Effects of Heavy Metalson Water Quality along Kenya Pipeline in Makueni County, Kenya

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Abstract

Globally, oil spills are a common phenomenon. At least one major oil spill incident is recorded annually. Oil spillages are widespread and occur across all stages in the petroleum industry- extraction, transportation, refining, and distribution. These spillages disrupt the ecosystem, pollute the environment, and pose severe health and socio-economic implications to the affected communities. Makueni County, an arid and semi-arid community in Kenya, experienced terrestrial oil spills in 2015 and 2019 along Kenya Pipeline, affecting surface and underground water along the Thange River Basin. The current study sought to bring to light the effects of water contamination along River Thange in Makueni County. The study adopted both descriptive and quasi-experimental research designs. Water samples analyzed revealed that there was high contamination of water by the heavy metals measured; Lead (Pb) (<0.05mg/L), Mercury (Hg) (>0.005mg/L), Chromium (Cr) (>0.05mg/L),and Cadmium (Cd) (<0.005mg/L)indicative of ineffective cleanup by Kenya Pipeline Company (KPC). The study recommends that KPC compensate or relocate the affected populations to enable them to embark on their livelihoods.

Keywords:

Environment, Heavy metals, Oil spill, Pollution,Terrestrial, Water quality

INTRODUCTION

In almost every region globally, crude oil spillages have been reported. These spillages often disrupt the ecosystem, pollute the environment, and pose severe health and socio-economic implications to the affected communities. The current study notes that oil spills are not uncommon. On average, one major spill is recorded yearly (Jha & Dahiya, 2022). A large number of emergency responders are often mobilized to clean up the oil, typically involving a tremendous manual effort with the consequences of oil spillages usually evaluated in terms of environmental damage, effects on marine species as well as economic losses in the fisheries as well as tourism industries (D'Andrea & Reddy, 2014).

On a global scale, the Gulf Oil Spill in 2010 increased attention to oil spills and their potential effects. The BP Deepwater Horizon oil spill in the Gulf of Mexico is considered the largest marine oil spill in global history. Between April and July 2010, an estimated 5 million barrels of crude oil were released after the explosion and sinking of the Deepwater Horizon drilling platform. Tens of thousands of individuals, including professionals and community workers, participated in the oil spill cleanup activities and were exposed to the various toxic components of the contaminated water (Pallardy, 2022). Given the toxicological properties of the oil components and the chemicals used to break up the oil slick, exposure to the BP oil spill resulted in health risks for those who participated in its cleanup operations (Bryant & Abkowitz, 2017).
The long-term epidemiological investigation focused on public health issues. It indicated that those involved in the BP oil spill cleanup operations experienced persistent alterations in their hematological, hepatic, pulmonary, and cardiac functions. The hematological alterations include increased mean White Blood Cell (WBC) counts, hemoglobin, hematocrit, and reduced platelet counts as well as Blood Urea Nitrogen (BUN) levels among the oil spill cleanup workers even seven years after the oil spill disaster (Wigle*et al*., 2008).

The wreckage of the oil tanker Prestige off the coast of northwestern Spain in 2002 resulted in a significant spill of about 67,000 tons of bunker oil. More than 300,000 people were involved in cleanup activities. During the first weeks of the disaster, cleanup work was predominantly performed by local fishermen without appropriate personal protective equipment. The potential effects of the Prestige oil spill on human health were evaluated in several epidemiological studies (Wigle*et al*., 2008; Bryant & Abkowitz, 2017). The large-scale longitudinal study project promoted by the Spanish Society of Respiratory Medicine (SEPAR) aimed at evaluating long-term respiratory health effects and chromosomal damage in fishermen who participated in cleanup activities of the Prestige oil spill. Exposure to oil spills was linked to potential genotoxic effects.

In Niger Delta, an average of 240,000 barrels of crude oil is spilled annually. The causes of the oil spill in the Niger Delta have been linked to unknown causes (31.85%), third-party activity (20.74%), and mechanical failure (17.04%). Marked by numerous oil wells, pipelines, and other infrastructure traversing residential areas and neighborhoods, residents face an elevated risk of exposure to oil pollution of varying scales near their homes, farms, and fishing grounds (Osuagwu & Olaifa, 2018). Oil companies' low standard of operation in the Niger Delta region, regarding extraction methods and infrastructure integrity, amplifies the risk of oil spills. Furthermore, residents in the study area engage mainly in primary economic activities like farming, logging, forestry, and fishing. Residents are also highly dependent on surface water, boreholes, and wells, which are polluted with oil chemicals, as their primary sources of drinking water.

Oil spills in Niger Delta often lead to fires, which release respire able particulate matter (PM) into the air (Babatunde *et al*., 2019). Hazards to human health may result from dermal contact with soil and water, ingestion of contaminated drinking water, crops, or fish, or inhalation of vaporized product or PM and partly burned hydrocarbons produced by fires. In addition, onshore oil spills may have indirect health effects via damage to livelihood resources, such as diminished yields from degraded agricultural land and fishing grounds (Chinedu & Chukwuemeka, 2018).

In the last decade, Kenya has not experienced significant oil spill incidents. However, onshore and offshore oil spills have occurred, posing different hazards to humans and the environment. In 2005, for instance, a single hull vessel MT *Ratna Shallini* while trying to berth at Kipevu Oil Terminal, ruptured its hull. The ship was carrying 80,000MT of Murban Crude Oil. Approximately 300 MT was released into the marine environment (Muthike, 2018).

On the other hand, accidental oil spills, such as the 2009 Sachangwan disaster in Molo Sub-County, killed at least 113 people, and hundreds more were treated suffering from first and second-degree burns. In Nairobi County, oil spillage along Kenya Pipeline in 2015 resulted in firing leading to the death of over 116 individuals in Sinai slums. During the same year, a similar oil spill happened along Kenya Pipeline in Makueni County, adversely seeping into water points and tens of meters beneath (K'orowe*et al*., 2020).

The current background notes that much emphasis on oil spills has focused on the response approaches, especially in cases where such spills lead to loss of human life and damage to property, with little focus on the effects such spills are likely to pose to public health through compromised water quality. This study sought to determine the effects of water contamination on the environment and communities along River Thange in Makueni County.

1.1 Heavy Metals in Oil

1.1.1 Arsenic in Oil and Water Quality

Arsenic is a toxic and carcinogenic metalloid and can be taken orally with seafood or drinking water and by inhalation route during industrial activities. It can cause liver, lung, and bladder cancers, vascular diseases, hypertension, and diabetes when taken orally. High-dose arsenic uptake (70-180 g) may cause acute death. The skin is the primary target organ in chronic arsenic exposure may cause a series of characteristic changes in the skin epithelium, and characteristic arsenic-associated skin tumors include squamous cell carcinomas in keratosis. Liver damage develops with prolonged or chronic arsenic intake, and peripheral neuropathy occurs at repeated low doses. Arsenic has been reported to cause skin, lung, bladder, kidney, liver,and prostate cancers and is classified in Group 1 by International Agency for Research on Cancer (IARC) (Tokar*et al*., 2013; IARC, 2012; Ramirez *et al*., 2017). Due to contamination of water points in Makueni County, the current study points out the gaps in the literature on the implications of exposure to Arsenic and other metals among communities living in the Thange area. The present study, by pursuing public health records since the onset of the first spill, sought to bring forth the public health impacts of exposure to oil spills.

1.1.2 Lead in Oil and Water Quality

Tokar*et al.,* (2013) study established that lead exposure in children and adults and long-term occupational exposure affect mainly the nervous system. Severe brain damage (encephalopathy) and kidney damage occur in adults and children with intense exposure to lead. The comet assay demonstrated the genotoxic effect of lead in human lymphocytes in various *in vitro* studies. The most severe effect of lead is on the hematopoietic system, and porphyrins, coproporphyrins, δ-aminolevulinic acid, and zinc protoporphyrin increase in urine. The inorganic lead has been classified in Group 2B by IARC (Ramirez *et al*., 2017). The current study noted that available literature on public health effects of exposure to oil spillage in Makueni is scarce, making it almost difficultto document scientifically.

1.1.3 Cadmium in Oil and Water Quality

Cadmium is a carcinogenic and mutagenic transition metal; therefore, its use has been limited in industry. Long-term inhalation of low cadmium levels can cause kidney damage and fractures. Occupational exposure is the primary concern rather than acute exposure. It has been classified in Group 1 by IARC as Cadmium related to increased cancer risk- lung, prostate, and liver cancer (Tokar*et al*., 2013; Ramirez *et al*., 2017). To date, there exists scarce information in existing literature from Makueni County's site of oil spillage. This presents sufficient gaps in knowledge that the current study sought to bring to light by interrogating the effects of terrestrial oil spills on water quality in Makueni County of Kenya.

1.1.4 Mercury in Oil and Water Quality

Tokar*et al*., (2013) study established that mercury is released from municipal waste incineration plants, chlorine alkali factories, mining, metal (Hg, Au, Cu, and Zn) smelting process, and coal combustion contaminate the environment. The organometallic compound methyl mercury is toxicologically significant to other inorganic mercury compounds. Methyl mercury is a neurotoxic compound that mainly affects brain functions and causes cognitive symptoms (Ramirez *et al*., 2017).

2 Materials and methods

2.1 Study Area

The study was conducted in Thange, Kibwezi sub-county, Makueni County (Figure 1). It lies between Latitude 1^{o} 35´ and 32 00´ South and Longitude 37^{o}10´ and 38^{o} 30´ east (County Government of Makueni, Kenya, 2018). It is an area characterized by a typically semi-arid climate, with average rainfall and temperature of 600 mm and 23°C, respectively (Mwangombe*et al*., 2011). The rainfall is bimodal, with long rains from March to May and short rains from November to December to early January. The study area is covered with reddish brown soils from weathering the volcanic deposits. However, the soils are darker on basement exposures due to weathering of basement rocks. Fine sands dominate the dry Riverbed. River Thange is a seasonal river within the Thange River Basin that starts at the source of the spillage near the River, approximately 50 meters from the River.

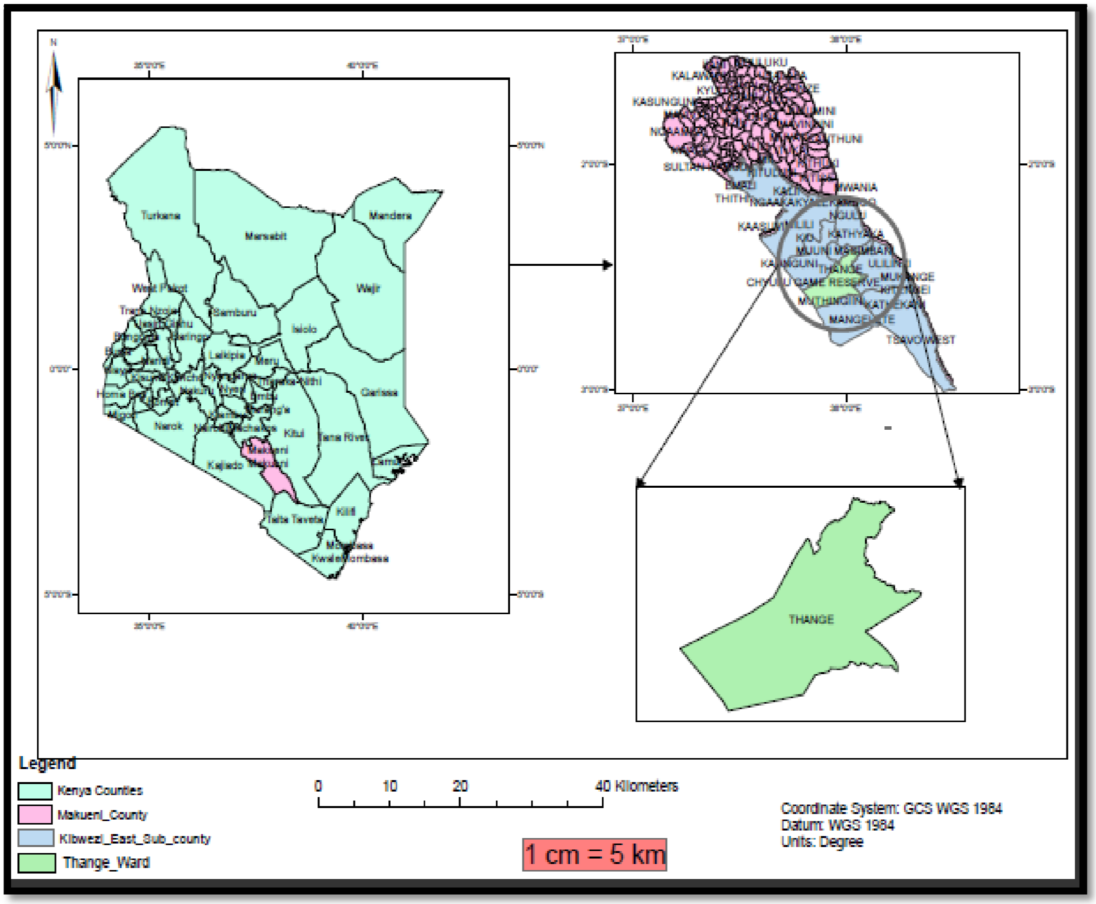

Figure 1: Map of the study area

Source: Researcher, 2021

2.2 Research Design

According to Kothari (2004),a research design is a conceptual structure within which the research is conducted and constitutes the blueprint for collecting, measuring, and analyzing data. Bryman and Bell (2007) assert that the research design adopted should provide an overall structure, orientation, and framework within which the collected data can be analyzed. The study adopted both descriptive and quasi-experimental research designs.

2.2.1 Descriptive design

This design provided an in-depth insight into the phenomenon under study. Therefore, this research applied quantitative and qualitative methods concurrently. The quantitative data enabled the researcher to use statistical tools such as descriptive statistics, correlations, and percentages. In contrast, the qualitative data gave narratives and people's voices that supported the quantitative data.

2.2.2 Quasi-experimental design

The samples for the quasi-experimental analysis were collected from the River. The researcher collected 2 liters per sampling point using cleaned bottles at a depth of 1-2 feet, and the samples were labeled by name, date and time collected, and depth. The sampling points were at an interval of 50 meters apart. The samples collected were then transported to the National central water testing laboratories in Nairobi by road. Figure 1 shows points 1-5 and wells 1 and 2 from where the water sample was collected for the physico-chemical analysis.

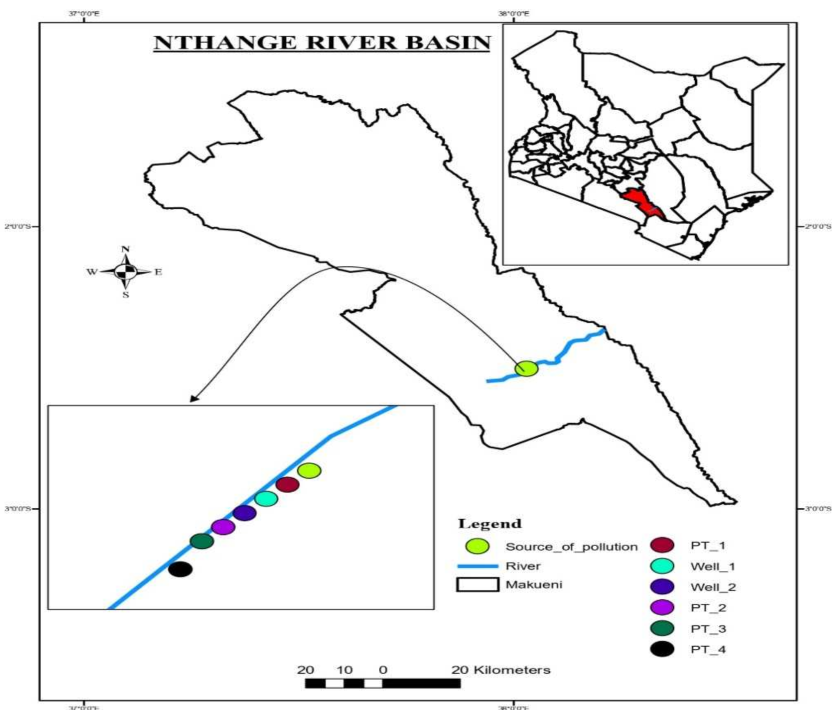

Figure 1: Quasi-experimental design of water sampling points along River Thange

Source: Researcher, 2022

The sampled points for the experimental analysis and their coordinates are summarized in Table 1.

Table 1: Summary of sampling points

Sampling Point	Latitude	Longitude
PT_1	$2^0$30'1.16"S	$38^0$1'26.41"E
PT_2	$2^0$30'0.24"S	$38^0$1'28.09"E
PT_3	$2^0$29'57.64"S	$38^0$1'28.59"E
PT_4	$2^0$29'55.97"S	$38^0$1'29.03"E
Well 1	$2^0$29'59.20"S	$38^0$1'26.59"E
Well 2	$2^0$29'58.25"S	$38^0$1'27.55"E

Source: Field data, 2022

2.3 Sampling Strategy

A sample is a smaller group or sub-group obtained from the accessible population (Mugenda and Mugenda, 2003). The sub-group is selected carefully to represent the whole population. The samples for the quasi-experimental analysis were collected from the River. The researcher collected 2 liters per sampling point using cleaned bottles at a depth of 30-60 cm, and the samples were labeled by name, date and time, and depth. The sampling points were at an interval of 50 meters apart. The samples collected were then transported to the National Central Water testing laboratories in Nairobi by road.

2.4 Data Analysis and Presentation

Data analysis is the computation of specific measures and searching for patterns among data groups (Kothari, 2004). Both qualitative and quantitative approaches were used for data analysis. The quantitative data from the questionnaires were organized, coded, and analyzed using Statistical Package for Social Sciences (SPSS) version 22.0. Both descriptive and inferential statistics were used in analyzing the data. The descriptive analysis was done using percentages and frequencies, while inferential statistics were done using Chi-Square tests and Spearman rank order correlation analysis.

Data was presented using graphs, charts, and frequency tables where appropriate to show the different household data collected. Chi-square tests were computed to show the significance levels between different variables. Correlation analysis was done to show the relationship between different variables in the study.

3 Results and discussions

Table2 shows points 1-3 from where the water sample for the heavy metals was collected for analysis.

Table 2: Sampled water points for heavy metals

Sampling Point	Latitude	Longitude
PT_1	$2^0$30'1.16"S	$38^0$1'26.41"E
PT_2	$2^0$30'0.24"S	$38^0$1'28.09"E
PT_3	$2^0$29'57.64"S	$38^0$1'28.59"E

Source: Field data, 2022

This study also sought to determine whether there were heavy metals arising from the oil spillage present in River Thange water samples drawn from 3 points, namely: Thange Source (P1), *Chiniya* SGR (P2), *Kwa Mulatya* (P3). Samples were collected, data analyzed, and the results are presented in Table 2.

Table 3: Results of analysis of heavy metals in River Thange, Makueni County

Points	Results of Analysis of Heavy Metals				
	Lead (Mg/l)	**Cadmium (Mg/l)**	**Mercury (Mg/l)**	**Chromium (Mg/l)**	**Analytical Method**
P1	0.01	<LOQ	<LOQ	0.26	M0333
P2	0.04	<LOQ	0.01	0.43	M0333
P3	0.03	<LOQ	<LOQ	0.29	M0333
KEBS standards	**0.05**	**0.005**	**0.001**	**0.05**	
WHO standards	**0.05**	**0.005**	**0.001**	**0.05**	

Source: Field Data (2022)

***LOQ-** Limit of Quantification

Data presented in Table 2 revealed the following. Study findings on the lead levels revealed that in P1,P2, and P3, the levels were at 0.01mg/l, 0.04mg/l, and 0.03mg/l, respectively. When measured against the KEBs and WHO standards, in 100% of the sampled points, levels of lead were within the acceptable standards of 0.05mg/l hence suitable for both human consumption and domestic use. According to the US EPA, however, there is no safe amount of lead in drinking water for individuals with kidney disease. In addition, EPA advances that children are at increased risk of exposure.

Study findings on the cadmium levels revealed that in P1,P2, and P3, cadmium levels were within the limit of quantification. This implies that in 100% of the points sampled, Cadmium was not detectable; hence, water was not contaminated with Cadmium. The study's findings on Cadmium agree with the US EPA, which established a Maximum Contaminant Level (MCL) of 0.005 milligrams per liter(mg/L) for Cadmium in drinking water. The Agency has found Cadmium to potentially cause various effects from acute exposures, including nausea, vomiting, diarrhea, muscle cramps, salivation, sensory disturbances, liver injury, convulsions, shock, and renal failure. Drinking water levels that are considered "safe" for short-term exposures are 0.04 mg/L for a 10-kg (22 lb.) child consuming 1 liter of water per day for one- to ten-day exposures, and 0.005 mg/L for a longer-term (up to 7 years) exposure. EPA has established a reference dose (RfD for Cadmium at – $5x10^{-4}$ mg/kg/day. The RfD is based on chronic intake, resulting in a kidney concentration of 200 µg/g. No-Observed-Adverse-Effect Level (NOAEL) for Cadmium for humans is 0.01 mg/kg/day. Cadmium has the chronic potential to cause kidney, liver, bone, and blood damage from long-term exposure at levels above the MCL. There is inadequate evidence to state whether or not Cadmium has the potential to cause cancer from lifetime exposures to drinking water.
Study findings on the mercury levels revealed that in P1 and P3,67% of sampled points were within the limit of quantification. This implies that mercury was not detectable in the two points. In P2, however, study findings revealed thatthe mercury level was 0.01mg/l. When measured against the KEBS and WHO standards, thisexceeds the acceptable threshold for drinking water of 0.001mg/l. This is indicative of contamination by mercury and hence unfit for human consumption.

Study findings on the chromium levels revealed that in P1, P2, and P3, the levels were 0.26mg/l, 0.43mg/l, and 0.29mg/l, respectively. When measured against the KEBs and WHO standards, these reveal that the chromium contamination level is beyond the set standards of 0.05mg/l. This indicates contamination by chromium in water and hence unfit for human consumption.

Study findings on the presence of heavy metals in water are in agreement with studies on water quality and heavy metals concentration conducted in the Niger Delta region (Umeoguaju *et al.*, 2021; Ejike *et al*., (2017); Ifelebuegu *et al*., (2017) and Nduka & Orsakwe (2011). In Umeoguaju *et al.*, (2021) study on the profile of heavy metals in surface and groundwater samples, the Pooled Mean Estimate (PME) from the meta-analysis indicated that the levels of Cadmium, Chromium, and Lead in the majority of the natural water bodies were higher than the WHO safe permissible limit for drinking water. The findings of the current study also concur with Ejike *et al*., (2017) study on concentrations of some heavy metals in underground water samples from a Nigerian crude oil producing community revealed the presence of cadmium chromium and lead in test and control water samples at concentrations significantly ($P < 0.05$) exceeding the maximum contaminant levels recommended by WHO. The total hazard index of the water samples showed that their consumption constituted significant health risks.

In addition, the study findings are also in agreement with Ifelebuegu *et al*., (2017) study on the environmental effects of crude oil spills on the physicochemical and hydrobiological characteristics of the Nun River, Niger Delta, whose findings indicated a significant deterioration of the river quality due to oil production activities. Heavy metals chromium, Cadmium, and lead were in breach of the national and international limits for drinking water aquatic health. They were also significantly higher than the initial baseline conditions of the River and, therefore, the need for water quality monitoring.

3. CONCLUSIONS

The general conclusion drawn from this study is that the river's water qualityand other water sources were affected by the oil spill in Thange ward, Makueni County, thus rendering it unfit for domestic purposes. This is due to the presence of heavy metals discussed in this paper which influencedthe diseases suffered by human beings in the study area.The study findings revealed that water contaminationdue to heavy metals was still present in the Thange river basin eight years after the spill. This is indicative of ineffective cleanup by concerned authorities. Therefore, through KPC, the government should ensure strict adherence to the 'polluter pays' principle, a commonly accepted practice that those who produce pollution should bear the costs of managing it to prevent damage to human health or the environment- In this case, KPC.

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