Available at www.ijsred.com

RESEARCH ARTICLE OPEN ACCESS

An Outlook of Oil and Gas Drilling Operations in Kenya – Trends and Challenges

Antony Fundia Simbiri[1], Ogbonna F. Joel[1a], Emmanuel E. Okoro[2], Daniel O. Oyoo[3]

[1]World Bank Africa Center of Excellence, Center for Oilfield Chemicals Research, University of Port Harcourt, Port Harcourt, Nigeria

[1a]World Bank Africa Center of Excellence, Center for Oilfield Chemicals Research, University of Port Harcourt, Port Harcourt, Nigeria

[2]Department of Petroleum Engineering, [1]World Bank Africa Center of Excellence, Center for Oilfield Chemicals Research, University of Port Harcourt, Port Harcourt, Nigeria

[3]Department of Gas and Petroleum Engineering, Kenyatta University, Nairobi, Kenya

Email address:

simbiri.anthony@ku.ac.ke (A. F. Simbiri),

--************************----------------------------------

Abstract:

After finding oil reserves in 2012, Kenya is now one of the world's top aspiring suppliers of crude oil. There are extremely high hopes for this discovery among all the interested parties, and this has sparked unparalleled interest both domestically and abroad. However, a careful examination and assessment of the nation's anticipated socioeconomic developments are required. Therefore, the purpose of this essay is to investigate and evaluate the drilling division of Kenya's upstream oil and gas industry. It examines the history, current state, potential future of drilling in the oil and gas sector. So as to accomplish this goal, the essay begins by outlining Kenya's historical examination of oil and gas operations, the legal environment surrounding drilling operations, and the drilling operations themselves. Additionally, definitions, types of drilling fluids, and drilling additives are discussed. Finally, the article evaluates the outstanding issues facing oil and gas drilling operations in Kenya and provides the required guidance for its prospective growth.

***Keywords* —** Additives, Drilling, Lokichar, Ngamia, Petroleum Act 2019, Rift Valley tertiary basin, Waxy crude oil.

--************************----------------------------------

1. Introduction

1.1. Oil and Gas Operations in the World

Operations involving gas and oil are very important to the world economy. Oil is the primary fuel used worldwide, making up around one-third of the energy consumed globally, [1]. According to the BP Energy Outlook for 2017, the global economy will increase by 3.4% annually over the next 20 years, with China and India being the main drivers of this expansion. Despite the expansion of renewable resources, oil, gas, and coal will still supply more than 755 of the world's energy needs in 2035. Demand for oil will increase from 94.4 million barrels per day in 2015 to 100 million barrels per day in 2021, while gas will surpass coal as the second-most popular fuel source by the year 2035 with an estimated growth of 1.6%[2].

While many developing and developed nations rich in hydrocarbon resources continue to rely on this sector for growth and revenue, the entire global economy holistically relies on fossil fuels. From the sunny and dusty deserts of the Middle East, and the frozen permafrost regions of Russia, to the deep waters of the Gulf of Mexico and the stormy weather, tossed the North Sea near the Arctic, oil and gas companies globally are tirelessly quenching the ever-growing energy thirst of the world. That oil and gas fuels have been the engine of commerce since the industrial revolution is a well-known fact. The upstream, middle, and downstream operations of the oil and gas sector, which also includes exploration, drilling, production, refining, transportation, marketing, distribution, and consumption, make it one of the most strategic and complicated industries in the world. Of late, however, climate change seems to be the waterloo of the fossil fuel industry, with it being blamed for contributing hugely to greenhouse gases, (EIA, 2016).

1.2. Oil and Gas Operations in East Africa

East Africa is already beginning to emerge as one of the continent's significant participants in the fossil fuel's sector after years of operating in West and North Africa's shadow. Huge gas discoveries offshore Mozambique and Tanzanian together with huge oil discoveries around Lake Albert in Uganda have significantly changed economic attitudes about East Africa, altering it into an attractive destination for extractive industry investments.

Figure 1 shows the quantity of oil wells dug in East Africa or from 2000 to 2015.

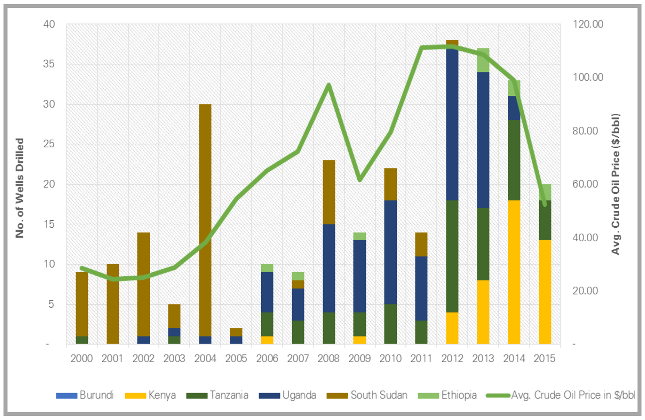

Figure 1. The quantity of wells drilled annually in East Africa (2000 – 2015). (Source: BP Statistical Review 2015, Wood Mackenzie)

1.3. Oil and Gas Drilling Operations in Kenya

The British colonialists started exploring for gas and oil in East Africa in the early 1930s, but they faced many obstacles until finding the first few oil wells in the 1990s [3]. Shell and BP were the leading companies in Kenya's initial wave of oil prospecting. Mandera in the East, Lamu in the South-east, Anza in the North, which is both offshore and onshore, and the Tertiary Rift basin in the North-West were detected by seismic studies, gravimetric surveys, and aeromagnetic surveys. The second wave of explorations started in 1985, the year Kenya passed its Petroleum Act. With a combined total of 15 wells, Total and Amoco took the lead. They concentrated on the Anza and Mandera and Anza basins and found signs of oil and gas, although this was of no economic significance.

Following state-sponsored geological research in the Lamu and Tertiary Rift basins, the third and current wave of exploration in Kenya's gas and oil business began in 2000. There are several oil firms, such as Tullow Oil, Africa Oil, Premier Oil, Apache, BG Group, Simba Energy, Cove Energy, CNNOC,Anadarko, Centric, Pancontinental and Total quickly entered the Kenyan gas and oil market in conjunction with onshore oil discoveries in 2006 in Uganda [4] and offshore gas discoveries in Tanzania and Mozambique and as well as the high global prices at the time, (Table 1)

Table 1. *Licensed Oil Majors in Kenya as at June 2014.*

No.	Exploring Firms	Exploration Block Nos	No of Blocks
1	Tullow Oil Corporation	10A,10BB, 10BA, 12B, 12A, 13T	6
2	Anardarko	L-11A, L-11B, L-12, L-5, L-7	5
3	BG Group	L-10B, L-10A	2
4	Ophir/Dominion	L-9, L-5	2
5	Apache (now withdrawn)	L-8	1
6	Vanoil Resources	3A, 3B	2
8	ENI Spa	L-21, L23, L-24	3
9	Africa Oil Corporation		1
10	Total Kenya B.V	L-22	1
11	Zarara	L-13, L-4	2
12	Imara Energy Corp	L-2	1
13	FAR/Flow Energy	L-6	1
14	Lamu Oil Exploration	L-14	1
15	Lion Petroleum	2B	1
16	Rift Energy	L-19	1
17	NOCK	14T	1
18	CAMAC Energy	L-27, L-28, L-16, L-1B	4
19	Simba	2A	1
20	A-Z Petroleum	L-1A, L-3	2
21	Afren	L-17/L-18, 1	3
22	Adamantine Energy Ltd	11A	1
23	Pacific Seaboard Inv. Ltd	L-20	1
24	ERHC Energy Inc.	11B	1

Kenya's prospects of entering the league of countries that produce oil have been revived since late March 2012, when

Tullow Oil, a British company, claimed the discovery of an oil potential of 300 million barrels in Turkana. Since then, Tullow has announced the finding of an additional 300 million barrels, increasing the total amount of commercially viable reserves to 600 million barrels, with an additional 1 billion barrels potentially available (Tullow, 2014). Tullow believes that Kenya may contain up to 10 billion barrels of oil, despite the fact that recent discoveries have only been made in the Lokichar region of Turkana County[5] (Eduard, 2013). Additionally, evidence of oil seeps and slicks on Lake Turkana's surface suggest that drilling in the body of water could open up yet another oil frontier, (Figure 2). Tullow Oil Plc's profile reports from 2013 and 2014 provide details on its oil exploration efforts in Turkana County. Tullow spent Kshs 23.4 billion ($23.4 million) on operations in Kenya alone in 2013, with the majority going toward exploratory activities in Turkana County. (Figure 2).

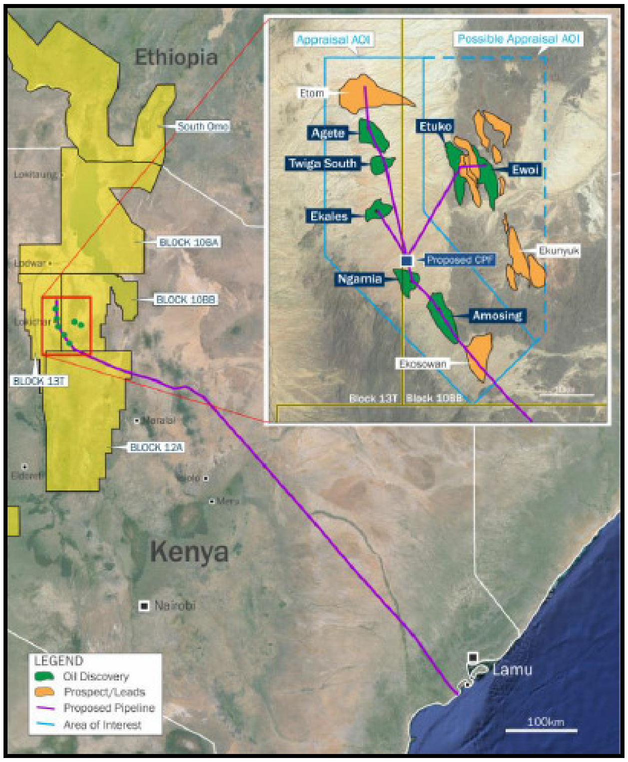

Figure 2: Exploration blocks in Turkana County

Since 2012, successful exploration and appraisal drilling operations have led to the development and segmentation of Kenya's fossil fuel industry into three different sectors: downstream, midstream and upstream. The upstream is still in its infancy, in contrast to the downstream and midstream parts, which have a rather mature economic and technological ecology. The production, exploration and drilling sectors typically make up the upstream sector of the fossil fuel industry. Geothermal drilling has still continued in Kenya despite the nation's gas and oil industry's low level of drilling and cementing activities compared to other significant producers of oil and gas worldwide. Combined with proven geothermal reserves of up to 10,000MW (GDC, 2018), that need to be drilled, oil and gas drilling in Kenya is an area for more intense research.

In 2012, Kenya discovered commercial amounts of oil deposits at Lokichar, Turkana county, northern Kenya. Oil and gas production in Kenya, therefore, is a new industry with much to be learned. Although the fossil fuel industry's upstream sector business is relatively new, the downstream and midstream sectors have been operating for some time. Consequently, what is challenging now is the insufficient information on upstream operations like drilling and cementing of oil wells in this new industry. Best practices in well-developed oil and gas industries in other countries e.g. Nigeria show the use of readily available local materials as components of additives of drilling fluids and oil cement, which consequently reduced the CAPEX cost of oil production. The need to investigate and understand concepts and principles of petroleum production like drilling fluid additives and cement slurry additives is now more appropriate than ever before.

2. Oil and Gas Drilling Laws in Kenya

The petroleum sector is governed by a number of legislative and regulatory frameworks in Kenya. The Electric Power Act of 1997 was passed in the middle of the 1990s, while the Energy Act of 2006 was passed subsequently. The Energy Act of 2006 brought together every law pertaining to the energy industry and established the Energy Regulatory Commission (ERC), later replaced by Energy and Petroleum Regulatory Authority (EPRA), as the sole statutory regulator of the industry. To further unbundle the energy sector, energy policies were laid out in the Sessional Paper Number 4 of 2004. This lays the foundational policy framework of the provision of quality and sustainable energy services, cost-effective, affordable, and adequate to the Kenyan economy from 2004 to 2023. The specific objectives outlined include:

1) Improving energy supply security
2) Fostering the exploitation of domestic energy sources.
3) Providing sustainable quality energy services for development.
4) Offering energy efficiency, conservation, and responsible environmental, health, and safety measures
5) Creating an atmosphere that facilitates the delivery of energy services
6) Accelerating economic empowerment for urban and rural development by using energy as a strategy
7) Expanding the availability of inexpensive energy services.

2.1. Kenya Vision 2030

This is a new long-term national progress strategy. Kenya Vision 2030 aims to establish "A globally competitive and prosperous country with a high quality of life by 2030." It prioritizes increasing energy generation and improving energy consumption efficiency when it comes to energy. The Vision outlines the objectives that must be attained in order to carry out the necessary institutional reforms, including accelerating the development of infrastructure, emphasizing the quality, aesthetics, and functionality of the infrastructure services created, and developing infrastructure to support designated flagship projects in order to ensure that they contribute to economic growth.

2.2. Oil and Gas Sub-Sector

2.2.1. Petroleum Act

Unlike the other component of the Petroleum Act, 2019, which are explicitly detailed on how firms should operate, the drilling aspect remains hazy in this Act. The need for a robust legal framework by the Kenyan government remains vital in this sector [6]. He noted that doing so would significantly help prevent the enduring "resource curse" that has plagued many countries around the world.

2.2.2. International Standards and Best Practices in the Oil and Gas Industry

For usage globally in the extractive industry, including oil and gas, the International Finance Corporation (IFC) and World Bank Group (WBG) have created guidelines and regulations, performance standards, and directives. The eight IFC Performance Standards (PS) on Social and Environmental Sustainability are meant to manage social and environmental risks and impacts. Kenya is also a consignee of these directives.

3. Upstream – Drilling

3.1. National Oil Company of Kenya (NOCK)

The majority of governments throughout the world have established national gas and oil companies to manage their governments' oil and gas operations in their countries, [14]. The National Oil Corporation of Kenya (NOCK) fulfills this crucial function in Kenya. Incorporated in 1981, NOCK is a wholly vertical state firm engaged in every facet of the oil supply chain, including upstream gas and oil exploration, midstream petroleum infrastructure construction, and marketing of petroleum products in the downstream level.

Drilling efforts in Kenya are facilitated by National Oil, which also actively engages in them. As a facilitator, National Oil is entrusted with managing gas and exploration data, marketing Kenya's exploration land, and overseeing the operation of the National Petroleum Laboratory, among other related duties. NOCK is one of the few national oil firms in Africa that is actively engaged in oil and gas exploration. Block 14T, located in the Tertiary Rift Basin and stretches from of Lake Magadi basin on the boundary of Tanzania and Kenya to the shores Lake Bogoria, is where National Oil operates its exploration acreage. Located in Kawi House, South C, Nairobi, National Oil is now establishing a Geochemical-Petrophysical analysis laboratory and a Seismic Processing Center.

Numerous national oil companies around the world are developing as rivals to the large multinational oil companies as well as joint venture partners with them [14]. As more NOCs become involved in mergers and acquisitions (M & A), there are more NOCs searching for international upstream, downstream, and asset targets. As a result of this growing trend, the balance of power over the vast bulk of the global fossil fuels has changed. In 2012, NOCs were in charge of more than 90% of the world's hydrocarbon resources, compared to less than 10% in the 1970s. As a result, the NOCs are now better able to directly access financial resources, human capital, technical services, and internal skill development.

3.2 Drilling

The act of installing a well and boring tubing through the Earth's surface is known as oil drilling. Oil and gas underground are forcibly evacuated from the surface using a pump attached to the tube. During oil and gas drilling, various drilling fluids are utilized mainly to provide several functions [15,16,17,18]. These include:

1. Lubrication and cool the drilling bit
2. Hydrostatic pressure control
3. Geology and lithology data information mining
4. Transport cuttings to the surface
5. Sustain wellbore stability
6. Minimize formation damage
7. Reduce danger to drilling equipment, workers, and the environment.

The fluid that incorporates all the components necessary to facilitate the extraction and removal of formation bits from a borehole in the Earth is known as a drilling fluid [16]. The American Petroleum Institute (API), on the other hand, describes the drilling fluid as a circulating fluid utilized in rotary drilling to carry out any or all of the many tasks necessary for drilling operations. [19]. Traditionally, drilling fluids have been divided into three categories: water-, oil-, and gas-based drilling fluids,[20]. It is imperative to note at this point that drilling fluid qualities have a major influence on the functionality of mud, [20]. The choice of suitable drilling fluid additives for the best drilling fluid attributes, [69], is crucial for effective drilling since drilling fluid is a crucial part of the oil and gas CAPEX [73,75]. Additionally, drilling fluids can be categorized as any mixture needed to remove cuttings from a borehole or as a complicated fluid made up of numerous additives [71].

So far, most of the drilling in Kenya has been for geothermal resources and more so in the Tertiary Rift Basin, [21, 22, 23]. These studies highlight the need for cement classes A and G to be manufactured to be API standards and the addition of silica flours in the design of cement slurry for prevention of strength retrogression in the extreme temperatures present in geothermal wells and the need for controlled directional drilling using computer programs. In addressing these pertinent issues, however, the issue of drilling wastes disposal is sourly missing.

The Tertiary Rift's high matrix compressive strength, swift lithology shifts, complex lithology, abrasive, cracked, and high temperatures of roughly 350°C are also discussed, [23]. Due to the numerous difficulties in drilling operations, such as low penetration rate, complete loss of circulation, high-temperature damage to mud motors and directional drilling steering tools high drilling string torque, breakdown of drilling foam structure at high temperatures, loss of cement slurry, and many others, this study notes these difficulties. These researchers claim that by combining traditional oil and gas drilling techniques with foam and air drilling techniques, it is able to address the issues with loss of circulation, enhance hole cleaning and cutting recovery, and thus increase penetration rates.

Furthermore, they assert that the use of directional drilling technology has led to wells that contact more cracks and reach a larger section of the reservoir, boosting the productivity of geothermal resources. The penetration rate was increased and the overall number of days per well was decreased by correct bit selection, increased hole cleaning effectiveness, and decreased drill string torque. Between May 2007 and April 2012, 57 geothermal wells in total were successfully drilled. The drilling operation was a complete success, and 98% of the wells produced. The report's authors conclude that the entire East African Great Rift Valley system may use this integrated high-temperature geothermal drilling method for the development of geothermal resources.

These drilling fluids are chosen based on the temperature, pressure, and drilling technique of the reservoir. The three major classes of oil and gas drilling fluids are synthetic, oil, and water-based mud. Specialized aerated and foam drilling is also techniques that are widely deployed in fossil fuel drilling. Subsequently, due to the readily available information and data on geothermal drilling operations in Kenya, a brief overview of it is instructive in this paper.

The examination of geothermal drilling fluids deployed in Olkaria well 38 (OW-38) located in Naivasha sub-county, Nakuru county, Kenya exhibited serious loss circulation, [71]. The well was dug 3000 meters deep using the GWDC 120 (Great Wall Drilling Company) drilling rig. At various stages of the well, it was dug with aerated water, foam, and water-based mud, and the daily losses were measured. This data was extracted from the daily drilling reports and is shown in Table 2.

Oil drilling firms in Kenya don't have to reinvent the wheel. The Turkana oil reserves lie in the same Tertiary Rift where the geothermal resources are located. The lessons learned from the many years of geothermal drilling can be replicated in the oil drilling in the entire Tertiary Rift where most of the oil blocks are located. Drilling fluid loss emphatically stands out as a major challenge, possibly due to the numerous faults in the Tertiary Rift, thus highlighting the need for special drilling fluid loss additives, advanced tools, and technologies, [24]. The estimates of a World Bank Report (2013)[1] put the cost of drilling a single oil well in Turkana at $574 million while the same in India costs $57.4 million. With these astronomical CAPEX figures, it remains a mystery how Africa Oil will recover its initial investment. However, despite this, other IOC's are busy drilling both onshore and offshore.[2]

Similar to this, the drilling for oil and gas produces drilling waste, which is a significant cause of environmental contamination. In studying how to dispose-off drilling wastes, many factors come into play. When selecting the optimum technology for drilling waste treatment, there are a number of issues to consider in addition to cost, such as the local ecology, safety concerns, and the applicable legal ecosystem, [25,26] The materials are discharged in various forms into the environment thus polluting it. A management approach through solids control, slim-hole drilling, and mud system monitoring should be adopted during drilling waste generation, [27]. Additionally, it is recommended that oil and gas drilling waste be treated and disposed of utilizing bioremediation, thermal treatment, land farming, slurry injection, and burial. This strategy is comparable to the finding that drilling techniques like pneumatic drilling, directional drilling, coil-tubing drilling and slim-hole drilling, may be used to generate significantly less drilling waste, [28].

Table 3. Summary of Basins and Wells Drilled in Kenya

No.	Basin	Area (Km^2)	Drilled Wells	Ave. Sediment Thickness
1	Tertiary Rift	105,673	34	40,000
2	Anza	81,319	15	10,000
3	Mandera	43,404	2	10,000
4	Lamu	26,100	19	12,000

New planning, equipment, operational theories, and design layout are offered for new wastewater management as crucial, including corral systems, drying-shakers, and augers. An evaluation of non-biological and biological technologies for the remediation of polluted drill cuttings is made while assessing the current choices for the treatment and safe disposal of drill cuttings, [25, 29]

The environment is at risk during drilling, not just from the drilling solids. Instead, a large amount of fluids are cycled through the well at high temperatures before entering open, partially enclosed, or completely enclosed systems, [30]. There is a substantial chance that drilling fluid will be released into the environment when the mud is stirred up during the looping process. The maritime ecosystem is impacted by drilling wastewater, which has an impact on fishing, the main occupation in coastal towns, [31].

For example, studies on the issue of drilling waste in Nigeria demonstrate that the dosages of total dissolved solids (TDS), chemical oxygen demand (COD), salinity, Pb, total suspended solids (TSS), biochemical oxygen demand (BOD),

1 World Bank Report (2013)

2 Offshore Staff Journal, 10th September, 2012

and Fe3+ were made less harmful after thermal desorption process and are therefore suitable for disposal, reuse, or recycling after environmental evaluation and biodegradability, [32,33].

The estimated accumulation of drill cuttings ranges within 130 to 560m^3 per well [27] which contain the following potential constituents:

1. Waste lubricants: organic compounds, heavy metals.
2. WBM cuttings: hydrocarbons, heavy metals, biocides, inorganic salts,
3. OBM cuttings: solids/cuttings, heavy metals, hydrocarbons, inorganic salts,
4. Spent OBM: surfactants, heavy metals, BOD, inorganic salts, solids/cuttings, hydrocarbons,
5. Spent WBM: inorganic salts, metals including heavy metals, biocides, solid/cuttings, hydrocarbons, BOD

Anthracene, Arsenic, Chromium, Copper, Diuron, Flouranthene, Naphthalene, Nickel, Phenanthrene, Pyrene, and Zinc are ecologically major chemicals present in mud wastes that pose an ecological hazard, [34,35,36]. According to the European Union Waste Framework Directive 2008/98/EC, drilling hazardous waste is classified into List I and List II. A similar legal ecosystem is simply absent in Kenya.

Oil pollution biodegradation is a relatively new technique that has the potential to be both successful and reasonably priced [33]. Additionally, appropriately managed solid wastes can be used as raw materials for brick, expanded clay, and cement manufacturing plants as well as for land restoration initiatives. Additionally, these methods improved drilling solid waste management and reuse from a sizable gas field [23].

In studies on the disposal of drill cuttings and fluids in Kenya, the choice of disposal method is highly influenced and determined by government policy as well as by operational, technical, and operational requirements and barriers [37]. Injection, heat treatment, bioremediation, and land application are further disposal techniques. Conclusively the paper suggests that it is better if Kenya can pass its laws to regulate disposal in the future.

One of the most chemically demanding oilfield operations that continues to be a major origin of chemical exposure and consequent health impacts is drilling [38,39]. Apart from ensuring proper disposal of drilling wastes, the drilling operations in Kenya need to have proper occupational and safety measures in place for their workers.

According to a study on the frequency of workplace bodily harm to employees engaged in onshore oil drilling activities in Turkana County, Kenya, 9.8% of the sampled workers had sustained such injuries, [40]. The research study also shows that the same number of respondents (18.75%) missed either 1–7 days or more than 1 month of work owing to occupational injuries. The study shows that on-shore oil drilling activities in Turkana County, Kenya, resulted in bodily injuries, the most frequent of which were cuts and lacerations. The body parts most frequently afflicted were the wrists and fingers. The number of days workers missed at work due to reported occupational physical injuries is a crucial injury severity metric in terms of the direct and indirect costs paid. To avoid work-related physical illnesses that raise the possibility of disability and death, oil drilling employees must be safeguarded. This position is upheld by Wasunna[3] et. al (2018) in exploring what Kenya needs to do to better protect those working in the oil sector.

3.3 Drilling Additives

Drilling fluids are critical to drilling success, simultaneously maximizing recovery and minimizing the duration it takes to achieve the first oil. Since the mud system represents one of the greatest ingredients of CAPEX, minimizing its cost and ensuring smooth and efficient drilling operationally means continuous main logical chronic concern once of the fluid properties throughout the drilling program. Some additives even perform more than one traditional role, [41]. Even more crucial is the situation in which drilling fluid degradation is accelerated by high temperature and high pressure. To counter and maintain these properties, special additives are usually added to the drilling fluids to significantly drilling parameters like lost circulation, filter cake formation, wellbore hydraulics, fluid stability, rate of penetration, and hole cleaning, [42-48].

Drilling fluid additives, therefore, include: filtration control additives, dispersants/deflocculants/thinners, Ph/alkalinity control chemicals, viscosifiers, lost circulation material (LCMS)/bridging agents, weighting materials, shale inhibitors, surfactant and emulsifiers, corrosion inhibitors/oxygen scavengers'/hydrogen sulfide scavengers and lubricants.

4. Challenges

4.1. Environment

The fossil fuels industry is known to consume colossal amounts of water during its operations, even during drilling. Drill cuttings, produced water, and used drilling fluid are all distinct from one another in terms of their characteristics and makeup. In the European Union, for instance, the Waste Framework (WFD) has adopted new laws for recycling trash to avoid and limit landfilling of waste in EU member states, including Britain, [49]. According to NEMA, county governments[4] in Kenya are primarily in charge of this function when it comes to waste management.

These authorities, however, have not given this obligation a high priority or provided enough funding for a

3 Melba K. Wasunna and Laura Muniafu, "What Kenya needs to do to better those working in the oil sector". October 24, 2018.

4 NEMA, The National Solid Waste Management Strategy, 2015. 15 Id.

successful implementation. Even more concerning are instances when some local residents stockpile water during droughts in old chemical containers! Due to reckless dumping, a lack of garbage collection, and a lack of waste segregation, Turkana County and the entire nation experience inadequate waste management.

Simiyu et al. (2016) investigated the safety, health, social responsibility and sustainability during the disposal of drilling fluids and cuttings in Kenya. This was in regards to methods of addressing drilling wastes, what influences the method of disposal, the Kenyan government's regulatory requirements on disposal of the drilling wastes, the hierarchy of drilling wastes, and the benefits and drawbacks of various methods of adjudication and ways of reducing the volume of wastes.

4.2. Capacity Building

The Kenya Pipeline Company Ltd. sponsors the Morendat Institute of Oil and Gas (MIOG), which was founded in 2014 to provide capacity building support for the Northern Corridor Integration Projects (NCIP). For partner states (South Sudan Rwanda, Kenya and Uganda), the Institute provides competency-based training in oil and gas pipeline maintenance operations, and management. The Directorate of Technical and Vocational Education and Training (TVET) oversees MIOG because it is a vocational education and training institution, therefore it is necessary for MIOG to abide by the Kenyan TVET Act and any associated rules and regulations. MIOG offers training that addresses the midstream component of the gas and oil value chain to guarantee that it is connected to industry standards in the fossil fuels sector. The currently available courses include firefighting, instrumentation and control maintenance, instrumentation and mechanical maintenance, pipeline operations course, and laboratory technologies for oil pipelines.

Linking Industry with Academia (LIWA), a regional forum that aims to establish and institutionalize links between academia (TVET's, research institutions and universities), industry, and government in the areas of skills, research, innovation, science, and technology, has been made possible through the Science, Technology, and Innovation Act of 2013. Currently, two public universities and one private university are offering petroleum engineering courses. However, even these best-intended efforts are largely hampered by a lack of modern laboratory facilities, insufficient faculty, and inadequate exposure to the latest gas and oil industry technical software packages. In a rare incident, Bentworth Ltd, an oil-well cementing firm, sponsored an engineering student whose research work was on the use of local bentonite in oil-well cement operations,

Since 2016, UNEP and the Norwegian government have been collaborating in capacity building and empowering the environmental management entities of fourteen nations globally, Kenya included[5]. This is under Norway's Oil for Development Program and UN –the Environment for Oil Development Partnership. However, this is not enough. More work needs to be done on risk assessment, and it appears that the World Bank is financing an expert who will collaborate with KRA to create a risk matrix for the oil and gas sector. In addition, it is supporting the establishment of a database that oil businesses will be able to input real-time data to in order to enable trend analysis, even though the IOCs are not complying to this.

4.3. Information Gap

Despite the fact that it is explicitly stated in the Petroleum Act of 2019 that "concessions, contracts, licenses, and permits issued thereunder must be made public, a provision within the Act must be included to that effect, and any perpetrator who fails to comply shall be prosecuted." The ministry has created a structure for reporting, transparency, and accountability in the upstream oil sector in compliance with section 119 of the Petroleum Act, but it is only currently on paper. For instance, in the US, Haliburton monitors the drill count[6] every week, serving the public at large, from potential investors to stern state regulators to young budding engineers. This is contrary to what is transpiring in Kenya, as regards oil and gas industry data. In Kenya, however, even the KNBS has no idea what the Kenyan drill count is.

44 or more agreements with oil and gas companies have been signed by the Kenyan government [50]. Only 10 of these contracts, though, have been disclosed. Contracts are not disclosed, which eliminates a crucial oversight tool. Tullow Oil has endorsed contract disclosure, but the government is unwilling to do so. Even more, awakening is the fact that the state has declined to sign the Extractive Industry Transparency Initiative (EITI) while at the same time claiming to support the Open Government Partnership (OGP), an endeavor to increase the Public Procurement Information portal's transparency and accessibility in an effort to minimize corruption. This lack of detailed information is confirmed[7] apart from the data availed by the Petroleum Master Plan, funded by the World Bank and prepared by Price Waterhouse Coopers. However, the fossil fuels firms are reluctant to upload their information to the Upstream Integrated Economic Planning System, which avails first-hand real-time information to state agencies in the oil and gas industry.

4.4. Resource Curse

Because of this, oil extraction in Turkana may exacerbate conflict [52] by fueling community thirst for enrichment and resentments over relative deprivation, social

5 UNEP, 2016.

6 Haliburton Drill Count

7 Discussion paper, (KCSPOGRDC and Cordaid/Timu-Community Development Associates, 2016).

exclusion and inequalities like ethnic differences. This was witnessed[8] in 2020 when the Early Oil Pilot Scheme started moving crude oil from Lokichar to Mombasa in iso-heated road tankers. In order to promote inclusive development, these ideas recommend carefully thought-out resource management and benefit-sharing.

For instance, Nigeria's oil wealth led to a major urban migration wave that significantly decreased the magnitude of the non-urban labor force [53]. This in turn caused production to decline, which raised food costs. On Kenya, a similar projection would prove disastrous: The price of agricultural items on the world market would skyrocket, putting 70% of Kenya's jobs at risk, and any job losses would further increase the country's already-high unemployment rate of 40%. As a result, the state would be forced to sustain a sizable unemployed population at a time when food prices are rising.

Rent-seeking is a manifestation of the resource curse mechanism, which mostly refers to disputes regarding distribution [54,55,56,57]. Despite the fact that they resulted from the unexpected abundance of resources, the curse and illness might spread in several ways as issues. Having noted this, it remains to see how the Kenyan government will swallow the vaccine for this disease.

4.5. Security

Security has been one of the main concerns of the fossil fuel industry has faced globally. This is because towns must undergo a significant transformation whenever oil or gas is discovered. Oil exploitation may exacerbate land loss and other concerns [58], triggering civil war with the Pokots. The perception of unequal income and employment prospects, new highways that help livestock rustlers, and the fact that Kenya Police Reservists and former community guards are now guarding Tullow Oil rather than the community have all contributed to a rise in insecurity.

The social, cultural, political, environmental, and security implications of oil and gas operations in Turkana impact conflicts, tensions, company and community flare-ups which may be catalyzed into full-blown violent confrontations due to the high prevalence of illegal small arms, unmet expectations, unfulfilled aspirations, suspended promises, perceived injustice and failed dreams unless quick and preventive measures are taken [59,60,61,62,63,64,65,66].

Additionally, these disputes over oil and gas are not restricted to Kenya's internal borders but have spread to the international stage, as seen by Kenya's decision to skip an important International Court of Justice (ICJ) hearing over its oceanic border dispute with Somalia. The issue revolves around a triangle-shaped marine region that is thought to have oil and gas reserves. Therefore, relative peace and stability are crucial issues that must be addressed along the entire Northern frontier regions if Kenya hopes to become a major transit hub of East Africa's oil boom, [70].

4.6. Legal and Regulatory Framework

By analyzing the law and practice on environmental protection in the fossil fuel industry in Kenya, it was determined that there are gaps in current environmental regulations [67].

If only Kenya's legislative framework had a transparent licensing system for oil and gas blocks, this would reduce opportunities for corruption and potential hostilities between the state, the community and the IOCs. The report recommends limiting the Cabinet secretary's authority over oil and gas in order to lessen the impact of the precipice that such arbitrary power hides. In order to bring clarity to the system and encourage transparency, it also suggests that a clear procedure be defined and implemented for calling and conducting bid rounds. It also suggests that, in the absence of competitive bidding, direct negotiation authority be given to an independent body. The study urges the National Assembly to pass legislation in this regard so that the state can reap the greatest possible profits from the extractive industry.

5. Recommendations

Consequently, the drilling sector of Kenya's gas and oil business has been examined in this essay. And certainly, it has demonstrated that this sector of the economy has the power to either raise living standards for Kenyans to extremely high levels or to send an entire generation into a cycle of poverty similar of that of the African continent. As a result, it is without bias suggested that the following actions be taken immediately:

a) The academic research area in Kenya's fossil fuel business is new and unexplored. The scope and variety of original research in this area is unmatched, ranging from the classification of drilling wastes to the development of new bio-additives to the use of nanotechnology in the emerging oil and gas business.
b) With the advent of climate change, all stakeholders should undertake sufficient and effective environmental adherence, oversight, and mitigation measures to benefit society and avoid the risk of stranded assets.
c) The training institutes should get quality investments in order to generate qualified human staff capable of managing, evaluating, monitoring, and operating the oil and gas business across all three sectors.
d) Analysis of all publications on oil and gas drilling in Kenya is grossly disappointing. Even more appalling is the lack of research on drilling fluids, drilling additives, and drilling wastes. Despite the global appetite for drilling operation, related publications, academic investigative interest in the Kenyan drilling scene remains scanty. Consequently, extensive research should be undertaken in this era of laser focus on fossil fuel

8 Hesboun Etyang, Star Newspaper, 27th June, 2018.

establishment.

e) In addition, sector-specific studies must be carried out to comprehend the internal and external dynamics of each oil and gas industry sub-sector, with unambiguous legal access to data and information. Selective amnesia is evident, with crucial information on exploration, drilling, and production laughably lacking, despite the existence of an accessible government data portal.

6. Conclusion

In this essay, recent studies conducted by diverse researchers were analyzed, and an effort was made to contrast and compare the outcomes. I therefore come to the conclusion that if Kenya wants to use its limited and finite gas and oil resources in a way akin to Norway, it has the chance to imitate the real procedures implemented and industry-proven through the years by adhering to the law.

Conflict of Interest

All the authors do not have any possible conflicts of interest.

Acknowledgements

The authors wish to express their deep gratitude to RUFUROM, the World Bank Africa Center of Excellence, Center for Oilfield Chemicals Research, University of Port Harcourt, United States International University, Nairobi, Pharmaceutical Sciences Department for the TGA Machine.

REFERENCES

[1] World Energy Council, (2016)
[2] IEA, (2016)
[3] Purcell P, (2014), "Oil and Gas Exploration in East Africa: A Brief History". September. P& R Geological Consultants Pty Ltd.
[4] Yabs J,(2015),"Potential Economic Effect of Oil and Gas in East African Countries". ISSN 2224-574X, Vol.28.
[5] Gismatullin E, (2013), "Tullow to Start Pumping Oil in Kenya After Resource Increase". 31st July.
[6] Omollo J, (2013), "Oil and Gas Sector in Kenya: The Legal Status on Exploration and Extraction".
[7] Therkildsen O, Buur L, Kjaer M, Hansen M.W,(2013),"Extractive Natural Resource Development: Governance, Linkages and Aid". DISS Report:28.
[8] Gallagher K.P, Di Caprio A, (2006), "The WTO and the Shrinking of Development Space". January, The Journal of World Investment & Trade 7(5): 781-803.
[9] Nwapi C, (2016), "A Survey of Literature on Local Content Policies in The Oil and Gas Industry in East Africa". April.
[10] Wachiya M.J, (2019), "The Effect of Local Content Policies on Sustainable Local Development by Upstream Oil and Gas and Companies in Kenya".
[11] Kakonge J.O, (2020), "Kenya's Turkana Oil and Gas Field Shows the Challenges of Implementing Local Content Policies". 25th May, LSE.
[12] Mobutu J.O, Nzulwa J, (2021), "Effect of Local Content and Security Issues on The Operational Efficiency of Oil and Gas Organizations in Kenya". International Journal of Strategic Management, ISSN 2519-0296, Vol, No.1 pp 1-19.
[13] Kenya Extractives Policy Dialogues, (2018), "Paper No. 2".
[14] Al-Fattah S, (2013), "The Role of National and International Oil Companies in The Petroleum Industry". USAEE Working Paper No.13-137. 28th July
[15] Bourgoyne A. J, Millheim K.K, Young F.S Jr, Chenevert M.E, (1991), "Applied Drilling Engineering, Vol.2 ISBN:978-1-55563-001-0.
[16] Darley H.C.H, Gray G.R, Caenn R, (2011), "Composition and Properties of Drilling and Completion Fluids," January.
[17] Hossain E.M, Al-Majed A.A, (2015), "Fundamental of Sustainable Drilling Engineering, ISBN:978-04-708-781-70. Scrivener Publishing LLC. ©All rights reserved.
[18] Bageri B, Mohamed A, Elkatatny S, Basfar S, (2020), "Impact of Perlite on the Properties and Stability of Water-Based Mud in Elevated Temperature Applications," December, ACS Omega 5(50).
[19] Fink J, (2011), "Petroleum Engineer's Guide to Oil Field Chemicals and Fluids". 1st Edition – May 13. ISBN: 9780123838452.
[20] Ljones T, (2013), "Drilling mud property estimator". M.Sc dissertation. Norwegian University of Science and Technology.
[21] Bett E.K, (2010), "Geothermal Well Cementing, Materials and Placement Techniques." United Nations University, Geothermal Training Programme, Orkustofnun, Grensasvegar 9, IS-108 Reykajvik, Iceland, Reports 2010, Number 10.
[22] Ong'au M.T, (2018), "Sensitivity Analysis of Geothermal Drilling Parameters – A Case Study OF Well Mw-17 in Menengai Kenya," Proceedings, 7th African Rift Geothermal Conference, Kigali, Rwanda.
[23] Feng Z, Zhang N, Zhou A, Yangsheng Z, (2012), "Development of hot dry rock geothermal resource in the Yangbajing Basin China". March, Renewable Energy 39(1): 490 – 495.
[24] Blankenship D, Finger J, (2011), "Handbook of Best Practices for Geothermal Drilling," May.
[25] Stewart R.J, Ball A.S, Schliephake K, (2012), "A review of the current options for the treatment and safe disposal of drill cuttings." Waste Management & Research 30 (5) 457–473, © The Author(s).
[26] Haut R, Theodori G.L, Willians T.E, Burnett D,(2010), "Balancing Environmental Tradeoff Associated With Low-Impact Drilling Systems To Produce Unconventional Natural Gas Resources". October.
[27] Nwakaudu M.S, Ibuchukwu O.S,(2012), "Drilling Wastes Generation and Management Approach," International Journal of Environmental Science and Development 3(3): 252-257.
[28] Sharif M.D.A, Sankar K.U, Nagalakshmu N.V.R, Vasanth G, Reddy S.S, (2017), "Drilling Waste Management and Control the Effects," Journal of Advanced Chemical Engineering, 7:1.
[29] Mirshekari B, Davarpanah A, Razmjoo A, (2018), "An overview of management, recycling, and wasting disposal in the drilling operation of oil and gas wells in Iran". Cogent Environmental Science, 4: 1, 1537066.
[30] Amorin R, Broni-Bediako E, (2010), "Effects of Drilling Fluid Exposure to Oil and Gas Workers Presented with Major Areas of Exposure and Exposure Indicators". Research Journal of Applied Sciences, Engineering and Technology. 710 - 719.
[31] Anon, (2010a), "Kosmos Energy to Pay a Fine for Spillage".
[32] Onwuka O.S, Uwom C.S, Ifediogwu S.I, Igwe O, (2018), "An Assessment of the Effectiveness of Drilling Waste Treatment Process in X-Gas Field, Niger Delta, Nigeria". Geology, Ecology and Landscape, Volume 2, 2018-Issue 4.
[33] Obayagbona N.O, Imarhiagbe E, (2019), "Environmental Evaluation and Biodegradability of Drilling Waste: A Case Study of Drill Cuttings from Ologbo Oilfield Wells at Edo State, Nigeria". November.
[34] Bignert A, Fumega J, Cossa D, Füll C, Emmerson R, Fryer R, (2004), "OSPAR/ICES workshop on the evaluation and update of background reference concentrations (B/RCs) and ecotoxicological assessment criteria (EACs).
[35] Pozebon D, Lima E, Maria M.S, Jandyra M.G.F, (2005), "Heavy Metals Contribution of Non-Aqueous Fluids Used in Offshore Oil Drilling," January. Fuel 84(1):53-61.
[36] Khodja M, Khodja-Saber M, Bergaya F, Cohaut N, Canselier J.P, (2010),"Drilling Fluid Technology", Performance and Environmental Considerations, November.
[37] Allan R, Lilian S.E, Esther M, (2016) "Drill Cuttings and Fluid Disposal; A Kenyan Case Study". SPE/AAPG Africa Energy and Technology Conference, Nairobi City, Kenya. Paper Number: SPE-AFRC-2580389-MS.

[38] Coussot P, Herzhaft B, Bertrand F, (2004), "Rheological Behavior of Drilling Muds, Characterization Using MRI Visualization". January, Oil and Gas Science and Technology – Revue de/IFP 59(1):23-29.
[39] Drilling Fluids and Health Risk Management, (2009), Report Number 396, IPIECA/OGP.
[40] Kamol C.O, Warutere P, Akunga D.N, (2019), "Occurrence of Occupational Physical Injuries among Workers in Onshore Oil Drilling Occupation in Turkana County, Kenya". Health Sci J Vol. 13. No. 1: 619.
[41] Awele N, (2014), "Investigation of Additives on Drilling Mud Performance with Tonder Geothermal Drilling as A Case Study," Aalborg University Esbjerg, January 6th.
[42] Zamora M, Roy S, (2019), "The Top 10 Reasons to Rethink Hydraulic and Rheology". Corpus ID:109407883
[43] Savari S, Teke K, Maxey J, Kulkarni S, (2013), "A Comprehensive Approach to Barite Sag Analysis on Field Muds". Haliburton, AADE-13-FTCE-30.
[44] Kabir M.A, Gamwo I, (2015), "Impact of Drilling Fluid Rheology and Wellbore Pressure on Rock Cuttings Removal Performance: Numerical Investigation". Asia-PACIFIC Journal of Chemical Engineering 10(6):n/a-n/a.
[45] Naccache M, Silva T.P.D, (2016), "Enhanced Fluid Rheology Characterization for Managed Pressure Drilling Applications". 12th April, Geology. Corpus ID:138409529.
[46] Roohi A, Pakdaman E, Niknam K, Osfouri S, Azin R, (2019), "Improving the Rheology, Lubricity, and Differential Sticking Properties of Water-Based Drilling Muds at High Temperatures Using Hydrophilic Gilsonite Nanoparticles". Colloids and Surfaces, September.
[47] Pandya S, Shah S.N, Ahmed R M, (2019), "Wellbore Cleanout in Inclined and Horizontal Wellbores: The Effects of Flow Rate, Fluid Rheology and Solids Density". September, SPE Drilling and Completion 35(01).
[48] Basfar S, Bageri B, Elkatatny S, Al.Jaber J, (2022), "Prevention of Hematitie Settling Using Perlite in Water-Based Drilling Fluid". Journal of Petroleum of Science and Engineering, Vol.210, March, 110030
[49] Fijal J, Ziaja J, Jamrozik A, Gonet A, (2015),"Selected Aspects of Drilling Waste Management in Poland". AGH Drilling Oil Gas 32(3):565, January.
[50] Kamau T, (2018), "Civil Society Pushes for Amendments to Petroleum Bill to Open Up Contracts." 33 Oxfam, Contract Disclosure Survey, (Oxford: Oxfam).
[51] Christa N. Brunnschweiler E.H, Bulte G, (2009), "Natural Resources and Violent Conflict: Resource Abundance, Dependence and the Onset of Civil Wars". Oxford Economic Papers, New Series, Vol.61, No.4, pp. 651-674.
[52] Switzer J, (2001), "Natural Resources: The Case of the Minerals Sector". Mining, Minerals and Sustainable Development, July, No.12. © 2002 IIED and WBCSD.
[53] Sala-i-Martin X, Subramaian A, (2003),"Addressing The Natural Resource Curse: An Illustration from Nigeria". International Monetary Fund, IMF Working Paper, WP/03/139
[54] Mikesell R.F,(1997), "Explaining the Resource Curse, With Special Reference to Mineral-Exporting Countries," Resources Policy. Vol.23, Issue 4, 191-199.
[55] Sachs J.D, Warner A.M, (2001), "The Curse of Natural Resources, European Economic Review 45(4-6): 827-838.
[56] Torvik R, (2001), "Learning by Doing and the Dutch Disease," European Economic Review 45(2):285-306.
[57] Gylfason T,(2002),"Natural Resources and Economic Growth: What is the Connection?" Fostering Sustainable Growth in Ukraine. January.
[58] Gupta J, Bos K, (2016), "Inclusive Development, Oil Extraction and Climate Change: a Multilevel Analysis of Kenya". International Journal of Sustainable Development & World Ecology, Vol.23 No.6 482-492.
[59] Agade K.M, (2014), "Ungoverned Space and the Oil Find in Turkana, Kenya" The Round Table 103(5), September.
[60] Patey L,(2014), "Kenya –An African Oil Upstart in Transition" ©Oxford Institute for Energy Studies.
[61] Zulu L.C, Kalipeni E, Johannes E.M, (2014), "Oil discovery in Turkana County, Kenya: A source of conflict or development?" African Geographical Review.
[62] Dismas M.M, (2017), "Oil and Gas – Society Relations and The Role of International Actors: A Case Study of the Kenyan State and The Northern Part of Kenya". UON – Institute of Diplomacy and International Studies, May.
[63] Schilling J, Scheffran J, Locham R, (2018), "A local to global perspective on oil and wind exploitation, resource governance and conflict in Northern Kenya". Conflict, Security & Development, Vol. 18, No. 6, 571–600
[64] Wasunna M.K, (2018), "Extractives Baraza", Strathmore University October 9.
[65] Naomi M, (2020), "Oil Exploration and Security Dynamics in Kenya – A Study of Lokichar Oil Exploration Site, Turkana County". UON, Sch. Of Law.
[66] Kamais C.E, Bor E.K, Mwangi S.W, (2019), "Emerging Security Management Issues Due To Oil Exploration Activities in South Lokichar Basin, Turkana County, Kenya," The International Journal of Humanities & Social Studies, Vol.7, Issue 6, June.
[67] Nyamai N.K, (2016), "Evaluation of Law and Practice on Environmental Protection During Exploration and Production of Oil and Gas in Kenya," UON, Sch. Of Law.
[68] Nandako S, (2020), "Transparency in the Management of Oil and Gas Blocks: A Review of Kenya Legislative Framework" Strathmore Law School (SLS).
[69] Ahmed S, Salehi S, Teodoriu C, Patel H, Ahmed R, (2020), "Numerical and Experimental Evaluation of Liner Dual Barrier System in Geothermal Wells, Proceedings, 45th Workshop on Geothermal Reservoir Engineering, Stanford University, Stanford, CA, USA.
[70] Oxford Institute for Energy Studies, (2014), "Kenya: An African oil upstart in transition", October, Copyright © 2014 Oxford Institute for Energy Studies (Registered Charity, No. 286084). ISBN 978-1-78467-011-5.
[71] Chemwotei S.C, (2011), "Geothermal Drilling Fluids" Kenya Electricity Generating Company Ltd, P.O. Box 785-20117, Naivasha Kenya. GTP Reports, Orkustofnun, Grensásvegur 9, Number 10 IS-108 Reykjavík, Iceland 149.
[72] Tordo et al (2013), supra note 19 at pp. 24–25.
[73] Vivas C, Rickard B, Tuttle J.D, Salehi S, (2020), "Challenges and Opportunities of Geothermal Drilling for Renewable Energy Generation. GRC Transactions, 44, 904-918.

Table 2. *Summary of Olkaria Well 38 Drilling Fluids and Losses.*

Hole Size	Bottom Hole Assembly	Casing Size	Depth	Casing Depth	Drilling Fluid	Losses
17½″	17½″ bit, 1 STB, 2 subs, 3 X/O, 9 X 8″ DCs, and 5″ DPs	13 ⅜″	306.45m	305.5 m	Water at 65 l/m	The loss was not measured (circulation returns at about 80%).
26″	26″ Bit, 1 sub, 1 STB, 3 X 8″ DCs, X/O and 5″ DPs	20″	63 m	62 m	Mud (10.7-42 m) at 50 l/s. Water (42-63 m, at 70 l/s	Total loss at 42 m. Drilled blind with water.
8½″	8½″ bit, 1 STB, 2 subs, 3 X/O, 15 X 6½″ DCs, and 5″ DPs.	7″ (liners)	3000 m	3000 m	Drilled out cement using water (686- 787 m), at 60 l/s. Aerated water and foam (787- 3000 m), at 55 l/m.	Total loss between 1403 and 2562 m
12¼″	12¼″ bit, 1 STB, 1 sub, 3 X/O, 9 X 8″ DCs and 5″ DPs.	9⅝″	753 m	751.7 m	Water (292.3-334 m) at 60 l/m. Aerated water and foam (334 m – 753) at 60 l/s.	Lost circulation at 334 m and switched to aerated water and foam. The loss was not measured when drilling with aerated water and foam

