Innovations

Hydrocarbon Contamination and Heavy Metal Levels in Ground water: A Case Study of Remediated Crude oil Spill Sites in Obite, Ogba/Egbema/Ndoni Local Government Area, Rivers State

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Abstract

Introduction: The exploration and exploitation of crude oil continues to rise, there is a corresponding increase in environmental pollution due to these activities. Incidents of oil spill during oil company operations contribute to major oil spill incidents offshore and onshore. The use and distribution of crude oil around the world continues to pose a threat to the environment. **Methodology:** A cross-sectional analytical study design was used for this study. This study was carried out in Obite in Ogba/ Egbema/ Ndoni Local Government Area of Rivers State. Rivers State is one of the 36 states of Nigeria. In the year 2016, the Port Harcourt metropolis was as an estimated population of 1,865,000 inhabitants up from 1,382,592 as of 2006. The data from the laboratory was entered into SPSS version 25 for data analysis. Inferential statistics, independent T test was performed. The p-value ≤ 0.05 was considered statistically significant result. **Results:** The shows that the THC in the tap water sources was below WHO acceptable limit with a value of (<0.01 mg/l vs 3mg/l). The value of the PAH (mg/l) of the tap water was below the WHO acceptable limit with a value of (<0.001 vs 0.2 μg/L). The result also showed the concentration of Phosphate, PO_4^{3-} of tap water was higher than the WHO acceptable limit (0.17 vs 0.005 - 0.05). The Nitrate (0.4 vs 10), Arsenic (<0.001 vs 10), were below the WHO acceptable limit. Also, Mercury (<0.001 vs 0.001), Lead (<0.001 vs 0.0015), Iron (<0.001 vs 0.3) in the tap water were below than the WHO acceptable level. **Conclusion:** This study investigated the quality of drinking water from crude oil remediated sites. It found that Total Hydrocarbons (THC) and Polycyclic Aromatic Hydrocarbons (PAHs) were present in the water, although Total Hydrocarbons (THC) and Polycyclic Aromatic Hydrocarbons (PAHs) were within WHO-recommended limits.

Key words: Hydrocarbon Contamination, Heavy Metal Levels, Groundwater, Remediated Crude Oil Spill Sites

Introduction

Water makes up about 70% per cent of the human body, it is required for the metabolic functions such as digestion, absorption, nutrient dissolution, transportation and elimination of waste products, yet most of the ill health that affects humanity especially in developing countries may be traced to lack of portable water supply (Ordinioha, 2011).The exploration and exploitation of crude oil continues to rise, there is a corresponding increase in environmental pollution due to these activities (Adeola et al., 2022). Incidents of oil spill during oil company operations contribute to major oil spill incidents offshore and onshore (Taleghani, & Tyagi, 2017). The use and distribution of crude oil around the world continues to pose a threat to the environment (Prendergast & Gschwend, 2014). In Niger delta region including Rivers State, there is an increase in the water exposure to crude oil products and pollutants caused by industrial processes, exploration, and spills of crude oil (Li et al., 2020). As of 2006, the eight states in Nigeria that produce crude oil had roughly 1500 villages affected by oil spills, drilling, and processes (Ordinioha & Brisibe, 2013; Ukhurebor et al., 2021). These crude oil activities such as gas flaring, artisanal refining or Kpor fire close to residential areas and disposal of industrial wastes have increased the environmental contamination which in turn pollutes the water bodies (Ordinioha & Brisibe, 2013; Obasi, 2019).

Water contamination is a significant problem for public health that affects people of all ages all over the world. It has been established that poor water quality and water pollution are caused by the discharge of contaminants (harmful substances) into water sources. But substances like gases, liquids, and solids can contaminate water sources (Obasi, 2019). Poor drinking water quality contributes to the spread of water-borne illnesses. Recent estimates indicate that the amount of water that is readily available is drastically declining in emerging nations, particularly in South Asia, the Middle East, and Africa. Rapid urbanization, deforestation, soil degradation, etc. are all contributing factors to the rapid degradation of water quality (Obasi, 2019).

Heavy metals are largely found in disperse form in rock formations Heavy metals are natural constituents of the earth's crust, but indiscriminate human activities have drastically altered their geochemical cycles and biochemical balance (Singh et al., 2011). Their multiple industrial, domestic, agricultural, medical and technological applications have led to their wide distribution in the environment; raising concerns over their potential effects on human health and the environment. Their toxicity depends on several factors including the dose, route of exposure, and chemical species, as well as the age, gender, genetics, and nutritional status of exposed individuals. Because of their high degree of toxicity, arsenic, cadmium, chromium, lead, and mercury rank among the priority metals that are of public health significance (Tchounwou et al., 2011). These metallic elements are considered

systemic toxicants that are known to induce multiple organ damage, even at lower levels of exposure. They are also classified as human carcinogens (known or probable) according to the U.S. Environmental Protection Agency, and the International Agency for Research on Cancer. Heavy metals are naturally occurring elements that are found throughout the earth's crust, most environmental contamination and human exposure result from anthropogenic activities such as mining and smelting operations, industrial production and use, and domestic and agricultural use of metals and metal-containing compounds (Tchounwou et al., 2011). The health concerns associated with chemical constituents of water, especially water meant for drinking differ from those associated with microbial contamination and they arise mainly from the tendency of the chemical constituents to lead to serious health effects after a long time. Some chemical constituents of water can lead to health problems resulting from a single exposure, except through massive accidental contamination of drinking-water supply (WHO, 2011; SON, 2015). Chemical contaminants in water may be categorized in different ways; however, the most appropriate is to consider the primary source of the contaminant, to group chemicals according to where control may be effectively exercised. These aids in the development of approaches that are designed to prevent or minimize contamination, rather than those that rely primarily on the measurement of contaminant levels (WHO, 2011). The primary source of contaminants includes; naturally occurring chemical constituents like rock soils, the effects of the geological setting and climate, mining, sewage, solid wastes, urban runoff, fuel leakages and agricultural activities (WHO, 2011).

Problem statement

According to the World Health Organization, over 1 billion people in developing nations, including Nigeria, lack access to clean drinking water (Alkire et al., 2020). Nigeria produced over 214 billion cubic meters of surface water between 1970 and 2019 (World data atlas 2019). Despite the abundance of water in Nigeria, 66.3 million people lack access to safe drinking water and must make do with subpar water (Ighalo & Adeniyi, 2020). It is documented that most of the drinking water in Nigeria is unpurified groundwater containing pollutants and chemical contaminants such as heavy metals responsible for causing water borne diseases such as cholera and typhoid (Pandit, & Kumar, 2019).

Nevertheless, crude oil polluted water greatly impacts on the human health causing several health problems (Onakpohor et al., 2020). These communities are faced with drinking water contaminated with heavy metals (like lead, mercury, chromium, zinc, copper, cadmium, manganese, nickel) and associated with serious health problems such as anemia, kidney failure, immune suppression, neurological impairments, gastrointestinal. Also, other possible illness associated with crude oil

pollutants are irritation, skeletal system abnormalities, liver inflammation, liver cancer, cardiovascular diseases after chronic exposure and other cancer diseases with negative health effects (Raimi et al., 2022).

Aim of study

To access the hydrocarbon contamination and heavy metal level in groundwater in remediated crude oil spill sites in Obite/Egba, Ndoni local government area of Rivers State.

Objectives of study

1. Determine the total level of hydro-carbon content in the water at Obite Ogba/ Egbema, Ndoni Local Government Area of Rivers State.
2. Assess the level of heavy metal in the water at Obite Ogba/Egbema, Ndoni Local Government Area of Rivers State

Research hypothesis

1. H0: There is no significant difference between the level of hydro-carbon content in the water at Obite Ogba/Egbema, Ndoni Local Government Area of Rivers State and the standard acceptable level
2. H1: There is a significant difference between the level of hydro-carbon content in the water at Obite Ogba/Egbema, Ndoni Local Government Area of Rivers State and the standard acceptable level
3. H0: There is no significant difference between the level of heavy metal in the water at Obite Ogba/Egbema, Ndoni Local Government Area of Rivers State and the standard acceptable level
4. H0: There is a significant difference between the level of heavy metal in the water at Obite Ogba/Egbema, Ndoni Local Government Area of Rivers State and the standard acceptable level

Significance of study

By evaluating groundwater quality post-remediation, the research contributes valuable data on the success or limitations of existing cleanup methods. This information is crucial for refining and developing more effective strategies for remediating crude oil-contaminated sites. The findings can inform environmental regulations and policies, ensuring that they are based on current and comprehensive data. This can contribute to the development of more robust regulatory frameworks for the prevention and management of crude oil spills. The study adds to the scientific knowledge regarding the persistence and behavior of crude oil components in groundwater. This knowledge can be used to improve models predicting the movement and transformation of contaminants, aiding future

research in environmental science and engineering. Sharing the study results with local communities raises awareness about the quality of their groundwater. Informed communities are better equipped to advocate for their environmental rights and participate in decision-making processes related to land use and resource management. This study will serve as a critical step towards mitigating the impact of oil spills on ecosystems and communities, fostering a healthier and more sustainable future.

Methodology
Study design
A cross-sectional analytical study design was used for this study

Study area
This study was carried out in Obite in Ogba/Egbema, Ndoni Local Government Area of Rivers State. Rivers State is one of the 36 states of Nigeria. In the year 2016, the Port Harcourt metropolis was as an estimated population of 1,865,000 inhabitants up from 1,382,592 as of 2006 (Arizona & Chinedu, 2011). It is located on latitude 5°21'N and longitude 6°57'E and found as one of the states in the South-South geopolitical zone and Niger Delta states. Ogba/Egbema, Ndoni is one of the 23 Local Government Areas in Rivers State. Omoku is the headquarters of Ogba/Egbema/Ndoni is one of the most beautiful cities in Rivers State, with about 283,294 people according to the 2006 census and 398,000 2016 projection. It is bounded by Imo, Delta Bayelsa, Abia, and AkwaIbom States and also by Ahuda west, Ahuda east, and Emohua LGA of Rivers State, they are part of Igbo speaking area of Rivers States with three tribes starting with ogba as the dominant tribe with 12 legislative wards and the Egbema and Ndoni tribes with 2and 3 legislative wards respectively making it a total of 17 wards, 67 communities, 27 health facilities,3general hospitals 13 private clinics, 74 government secondary schools, 82 primary schools both government and privates. There are churches of different denominations, markets, and a tertiary institution (Federal College of Education, Omoku).

Population of study
The public groundwater sources in remediated crude oil spill sites in Obite in Ogba/Egbema, Ndoni Local Government Area of Rivers State.

Inclusion criteria
1. Public tap water source for drinking in remediated crude oil spill sites in Obite in community of Ogba/Egbema, Ndoni Local Government Area of Rivers State.

Exclusion criteria
1. Private boreholes in individual houses in in remediated crude oil spill sites Obite community of Ogba/Egbema, Ndoni Local Government Area of Rivers State.
2. Bottled water and Sachet water in Obite community of Ogba/Egbema, Ndoni Local Government Area of Rivers State.

Sample size
Two samples were collected from the drinking water sources in the community.

Sampling technique
Multi-stage sampling method was used in this study.

The different stages include:
Stage 1: Identificationof13 wards in Ogba/Egbema, Ndoni Local Government Area
Stage 2: Selection of 2 wards from 13 wards in Ogba/Egbema, Ndoni by simple random sampling method of balloting (wards in Obite was selected)
Stage 3: Water samples were collected from 2 taps for drinking in the wards in Obite

Study instruments
One (1) liter plastic bottle was used to collect water samples from the taps water.
The water samples were collected in sterile one (1) liter plastic bottle and stored in iced lined coolers, then transported to the laboratory for analysis.

In the laboratory, the following equipment were used to analyze the water samples:
- A pH meter (Extech product) with buffer solution, reagent and a colour coded chat.
- DR/890 Colorimeter
- A Nephelometer (Hach 2100Q portable turbidimeter).
- A Copper/Iron metal test strip kit.
- Durhams tube.
- An Atomic Absorption Spectrophotometer (AAS) (Parkin Elmer 5100 PC).

Reliability and validity of study instruments
The laboratory equipment was ensured to be in a good condition and was calibrated for accurate measurement. A checklist was used for the sanitary survey of the water source environment.

Measurement of pH, Salinity, Temperature and Conductivity
A pH meter (Extech product) with buffer solution, reagent and a colour coded chat was used to determine these parameters. The pH meter works with a litmus battery and properly calibrated before use with buffer solution, it also has a sensor that detects the values, the pH meter mode is used to do the selection for the results. The chat with reagent is also used to verify the pH.

3.6.2 Measurement of Apparent and True Color
The apparent and true color of each water sample was determined using the LaMotte (Color) model LTC3000e basic unit USB color meter using 200ml of the water sample.

3.6.3 Total Dissolved Solids (TDS)
TDS was measured using Orion 3 Star instrument, 100 millilitres of each sample was poured into a 250 ml beaker. The probe was then immersed in the sample and the value read on the digital screen.

3.6.4 Measurement of Turbidity
Turbidity of the water samples was measured in-situ with a microprocessor turbid meter HACH 2100Q. The instrument was first calibrated by dipping the probe into standard solution with turbidity values of 0.00 and 10.00 Nephelometric Turbidity Unit (NTU) and calibrated before using the turbidity values of the samples.

3.6.5 Measurement of Iron and Copper
A Copper/Iron metal test strip kit was used to measure the copper and iron content in the water samples. For each, 15mls of the water sample was poured into the calibrated beaker. For Iron assessment, a tablet was added and stirred with a rubber spatula for faster dissolution, then a white test strip was dipped into the sample solution and left for 15 minutes before it was matched on the bottle with color codes for interpretation. While for copper assessment, no tablet was added, just the test strip was inserted into the sample in the beaker and interpreted after 15minutes.

3.6.6 Determination of metals (Lead, Sulphate, Cadmium and Arsenic)
Fifteen millilitres (15 ml) of concentrated HNO_3 were added to 50 ml of each sample collected. The mixture was heated slowly to evaporate to a lower volume of 15-20ml after which 5 ml of concentrated HNO_3 was again added to 15 ml of the mixture obtained. The mixture was then diluted to 50 ml with distilled water. This was then heated slowly to obtain a gentle refluxing action. Further heating continued until digestion was complete (a light-coloured solution). The sample was then transferred

to a 50 ml volumetric flask and diluted to the mark after allowing it to cool for about 30 minutes.

The levels of individual metals were then determined using an Atomic Absorption Spectrophotometer (AAS) (Parkin Elmer 5100 PC). The absorbance of the standards and samples as well as the blank solution was at 193.7mm. Sensitivity for 1% absorption was 2.5 ug/l. A calibration curve was constructed and then concentration equivalent to the absorbent of the sample was read from the curve and was recorded accordingly.

Determination of Chloride, Alkalinity and Acidity levels of the water sample

Titration methods were used. 50 mls of the water sample was poured into a conical flask for each analysis. For chloride test, 10 drops of potassium dichromate indicator were added to the water sample, the burette was filled with silver nitrate solution. Initial reading was taken, 0.1 ml was titrated at a time before the final reading was taken. The colour change from yellow to brick red was noted. For Alkalinity test, 2-3 drops of methyl orange indicator were added to the water sample, the burette was filled with sulfuric acid solution. Initial reading was taken, 0.1 ml was titrated at a time before the final reading was taken. The colour change from yellow to orange was noted.

For Acidity test, 2-3 drops of phenolphtaleine indicator were added to the water sample, the burette was filled with sodium hydroxide solution. Initial reading was taken, 0.1 ml was titrated at a time before the final reading was taken. The colour change from colourless to pink was noted.

All the final readings were multiplied by 20, to convert to milligrams per litre.

Method of data collection

A sanitary survey was conducted in the selected wards to identify the source of drinking water and potential sources of contamination of the various sample collection point. Sample collection was done in one day. Public drinking water sources (taps) in the community were collected with sterile 1 liter plastic bottles. About 2.5cm space was left in the container to enable mixing of particles inside the water by shaking. Samples were collected in non – reactive plastic bottles that was initially sealed, it was opened, and rinsed carefully with the source of water. The samples were properly labelled at the same point of collection and stored in a container at a room temperature. The water samples were stored in iced lined cooler for transportation to the laboratory within 24 hours for analysis. The researcher employed the services of 2 research assistants who were trained on the purpose of the study and collection of data. These research assistants proved to have good knowledge of the study, and conversant with the study location.

Data analysis
The data from the laboratory was entered into SPSS version 25 for data analysis. Inferential statistics, independent T test was performed. The p-value ≤ 0.05 was considered statistically significant result.

Ethical approval
Ethical clearance for the study was gotten from the Research and Ethics Committee of the University of Port Harcourt. Informed consent was obtained from the community leaders and was ensured that the data collected would be kept confidential and only be used for academic purpose.

Results

Sources of drinking water for public use

Table 1: Sources of drinking water for public use

Variables	Frequency (n=16)	Percentage (%)
Tap/Borehole	2	12.5

Table 1 showed that 2(12.5%) of the drinking water is sourced from the general or public tap.

Table 2: Distance of water source from the household

Variables	Frequency (n=16)	Percentage (%)
Distance of the house to water source is 5-15 minutes	2	100
Less than 100 meters distance of tap from houses	2	100

Table 2 indicated that the distance of the tap from houses is 5-15 minutes, and water is located less than 100 meters from the households.

Table 3: Structure of tap water

Variable	Frequency(n=2)	Percent (%)
Tap water has concrete plastering	1	50
Taps have a drain		
No	2	100.0
Sanitary condition		
Unsanitary	2	100.0

Table 3 indicated that the half (50%) of the sampled tap water source has concrete plastering. The result showed that all the sampled tap water sources do not have a drainage. However, the sanitary condition of the tap was poor, thus unsanitary.

Objective 1: Level of hydrocarbon content in water

Table 4: Level of hydrocarbon content in drinking water (Tap Water)

S/N	Parameter (s)	Public Tap 1	Public Tap 2	WHO
1.	THC (mg/l)	<0.01	<0.01	3mg/l
2.	PAH (ug/l)	<0.001	<0.001	0.2 µg/L

Table 4 shows that the THC in the tap water sources was below WHO acceptable limit with a value of (<0.01 mg/l vs 3mg/l). The value of the PAH (mg/l) of the tap water was below the WHO acceptable limit with a value of (<0.001 vs 0.2 µg/L).

Table 5: Mean and STD of laboratory analysis of hydrocarbon content in drinking water (Tap Water)

Variable	Tap water 1	Tap water 2	Mean±SD
THC (mg/l)	<0.01	<0.01	0.01±0.0
PAH (ug/l)	<0.001	<0.001	0.001±0.0

Table 5: shows mean and standard deviation of the THC (mg/l) and PAH (ug/l) parameters of the drinking water (Tap) were 0.001±0.0 for each.

Table 6: t-test of difference in chemical parameters of the drinking water (Tap Water)

Parameters	Mean	SD	Mean Difference	df	P-value	t-test	95% Confidence Interval of the Difference	
							Lower	Upper
THC	1.5050	2.11425	1.50500	1	0.498	1.007	17.4908	20.5008
PAHs	.1005	.14071	.10050	1	0.497	1.010	1.1638	1.3648

P≤0.05 (statistically significant)

Table 6 shows there was no statistically significant difference in THC (p=0.498) in water samples and the WHO/National acceptable level. Also, there was no statistically significant difference in the PAHs in water samples and the WHO/National acceptable level.

Objective 2: Level of heavy metal in the water in water
Table 7: Level of heavy metal in the water (Tap Water 1)

S/ N	Parameters	Tap Water (1)	WHO
1.	Phosphate, PO_4^{3-}(mg/l)	0.17	0.005 - 0.05
3.	Nitrate, NO_3^- (mg/l)	0.4	10
4.	Arsenic, As (mg/l)	<0.001	10
5.	Mercury, Hg (mg/l)	<0.001	0.001
6.	Lead, Pb (mg/l)	<0.001	0.0015
7.	Iron, Fe (mg/l)	<0.001	0.3

Table 7 shows that the concentration of Phosphate, PO43- of tap water was higher than the WHO acceptable limit (0.17 vs 0.005 - 0.05). The Nitrate (0.4 vs 10), Arsenic (<0.001 vs 10), were below the WHO acceptable limit. Also, Mercury (<0.001 vs 0.001), Lead (<0.001 vs 0.0015), Iron (<0.001 vs 0.3) in the tap water were below than the WHO acceptable level.

Table 8: Level of heavy metal in the water (Tap Water 2)

S/N	Parameters	Tap Water 2	WHO
1.	Phosphate,PO_4^{3-}(mg/l)	0.43	0.005 - 0.05
2.	Nitrate,NO_3^-(mg/l)	1.1	10
3.	Arsenic,As(mg/l)	<0.001	10
4.	Mercury,Hg(mg/l)	<0.001	0.001
5.	Lead,Pb (mg/l)	<0.001	0.0015
6.	Iron,Fe(mg/l)	0.066	0.3

Table 8 shows that the concentration of Phosphate, PO43- of tap water was higher than the WHO recommended limit (0.43 vs 0.005 - 0.05). The Nitrate (1.1 vs 10), Arsenic (<0.001 vs 10) were below the WHO acceptable limit. Also, Mercury (<0.001 vs 0.001), Lead (<0.001 vs 0.0015), Iron (0.066 vs 0.3) in the tap water were below than the WHO recommended level.

Table 9: t-test of difference in chemical parameters of the drinking water (Tap Water)

Parameters	Mean	SD	Mean Difference	df	P-value	t-test	95% Confidence Interval of the Difference	
							Lower	Upper
Phosphate	.0010	.00000	.08750	1	.481	1.061	0.9608	1.1358
Nitrate	.0010	.00000	5.20000	1	.475	1.083	55.7898	66.1898
As	.0875	.11667	5.00050	1	.500	1.000	58.5242	68.5252
Pb	330.2500	381.48411	.00125	1	.126	5.000	0.0019	.0044
Fe	5.2000	6.78823	.16925	1	.419	1.294	1.4921	1.8306

P≤0.05 (statistically significant)

Table 9 shows there was no statistically significant difference in Phosphate, Nitrate, Arsenic, Lead and Iron in water samples and the WHO/National acceptable level.

Discussion

Level of hydro-carbon content in the water

Finding in this study showed that there is presence of THC in the drinking water sources gotten from the crude oil remediated sites, but was below WHO recommended limit. Similarly, there was presence of the PAH (mg/l) in the drinking water gotten from the crude oil remediated sites, however, it was lower than the WHO acceptable limit. The mean and standard deviation of the THC (mg/l) and PAH (ug/l) parameters of the drinking water (Tap) were lower than the acceptable values. The finding revealed that there was no statistically significant difference in THC in water samples and the WHO/National acceptable level. Also, no statistically significant difference in the PAHs in water samples and the WHO/National acceptable level. Finding in the present study is in line with finding Adeniji et al., (2017) in the Eastern Cape Province, South Africa who reported that total mean concentration of TPH in all the sites was lower than the EU acceptable standard limit for hydrocarbons in estuary and harbour basin water. This present finding is consistent with finding by (Utona, & Horsfall, 2008) who reported that the concentration of petroleum hydrocarbon in water of New Calabar River ranged from with mean level of 0.26. Zone C has the highest concentration of while Zone F is the lowest with 0.033mg-1. Thus, it was lower than the WHO recommended limit. The similarity between the current finding and finding in the previous study may be linked to the amount of crude oil spillage, level and type of crude oil remediation. Based on result, it can be inferred that there is presence of THC and PAHs in the drinking water gotten from the crude oil remediated sites, but were below WHO recommended limit.

Level of heavy metal in the water

This present study found that the concentration of Phosphate, PO4^{3-} of gotten from the crude oil remediated sites were higher than the WHO acceptable limit. This is similar to concentrations of Nitrate and Arsenic in the drinking gotten from the crude oil remediated sites were below the WHO acceptable limit. Also, the amounts of Mercury, Lead, Iron, in the drinking water gotten from the crude oil remediated sites were less than the WHO recommended level. The finding revealed that there is no statistically significant difference in Phosphate, Nitrate, Arsenic, Lead, Iron in water samples and the WHO/National acceptable level. However, the finding implies that the residents are exposed to health conditions associated with high amounts of Phosphate. There is Appiah-Opong et al., (2021) in drinking water along the southwest coast of Ghana. The ranges of metal concentration in water in the wet season were; As (1.23–7.84 µg/L), Cu (4.10–24.09 µg/L), Pb (4.08–57.98 µg/L), Se (BDL–0.38 µg/L), Zn (2.86–17.75 µg/L) and Hg (0.023–0.068 µg/L), whereas the ranges of metal concentration in the dry season were; As (2.30–5.78 µg/L), Pb (25.47–70.73 µg/L), Se (0.081–0.158 µg/L), Zn (79–22.80 µg/L) and Hg (0.004–0.047 µg/L). These findings were below the WHO recommended level. There is consistency between present finding Cobbina et al., (2015) in Northern Ghana. The study revealed that mercury concentrations in water samples from Nangodi ranged from 0.001 to 0.191 mg/L with a mean of 0.038 ± 0.001 mg/L, whilst levels recorded in Tinga ranged from 0.010 to 0.259 mg/L with a mean concentration of 0.064 ± 0.007 mg/L. Arsenic concentrations in the water samples from Nangodi ranged from 0.001 to 0.115 mg/L with a mean of 0.031 ± 0.005 mg/L. Samples from Tinga ranged from 0.001 to 0.003 mg/L with a mean concentration of 0.002 ± 0.001 mg/L for arsenic. The lead concentrations in samples from Nangodi ranged from 0.005 to 0.791 mg/L with a mean of 0.250 ± 0.008 mg/L, however, samples from Tinga recorded lead concentrations ranging from 0.001 to 0.227 mg/L with a mean of 0.031 ± 0.001 mg/L. The zinc concentrations recorded in samples from Nangodi ranged from 0.005 to 0.786 mg/L with a mean of 0.034 ± 0.001 mg/L. Samples from Tinga recorded zinc values that ranged from 0.001 to 0.005 mg/L with mean concentration of 0.003 ± 0.001 mg/L. The cadmium concentrations obtained from Nangodi samples ranged from 0.001 to 2.227 mg/L with a mean of 0.534 ± 0.088 mg/L. Samples from Tinga recorded cadmium concentrations that ranged from 0.002 to 0.071 mg/L with a mean concentration of 0.023 ± 0.008 mg/L. The findings were below and within the WHO recommended level. The agreement between the current finding and finding in the previous study may be attributed to the level of crude oil spillage and water exposure to crude oil, type of crude oil remediation and environmental cleaning. From the result, it can be deduced that the concentration of Nitrate, Arsenic, Mercury, Lead, Iron in the drinking water gotten from the crude oil remediated sites

were less than the WHO recommended amount, while amount of Phosphate was greater than the WHO recommended level.

Conclusion

This study investigated the quality of drinking water from crude oil remediated sites. It found that Total Hydrocarbons (THC) and Polycyclic Aromatic Hydrocarbons (PAHs) were present in the water, although Total Hydrocarbons (THC) and Polycyclic Aromatic Hydrocarbons (PAHs) were within WHO-recommended limits. The mean and standard deviation values for THC and PAHs in tap water met acceptable standards, and there were no statistically significant differences concerning WHO and national standards.

Recommendation

- Although the study found acceptable levels of heavy metals like Mercury, Lead, and Iron, continuous monitoring and adherence to recommended limits are essential to safeguard public health.
- There should be involvement of the local community members in decision-making processes and management of drinking water sources to ensure sustainability and promote a sense of ownership.

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