaking down the harmful organisms and materials in the effluents and sewerage. They also help in purifying the mix and clean water with acceptable parameters is released from these systems to the environment. This water is used to irrigate tress to compensate for the lost vegetation during site preparations. This water is also used to suppress dust on the roads for enhanced visibility for drivers while veering the roads.

The roads are usually graded seasonal roads that can be very dusty during the dry spell, which is normally the case. Concrete rubble from constructions is used to make roads as a blinding material. The contaminated ones are disposed of through the disposing contractor. Treated grey water is used to irrigate planted vegetation as a way of compensating for the lost vegetation during well pad construction. The figure 4.10 below shows an irrigated plant using treated grey water.

Figure 14. Effluent treatment bio-box (left) and vegetation irrigated by treated wastewater (right)

Scrape metals were taken to scrape yards, where they were eventually taken for recycling. The contaminated ones were sent to the licensed disposer.

Though non-hazardous waste, plastics have formed the largest non-drilling waste by volume. This is due to the fact that a lot of water is consumed, and the bottles collected per day are so enormous. With an average of five bottles per day per person, it simply means that 6000people will consume 30,000 bottles of 1litre of water. In cases where one liter and half liter bottles are used, then a total of 60,000 bottles are generated. This can fill a 6tonne truck each day. The company has contracted a non-hazardous waste management company to dispose these wastes at designated disposal sites. The water bottles menace was however ended when water igloos and water purifying plant was installed at the main camp. This means that every person was given an igloo and would fetch drinking water from the purifying plant at his own convenience. This is a reduction method of waste management.

5.8 Compliance to the local legal and regulatory frameworks.

The Waste Management Regulation, 2006 was used to screen the major activities regarding hazardous waste management at the study area to gauge the compliance level. The observable practices were compared against this regulation's requirements using a checklist and scored as shown in the table below. It also shows that the compliance level was rated at 66.43%. Other regulations that are closely related to this regulation were also compared alongside as per the degree of influence in each practice identified. The screening was done as per the ***Table 10*** below:

Table 10. Scores of practices against compliance level.

	Score of the major practices in regard to hazardous waste management against the requirements of the waste management regulation of Kenya, 2006. ***(Scale of 1-10, with 1 being least compliance and 10 being most compliance*)**		
S/No	Observable Practices	Regulations Requirement	Score against Waste Management Regulation, 2006.
	Average		6.643
	% compliance level		66.43%

EIA regulation of the EMCA1999 of Kenya requires that prior to every project, an Environmental Impact Assessment is done and to which a public participation is mandatory.

There was evidence that Environmental Impact Assessment (EIA) was done in the study area as was observed. During the EIA process, there was public participation to ensure the local community views were considered to mitigate the foreseen environmental impacts. Figure 4.10 shows a public participation session during an EIA process.

Figure 15. Public Participation Session (Source: Block 13 EIA Report)

The issue of health and safety under The Mining Act is regulated by the Mining (Safety) Regulations which prescribe rules relating to general precautions, surface protection, underground workings, winding and hauling, raising or lowering persons by mechanical power as well rules on ventilation and sanitation, workmen, explosives, machinery and mine plans as well as procedures in cases of accidents and incidents. At the study site, rigorous EHS system for risk assessments prior to any duty and stringent measures for emergency rescues have been established. Housekeeping procedures to keep workplaces clean and neat are also made mandatory by ensuring there are designated areas for litter and waste holding.

The Explosives Act, cap115 puts restrictions on the storage and possession of explosives. A permit is required to purchase and use blasting materials as well as to convey explosives within Kenya. An inspector of explosives may prohibit, or restrict the use of explosives in places where blasting may endanger life or property. The use or transport of explosives, in the working of a mine, quarry, excavation or other project is forbidden, unless an explosives manager has been appointed and the inspector notified in writing. The explosives manager is responsible for the safety and security of all explosives used, transported or stored, until they are handed to the blaster for use. During this study, it was identifiable that Kenyan Police personnel is appointed as an explosive's inspector, who oversees the use of explosives which are stored and transported as per the OGP regulations and the explosives Act, cap115 of Kenya.

The Kenyan Occupational Safety and Health Act, No. 15 of 2007 legislation applies to all workplaces. Every occupier must ensure the health, safety, and welfare at work of all the people working in his workplace as well as protect other people from risks to safety and health occasioned by the activities of his workers. The occupier's duty to ensure the safety, health, and welfare of all persons at work in his premises includes providing a working environment and work procedures that are safe. The likely emission of poisonous, harmful, or offensive substances into the atmosphere should be prevented, and where such incidents occur, they must be rendered harmless and inoffensive. Machinery, protective gear, and tools used in all workplaces must comply with the prescribed safety and health standards. Dust, fumes, or impurity must not be allowed to enter the atmosphere without appropriate treatment to prevent air pollution or harm of any kind to life and property. There was a certificate of workplace registration for the study site, annual audits were also done, and this served as a proof for some level of compliance to this regulation.

The National Museums and Heritage Act, Cap. 216 assert that the Minister may prohibit or restrict access or any development, which in his/her opinion is liable to damage a monument or object of

Archaeological or paleontological interest there. All antiquities lying in or under the ground, or on the surface of any land protected under the law as a monument, or being objects of archaeological, paleontological, and cultural interest are the property of the Government (Sections 25, 34, 35, 46). This statute relates to the disturbance of, and interference with, sensitive cultural, natural heritage and archaeological sites. At the study area, it was observed that consultative meetings with officers from the Kenya Museums to identify and map the areas of national heritage were done prior to the activities. These were safeguarded and protected against human interference. ***Figure 16*** shows such protected artifacts that were discovered during field study.

Figure 16. Paleontological artifacts from Turkana region

Section 115 part (b) of the ***Water Act*** states that, no person shall without authority under this act, throw or convey, or cause or permit to be thrown or conveyed, any rubbish, dirt, refuse, effluent, trade waste or other offensive or unwholesome matter or thing into or near to any water resource in such manner as to cause, or be likely to cause, pollution of the water resource. From the study, a contractor is involved who treats the biological effluents before they can be discharged into the environment. Moreover, these are tested in accredited laboratories to confirm if they meet the required standards for discharging.

Section 89 of ***The Wildlife Act, 2013*** states that, any person who discharges any hazardous substances or waste or oil into a designated wildlife area contrary to the provisions of this Act and any other written law; pollutes wildlife habitats and ecosystems; discharges any pollutant detrimental to wildlife into a designated wildlife conservation area contrary to the provisions of this Act or any other written law, commits an offence and shall be liable upon conviction to a fine of not less than two million shillings or to imprisonment of not less than five years or to both such fine and imprisonment. The study has shown some commitment of ensuring that waste is not spilled to the wildlife ecosphere situated closer to the oil fields. The drillers carry out green days every Sunday, where all the personnel are charged with the responsibility of collecting any discarded waste in the natural ecospheres. **Figure 17** shows accumulated waste collected and safeguarded, waiting for transportation and final disposal. From the observable practices, it was not clear how the waste was traced to ensure no bit spills into the ecosphere.

Figure 17. Safeguarded waste, awaiting transportation

Generally, whether the practices were compliant to various local regulatory requirements or not was summarized in the ***Table 11*** below, as a checklist:

Table 11. Local regulatory compliance checklist

	National Regulation	Compliance *(Tick as appropriate)*	
		YES	NO
	The Kenyan Constitution	√	
	EMCA Act 2015	√	
	Occupational Safety and Health Act, Regulation 2007	√	
	Waste Management Regulation 2006	√	
	Turkana County laws and by-laws on Waste Management	√	
	The Wildlife (Conservation and Management) Act, Cap. 376	√	
7.	The National Museums and Heritage Act, Cap. 216	√	
.	The Land Act, 2012	√	
9.	The Petroleum Exploration and Production Bill 2014		√
10.	The Water Act, 2012	√	
11.	Mining Bill 2014	√	

The relevance and compliance level to the above legal concepts were investigated through a checklist and weighed against the critical mandatory required aspects of the statute. The level of compliance has been provided for in the results area. The same results have been discussed above and summary given in ***Table 11.***

CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

During the study, there were critical findings that need to be put into further critiques and study to ensure the safety and environmental sustainability in enhanced. The study recognized a critical gap in the legal framework and conflict of the same. It was possible to characterize the waste into two categories: drilling waste and drilling associate wastes. The drilling waste comprised of cuttings, produced water which is the highest by volume and well maintenance chemicals. The associated waste comprise of chemical packaging, office and kitchen waste and effluents from washrooms. For all the classes of waste identified, it was also possible to determine the methods of disposal for each category. It was also noticeable that the waste produced was not disposed of with 100% efficiency.

This means that traces of the waste would still find their way into the ecosphere and cause environmental liability. It was not easy to verify that the methods of disposal involved were sufficiently effective to enhance proper disposal and the cradle to grave approach of waste disposal as envisaged in the waste management regulation of 2006. Segregation was well done, but not all the waste were being collected for disposal. The worst affected streams of waste were the drill cuttings. It was not possible to ensure 100% collection and disposal of the cuttings, and the associated chemicals thereof. Some of the methods of disposal included evaporation where liners were used to evaporate the silicate water, then the residue slats were being collected, safeguarded and transported for disposal. This had a weakness, since the domestic animals could access these evaporation ponds and drink the silicate water which is highly poisonous. The liners could also get perforated leading to silicate water leaking and seeping into the arable land, proving hazardous to the natural environment. Sometimes, the local community would complain of their livestock being poisoned from such incidents, but the study was not able to scientifically demystify such claims.

Whereas there exists a national legal frame that governs the waste management strategies within the oil and gas sector, there was evidence of lack of institutional coordination for implementation of these frameworks. Moreover, there were conflicts between the implementers at the county level and the national institution that is meant to coordinate the enforcement, since the study was done at a time when waste management function was being devolved to the county governments. The scope of each side of the devolvement arrangements was not expressly clear and may need further interrogation.

The area of study was a new venture in the country Kenya that has been exhausted in terms of literature within the nation. It is noteworthy that that as much as oil and gas exploration has never been done in Kenya, the main environmental issues that affect the sector worldwide remains constant. The only great difference is that there have never been specific regulations that are put in place to safeguard the environment from pollution by the waste from drilling operations.

The findings here were based on one well site where synthetic based mud was used in the drilling process. These are usually easy to recycle and reuse, and thus reduce the cost of drilling. Moreover, the phases of oil and gas extraction are normally categorized into; exploration, appraisal, drilling, extended well tests and production. At each of these stages, different classes of waste are usually produced and in different proportions. The results presented in this research are mainly based on the drilling phase of the cycle. However, this is deemed to be the most critical stage where the highest amounts of waste are produced. The previous and subsequent stages may not yield as much waste as have been seen in this stage. However, it is expected that a lot of hydrocarbon waste may be produced during the production stage.

6.2 Challenges facing drilling waste disposal

The drilling wastes are usually very voluminous and high risks in terms of chemical composition. This makes it a complex issue to handle. They remain a great challenge to the oil and gas industry all over the world and must be handled with a lot of caution. From the research, it was revealed that the cost of transporting and disposing a kilo of hazardous waste in approximately KShs. 100. Therefore, to dispose adequately the drilling muds and the chemical wastes the drillers require at least KShs. 68,850,000. This excludes the produced water which is still evaporated at the evaporation pits and the sediments still incinerated. This may pile up financial burden as far as the waste management is concerned for the drilling waste.

The waste disposal site is about 700Km away from the drilling sites and this also raises the cost of disposal. The risk of spills is also high due to the distance. The road to and from the drilling sites are also dilapidated and the trucks experience difficulties in accessing these sites. Some uncertified waste handlers have also attempted to make their way into the rigs and collect waste with doctored documents. There is no government site where hazardous waste is disposed or treated. Climatic factors also influence the waste management a great deal in this region. This is because when it rains, the waste pits are usually filled such that the level of the sludge is greatly increased. This helps to increase the cost of disposal. During the dry spell, the pits dry faster, and the remaining sludge can be easily scooped and transported for disposal.

The waste pits also pose risk to wild animals and birds. When these access the site, they would strive to drink this contaminated water, and this causes them to slide into the pits and drown. Swarms of insects have been trapped into these water pits and lost. Reptiles like snakes and lizards which are numerous in these places have also been found struggling to get out of these pits after falling in. This means that biodiversity is greatly affected due to the waste pits.

The legislative frameworks that exist in the country are not adequate in the management of oil and gas drilling waste. There is no specific regulation that has ever been enforced to guide the drillers on how to manage the waste from these sites. This means that initiatives that have been put by the drillers are mainly from the codes of practice by the drilling parties. There is need for clear guidelines for site commissioning and decommissioning.

The environmental effects of oil spills and gas flaring could be damaging to communities near oil extraction, and this could put communities in conflict with oil companies who are often accused of destroying the environment. This has the potential of disrupting oil operation. Again, spills and flaring of gas adversely affect livelihoods.

Both the state and oil companies are at risk of losing substantial revenues during oil spills because of committing large number of resources to compensate affected communities. Compensation against damage or pollution from spills could run into several millions of dollars in a lifetime. This is why a "preventive policy" is preferred to a "response policy". It is important to mention however that, Kenya's environmental laws and regulations have not been updated yet to address oil-related environmental challenges. Also, Kenya's environmental institutions have limited capacity to deal with both onshore and offshore oil waste and other environmental hazards. The capacity challenge ranges from training deficits to logistics constraints.

The only way to mitigate land and environmental risks is to ensure that local community groups participate meaningfully in investment decisions and project development via the implementation of well-thought-out community engagement processes.

With over three million kilos of waste to dispose of, it simply becomes expensive for the drilling company to manage. Note that this is only based on one well site. The drilling process now takes one month to complete one well, and thus approximately 3million kilos of waste is produced every month. So far, over twenty-seven wells have been completed and this extrapolates to about 81 million kilos of waste. Nevertheless, there is never a debate on where to dispose of it as the regulations must be followed to the latter.

Before the waste disposal method to be used is established, several factors influence the decision and these include and not limited to; financial implication, waste type, toxicity level of the waste material, available technology, and the legal requirements to dispose the specific waste stream.

6.3 Recommendations

During the research there were environmental issues that were pointed out which need actions to ensure sustainability in terms of resources development. These were related to waste management and the hazardous materials handling during oil and gas extraction process. The following recommendations have been suggested by the research to close the gaps identified in the study area.

The government through the ministry of environment and natural resources development should draw regulations that guide disposal of oil and gas production-related wastes. Clear guidelines that state commissioning and decommissioning requirements must be drawn in such regulations and rules and gazette in the Kenyan laws.

Waste disposal facilities that can handle all sorts of hazardous waste should be put up by the government through private public partnerships to increase the capacity of waste disposal and avoid the risk of inappropriate disposal. These should be placed in every county to avoid inter-county movement of the hazardous waste, and only allow the small amount that must be transferred to major disposal facility.

The oil drillers need to work closely with the government agencies in charge of the environment to protect the natural heritage and collect the artifacts found on drilling sites. This research found out that there was community engagement in public participation before the explorations were done. The 3Rs (Reduce, Reuse, Recycle) of waste management should be utilized to reduce the cost of waste management.

The existing legal frameworks need to be institutionalized to ensure keen follow-up for compliance. There needs to be further study to decipher whether the chemicals waste have any direct health impact on the local community and livestock. This means sampling of soil and water around the areas of operation to carry out lab tests and analyses to determine the effects and the impacts.

REFERENCES

Adipepe, A. (1991). The Making of the Nigerian environment policy. *International Workshop on the Goals and Guidelines on National Policy for Nigeria* (pp. 1-329). Lagos, Nigeria: Federal Environmental Protection Agency.

Amoasah, G. (2010). *The Potential Impacts of Oil and Gas Exploration and Production on the the Coastal Zone of Ghana.* . Accra, Ghana: Wegenigen University.

APHA. (2018, November 13). *American Public Health Association website*. Retrieved from Apha.org: https://www.apha.org/policies-and-advocacy/public-health-policy-statements/policy-database/2019/01/28/impacts-of-unconventional-oil-and-gas-industry.

Bashat, H. (2002). *Managing Waste inExploration and Production Activities of the Petroleum Industry. Environmental Advisor.* LAgos, Nigeria: SENV.

Carson, P., & Murmford, C. (2005). *Hazardous Chemicals Handbook.* Amsterdam: Oxford.

Climate-Data.Org. (2022). *Climate-Data Website*. Retrieved September 15, 2022, from www.climate-data.org: https://en.climate-data.org/africa/kenya/turkana-1669/

Commission, E. (2006). *Intergrated Pollution Prevention and Control* . New York: European Union.

D.W, W. (2011, December). *Openoil Website.* Retrieved March 17, 2015, from www.openoil.net: http://openoil.net/wp/wp-content/uploads/2011/12/Chapter-2-reading-material.pdf.

Durasaimy, R., Heyadi, B. A., & Amir, H. (2013). *Intech International Website.* Retrieved 2 4, 2015, from www.intechopen.com: http://www.intechopen.com/books.

Enviromental Agency. (2006). *Treating Waste by thermal desorption* . London: Environmental Agency.

Environment Agency. (2008). *Treating waste by thermal desorption.* Bristol: Environment Agency -UK.

EPA. (2013). *Hazardous Waste Interpretation of the definition and classification of hazardous waste* . New York: EPA.

GoK. (2010). The Kenyan Constitution, 2010. In T. N. Kenya, *The Contitution of Kenya, 2010* (pp. 69-70). Nairobi: Government Press.

GoK. (2016). *Environmental Management and Co-ordination (Waste Management) Regulation.* Nairobi: GoK Press.

Holdway, D. (2002). *The acute and chronic effects of wastes associated with offshore.* New York.

Hosam, E.-D., Saleh, M., Rehab, & Rahman, A. (2016, October 19). *www.intechopen.com*. Retrieved January 22, 2022, from https:www.intechopen.com: https://www.intechopen.com/chapters/51380.

Kibwage, J. (2002). Integrating the Informal Recycling Sector into Solid Waste Management Planning in Nairobi City. PhD Thesis. *American Journal of Environmental Protection*, 96-101.

Nagy, C. (2002). *Oil Exploration and Production Waste INitiative* . Carlifornia : Environmental Protection Agency.

NEMA. (2006). *Waste Management Regulation.* Nairobi: Kenya Gazette.

NEMA. (2016). *Kenya Waste Management.* Nairobi: NEMA.

Nwakaudu. (2012). Drilling Wastes Generation and Management Approach. *International Journl of Environmental Science and Development Vol.3, No.3*, 252-257.

Okeke, P. N., & Obi, C. (2013). Treatment of Oil Drill Cuttings Using Thermal Desorption Technique. *ARPN Journal of Systems and Software*, Vol 3, No.7.

Reiss, J. (1996). *Environmental Control in Petroleum Engineering.* Houston, Texas: Gulf Publishing Company.

Shariff, A., & al, e. (2017). Drilling Waste Management and Control the Effects. *Journal of Advanced Chemical Engineering*.

Smith, P. G., & Scott, J. S. (2005). *Dictionary of water and waste Management* . Oxford: Elsevier.

Tullow Oil PLC. (2017, May 17). *Google.com*. Retrieved January 22, 2022, from tullowoil.com: https://www.tullowoil.com/our-operations/africa/kenya/.

UNEP. (2000). Basel Convetion on The Control of transboundary movement of dangerous goods. *Basel Convention* (pp. 85-100). Geneva: United Nations.

UNEP. (2010). *Sustainable Development* . New York: United Nations .

UNEP. (2022). *Caribbean Environment Programme*. Retrieved 03 30, 2022, from www.unep.org: https://www.unep.org/cep/heavy-metals.

Va'zquez -Luna, D. (2014). *Chronic toxicity of weathered Oil-contaminated Soil.* New York: Intech.

Verdict Media Ltd. (2022). *https://www.hydrocarbons-technology.com*. Retrieved from Hydrocarbons-technology Website: https://www.hydrocarbons-technology.com/projects/south-lokichar-development/

World Bank. (2007). *Environmental, Health and Safety Guidelines* . New York: World Bank Group.

APPENDICES

Appendix 1: Checklist for Legal and Regulatory Framework

	National Regulation	**Compliance** *(Tick as appropriate)*		**Unilateral Environmental Conventions**	**Compliance** *(Tick as appropriate)*		**Reasons for Non-compliance**
		YES	NO		**YES**	**NO**	
1.	The Kenyan Constitution			OSPAR 1992			
2.	EMCA Regulation 1999			Kuwait 1978			
3.	OSHA Regulation 2007			UNCLOS 1982			
4.	Waste Management Regulation 2006			EMEP 1994			
5.	Turkana County laws and by-laws on Waste Management			UNEP (drilling muds)			
6.				UNEP(Oil spills)			
7				Biodiversity Convention			
8.				Montreal Protocol			
9.				Basel Convention			
10.				Helsinki 1992			
11.				UN Law of the sea			
12.				UNEP Law for cleaner Production			
13.				Framework Convention on Climate Change (UNFCC)			
14.				Convention on Migratory Species			

Appendix 2: Oil drillers' Questionnaire

Drillers' Questionnaire

General Information			
Respondent:		Position:	
Date:		Site:	
Duration of Camp/Drilling operation (Weeks)			

Drilling Waste

Kindly provide the waste volumes produced by the drilling operations for at least one well site:

Type of Mud used: SBM { } OBM { } WBM { }

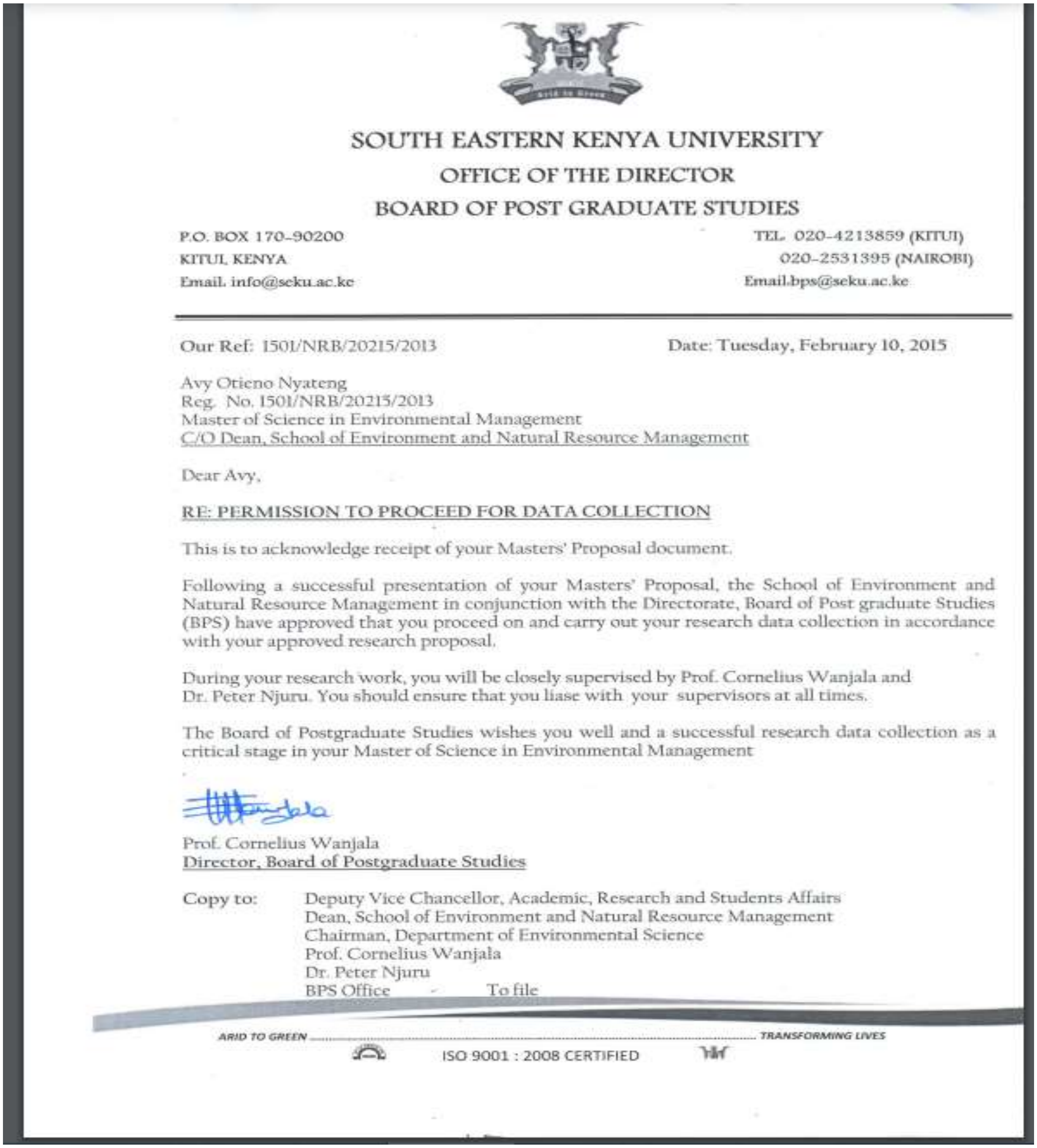
Waste Stream	**Amount produced in Kgs/Ltrs/Week**	**Amount disposed**	**Method of disposal**	**Residual Amount (Kgs)**
Produced water (Silicate water)				
ii. Drilling mud produced				
iii. Drilling Chemical Wastes				
iv. Produced oil				
v. Any other (Specify)				

Table 12. Waste Produced Schedule

Hazard Levels analysis for the waste				
Kindly rate the waste rate the hazard level of the waste in terms toxicity to both health and environment. Use the classification below: **1 – Carcinogenic 2. – Chronic 3. - Greenhouse effect 4. – Soil/ vegetation toxicity**				
Waste Stream	**Hazard level (1-4 as above)**	**Pollutants present e.g. PCBs, heavy metals**	**Recyclable/ reusable/ alternative benefit**	**Remarks e.g. counter benefits**
Produced water (Silicate water)				
ii. Drilling mud produced				
iii. Drilling Chemical Wastes				
iv. Produced oil				
v. Any other (Specify)				

3. Other related waste				
Kindly provide the waste volumes produced by other related drilling operations for at least one well site: i.e. Camp management and vehicles related waste				
Waste Stream	**Amount produced in Kgs/Ltrs/Week**	**Amount disposed**	**Method of disposal**	**Period of production**
Produced water – grey water/ black water				
Sewerage/Effluents				
iii. General non-hazardous solid waste				
Used oil from vehicles and generators servicing				
v. Wood waste				
vi. Plastics				
vii. E-waste				
viii. Construction waste (concretes, rubbles, etc)				
ix. Any other (Specify)				
Kindly comment briefly on the environmental liability expected to emanate from these waste				

Appendix 3. Letter of authorization to collect Data



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Our Ref: 1501/NRB/20215/2013

Date: Tuesday, February 10, 2015

Avy Otieno Nyateng
Reg. No. 1501/NRB/20215/2013
Master of Science in Environmental Management
C/O Dean, School of Environment and Natural Resource Management

Dear Avy,

RE: PERMISSION TO PROCEED FOR DATA COLLECTION

This is to acknowledge receipt of your Masters' Proposal document.

Following a successful presentation of your Masters' Proposal, the School of Environment and Natural Resource Management in conjunction with the Directorate, Board of Post graduate Studies (BPS) have approved that you proceed on and carry out your research data collection in accordance with your approved research proposal.

During your research work, you will be closely supervised by Prof. Cornelius Wanjala and Dr. Peter Njuru. You should ensure that you liase with your supervisors at all times.

The Board of Postgraduate Studies wishes you well and a successful research data collection as a critical stage in your Master of Science in Environmental Management

Prof. Cornelius Wanjala
Director, Board of Postgraduate Studies

Copy to: Deputy Vice Chancellor, Academic, Research and Students Affairs
Dean, School of Environment and Natural Resource Management
Chairman, Department of Environmental Science
Prof. Cornelius Wanjala
Dr. Peter Njuru
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Appendix 4: Certificate of Manuscript publishing

Certificate No: PUB. 2021/AJEE/77438

Asian Journal of Environment & Ecology

Certificate of Publication

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Appendix 5: Plagiarism Check results

Nyateng-CHARACTERIZATION, ANALYSIS AND REVIEW OF HAZARDOUS WASTE MANAGEMENT IN OIL DRILLING FIELDS IN TURKANA

ORIGINALITY REPORT

24%	24%	7%	11%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

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