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Assessing Environmental Impact and Socioeconomic Consequences of Oil and Gas Spillage on Soil in Warri, Southern Nigeria

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ABSTRACT: *The Niger Delta terrain is often prone to environmental degradation resulting from oil and gas spillage. This research aims to assess the environmental impact of oil and gas spillage on the soil of Warri, Southern Nigeria, by utilizing physicochemical properties, statistical analysis, and socioeconomic information to evaluate the impact of heavy metals in the study area. A total of six (6) soil samples were collected and examined with the aid of an atomic absorption spectrometer (AAS) using a procedure that adheres to World Health Organization (WHO) standards. Concentration levels of Sodium (Na), Potassium (K), Calcium (Ca), Magnesium (Mg), Exchangeable Acidity (EA), Exchangeable Cation Exchange Capacity (ECEC), Total Petroleum Hydrocarbons (TPH), Zinc (Zn), Copper (Cu), Iron (Fe), Cadmium (Cd), and Lead (Pb) were analyzed and found to range from (21.1-74.98) ppm, (23.46-105.57) ppm, (128-1442) ppm, (58.80-341.60) ppm, (0.25-13.50) ppm, (11.51-14.78) ppm, (11.30-226.34) mg/kg, (98.26-122.60) mg/kg, (10.10-18.43) mg/kg, (321.86-994.04) mg/kg, (0.26-0.50) mg/kg, (0.4-1.15) mg/kg, respectively. The research revealed that the soil pH ranged from highly acidic to slightly acidic, which can negatively affect nutrient availability and plant growth. The research also highlighted the detrimental impact of oil spillage on the health, livelihood, amenities, and socioeconomic state of affected communities. Agricultural produce, crop yield, and livestock production were negatively affected due to poor soil fertility and damage to water bodies. Basic amenities were polluted, leading to abandonment and contamination of drinking water. The social environment of these communities experienced setbacks in occupation, income, and education. The findings provide valuable insights into soil characteristics and contamination levels and also show that regular soil quality monitoring and assessment are essential to detect any degradation in soil quality in the examined area.*

KEYWORDS: Soil impact, Physiochemical properties, heavy metal, Environmental degradation, Niger Delta terrain.

INTRODUCTION

The exploration and production of oil and gas resources in Nigeria's South-south region have been major sources of economic growth and development for the country. However, the oil and gas industry has also been associated with negative environmental impacts, particularly the contamination of soil, water, and air through oil spills and gas flaring (Adeola *et al*., 2022).. Elekwachi *et al.*, 2022 stated that insufficient servicing and poor maintenance of the oil and gas equipment such as preventer blowout, wellhead, flow lines or pipelines, sabotage, accidental and equipment failures by the oil companies. Between 1976 and 1997, there were 5,334 reported cases of crude oil spillages releasing about 2.8million barrels of oil into the land, mangroves, waterways, estuaries, and coastal regions of Nigeria (Dublin-Green *et al*, 1998; Elekwachi *et al.*, 2022; Orish 2021; Sakib 2021). Crude oil spillage can cause a reduction of the available nutrients in the soil and add some toxic elements, which results in the death of plants and diminished soil fertility (Aghalino, 2000). In recent years, there has been growing concern about the environmental impact of oil and gas activities in the region, particularly the impact of oil spillage on the soil. Oil spillage can have severe and long-lasting impacts on soil quality and fertility, as well as the health and livelihoods of the local communities that depend on the land for their survival. Environmental impact assessment (EIA) is a tool used to identify and evaluate the potential environmental impacts of development projects, including oil and gas exploration and production activities. This tool provides a framework for assessing the potential environmental impacts of a project and identifying appropriate measures to mitigate or prevent those impacts. Crude oil pollution has deleterious effects on plant growth, soil macronutrients, microorganism and the terrestrial ecosystem in general (Correa 2022). As a result of crude oil pollution, soil physical properties such as pore spaces might be clogged, thereby reducing soil aeration, infiltration of water into the soil, and increased bulk density of the soil, which may affect plant growth (Okpowasili and Odokuma, 1990). This study focuses on the environmental impact assessment of soil contamination resulting from oil spillage in parts of Warri, Delta state. The aim of this study is to examine the environmental impact of oil and gas spillage on the soil of Warri, Southern Nigeria, using physicochemical parameters, statistical analysis, and socioeconomic data (Figure 10) to estimate the impact of heavy metals in the studied region and identifying appropriate measures to mitigate or prevent further contamination. Addressing these problems requires a comprehensive environmental impact assessment that analyzes the extent of soil contamination, evaluates its ecological and health impacts, and develops suitable strategies for remediation and prevention. Such an assessment will contribute to sustainable development, the preservation of the region's ecosystems, and the well-being of its inhabitants.

Location of the Study Area

The city of Warri is an oil hub within South-South Nigeria, with coordinates of 5^{o}31'N and 5^{o}45'E, and houses an annex of the Delta State Government House (Figure 1). Warri City is one of the major hubs of the petroleum industry in Nigeria. It is the commercial capital city of Delta State,

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with a population of over 311,970 people in 2006. The city is the indigenous territory of the Urhobo, Itsekiri, and Ijaw people. Warri sits on the bank of the Warri River, which joined the Focados River and the Escravos River through Jones Creek in the lower Niger-Delta Region (Figure 1). The city has a modern seaport, which serves as the cargo transit point between the Niger River and the Atlantic Ocean for import and export (Okoh and Oghenetoja, 2016).

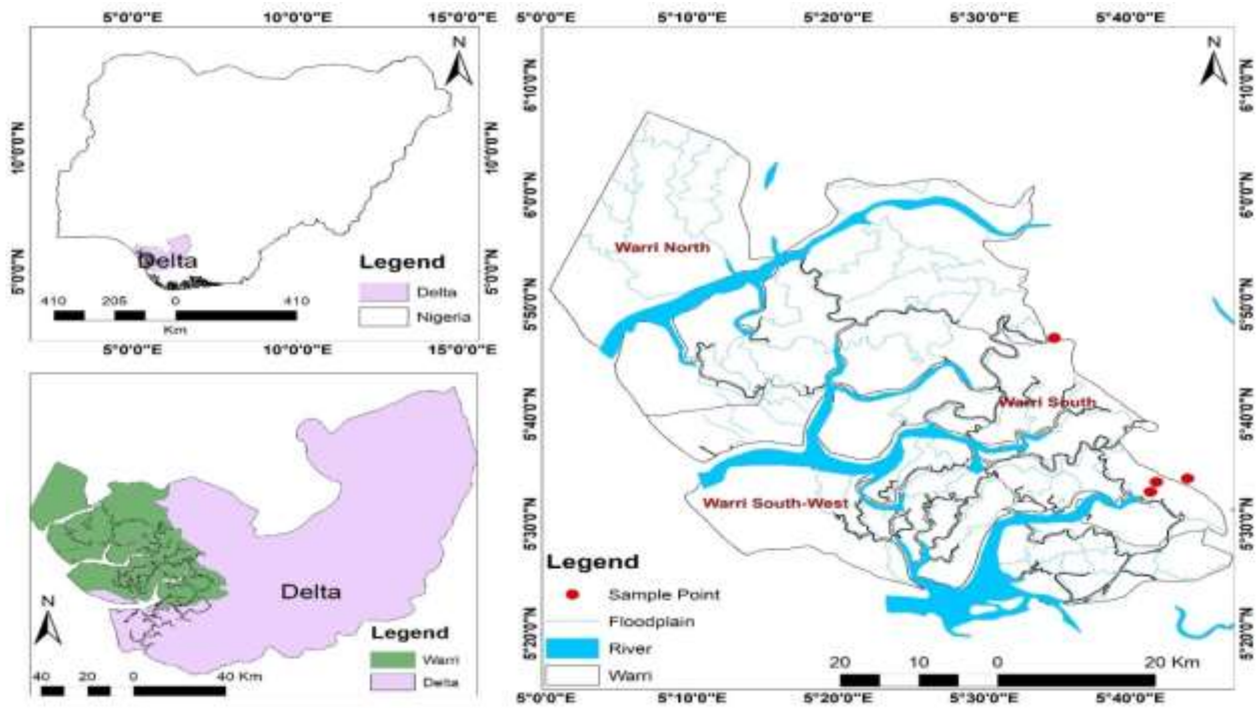

Figure 1: Map of Delta State showing study area

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Figure 2: Sample Location 1

Figure 3: Sample Location 2

Figure 4: Sample Location 3

Figure 5: Sample Location 4

Figure 6: Sample Location 5

Figure 7: Sample Location 6

MATERIALS AND METHODS

Soil samples were collected (Figure 8) with the aid of a well-calibrated stainless-steel hand-dug soil auger (2.50 cm in diameter) from six (6) sampling points at a depth of 0–30 cm from a contaminated site within the same study area (figure 2, 3, 4, 5, 6 and 7). The soil samples were immediately transported to the laboratory for standard chemical analysis. This was done in line with ISO Standards (the International Organization for Standardization ISO).

Determination of pH

About 20g of air-dried soil samples were weighed into a 50mL beaker and 20mL distilled water was added and allowed to stand for 30mins. The solution was filtered and the filterate used to determine pH of soil sample. Meter was calibrated using pH calibration buffer solution for pH 4, 7 and 10. The electrode of the meter was dipped into the filtrate and the pH meter readings taken to the nearest 0.05unit.

a) Determination of conductivity

Twenty grams of air-dried soil samples were weighed into a 50-mL beaker, and 20 mL of distilled water was added and allowed to stand for 30 minutes. The solution was filtered, and the filtrate was used to determine the conductivity of the soil sample. A conductivity meter was used

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to determine the conductivity. The conductivity meter was calibrated using a conductivity calibration solution. The electrode of the meter was dipped into the filtrate, and the conductivity meter readings were taken to the nearest 0.05 unit.

b) Determination of heavy metals

One gram of the dried fine soil sample was weighed and transferred into an acid-washed, round-bottom flask containing 10 cm3 of concentrated nitric acid. The mixture was slowly evaporated over a period of 1 hour on a hot plate. Each of the solid residues obtained was digested with a 3:1 concentrated HNO_3 and $HClO_4$ mixture for 10 minutes at room temperature before being heated on a hot plate. The digested mixture was placed on a hot plate and heated intermittently to ensure a steady temperature of 150°C over 5 hours until the fumes of $HClO_4$ were completely evaporated. The mixture was then allowed to cool to room temperature and then filtered using Whatman No. 1 filter paper into a 50 cm3 volumetric flask and made up to the standard mark with deionized water after rinsing the reacting vessels to recover any residual metal. The filtrate was then stored in pre-cleaned polyethylene storage bottles, ready for analysis. Heavy metal concentrations were determined, each with a specific lamp, using an Atomic Absorption Spectrophotometer (AAS) AA600 Series.

c) **Determination of Total Petroleum Hydrocarbon (TPH) in soil**

Ten grams (10g) of the sample were weighed into an extraction bottle, and 20 mL of extraction mixture (DCM, hexane, and acetone) in a ratio of 2:2:1 was added. The mixture was sonicated for 1 hour, and the organic aqueous layer was decanted. The extracted organic phase was dried using anhydrous sodium sulfate salt and concentrated using vacuum rotary evaporator gas to about 1.0 mL.A round-bottom flask was rinsed to make the final volume of the extract 1.0 ml. One microliter (1.0 µL) of the final extract was injected into an already calibrated gas chromatograph (HP 5890, USA) equipped with a capillary column. The peak areas are used in the quantifications.

All QA/QC procedures were strictly followed. The extract was fractionated by using column packing. The column was packed by placing 1 gram of glass wool into the column and gently packing. One milliliter (1 ml) of silica gel was placed on it, and 1 ml of sodium sulfate was added on top of the silica gel. The column was pre-conditioned by running 10 mL of n-hexane through it. One milliliter (1 mL) of the concentrated extract was placed on the column and eluted with 10 mL of n-hexane. Eight milliliters (8 mL) of the eluents were taken and discarded, and the remaining 2 mL was collected and kept in a 2 mL vial for aliquots. In the same column, 10 mL of DCM was allowed to drain through the column, and 8 mL of the eluent was collected and discarded. The remaining 2 mL was collected into a vial and kept for AROMATICS. One microliter (1.0 µL) of the aromatic and aliphatic extract was injected into an already TPH-calibrated standard GC, and the result was expressed in mg/kg.

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d) Determination of Cation Exchange Capacity of the soil samples

The method used by Burt was adopted. Ten (10g) grams of air-dried soil ground to less than 2 mm were weighed and placed into a 250 ml beaker. Twenty-five milliliters (25 mL) of NH4OAc were in the soil. It was covered and left to set overnight. For each sample, a 7-cm Buchner funnel was prepared by fitting it with a 7-cm Whatman No. 42 filter paper. The filter was wetted with a minimum amount of NH4OAc. The funnel was inserted into a 250-ml suction flask. The vacuum pump was turned on to seat the moistened filter. The soil-NH4OAc mixture was stirred and transferred into the filter. Approximately 75 mL of NH4OAc for each sample was measured into a plastic squirt bottle, with one bottle for each sample. The above was used in the bottle to transfer all of the soil to the Buchner funnel. The soil was covered with a 7.0 cm Whatman No. 1 filter paper to keep the soil moist between leaching. The soil was leached 5 to 7 times with 10 to 15 ml increments of NH4OAc. The leachate was transferred to a 250-mL volumetric flask and brought to volume with 1 M NH4OAc. The solution was analyzed for Ca, Mg,
K, and Na using atomic absorption spectrophotometry.

e) Other parameters

Other parameters such as temperature (OC) and conductivity (µsdm-3) were measured in situ using a portable pH/Eh meter (WTW 90) and a conductivity-temperature meter (Hach instrument) in soil or water. Base saturation was estimated as a sum of exchangeable basic cations by ECEC and expressed in percentage.

f) Interview and Questionnaires

Residents of the host community were engaged in interviews and questionnaires administered to determine the effects of oil spillage in the community. The study employed a questionnaire to acquire data relating to environmental pollution in Warri Township. Eighty (80) copies of the questionnaire were administered to the residents of the Warri community using the random sampling technique, which gives room for an equal chance of any resident that was chosen in the study area, but only seventy-six (76) questionnaires were retrieved, and all further statistical analyses were based on the retrieved questionnaire. Descriptive statistics were used to explain the frequencies of the variables in terms of their percentage. The results of the analysis were presented using tables and graphs such as pie charts and bar charts, among others. The questionnaires were structured in such a way that they captured a large range of stakeholders in the community. This was based on the under listed structures:

Section A: Demographic Survey on household heads.
Demographic Survey; this section will focus more on the age range, occupation, gender, and education level of the residents of the community. (figure 9 and 10)
Section B: Environmental Exposure Questions (EEQs)

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Section C: Survey on Health Practitioners and Providers in the Community (figure 11 and table 3).

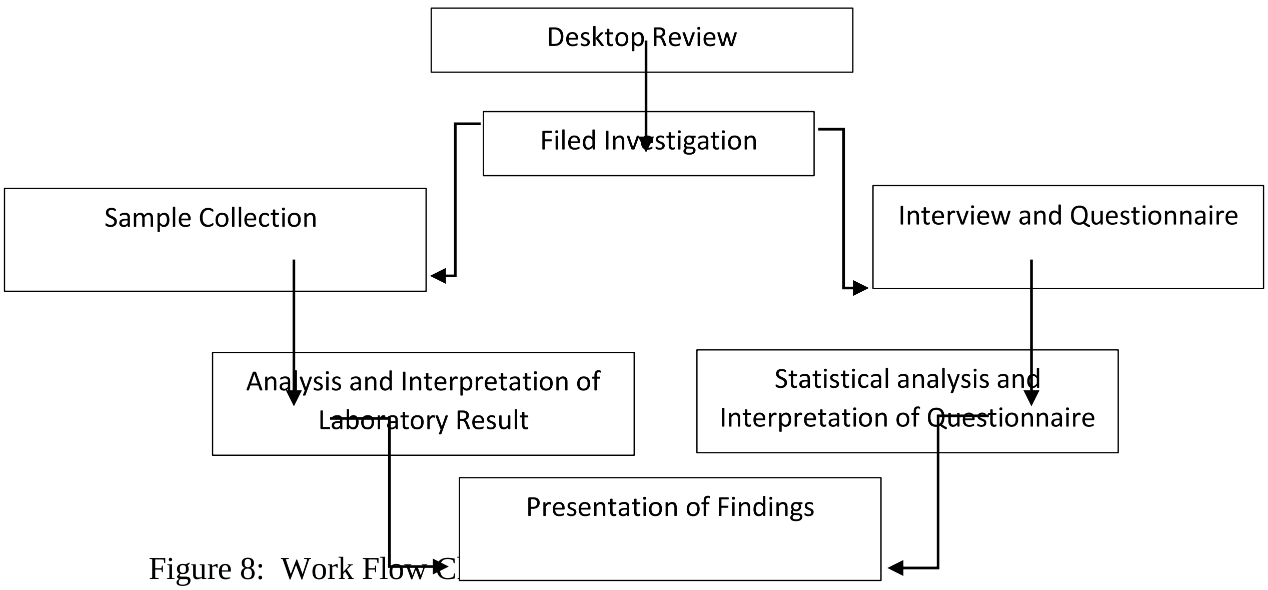

Figure 8: Work Flow C

RESULT AND DISCUSSION

Laboratory Result

Table 1.0: Result for Physiochemical & heavy metals analysis

PARAMETERS	UNITS	S1	S2	S3	S4	S5	S6	Mean
Ph		7.0	3.35	6.90	5.75	5.333	3.26	5.2655
Na	Ppm	31.97	21.16	74.98	42.703	46.28	21.1	39.698
K	Ppm	105.57	23.46	68.425	65.818	52.56	23.91	56.623
Ca	Ppm	1410	128	1442	993.33	854.4	133	826.78
Mg	Ppm	456	58.8	510	341.6	303.4	59.1	288.15
EA	Ppm	0.25	13.50	0.25	4.6666	6.138	12.1	6.1507
ECEC	Ppm	11.51	14.78	12.21	12.833	13.27	12.1	12.783
Organic Carbon	%	0.704	3.76	0.864	1.776	2.133	3.26	2.0828
TPH	Mg/kg	138.11	11.509	226.34	125.31	121.0	11.30	105.59
Zn	Mg/kg	122.6	98.76	118.59	113.31	110.2	98.26	110.28
Cu	Mg/kg	14.29	10.3	18.43	14.34	14.35	10.1	13.635
Fe	Mg/kg	321.86	994.04	683.40	666.43	781.2	991.04	739.66
Cd	Mg/kg	0.35	ND	0.50	0.2833	0.261	ND	0.3485
Pb	Mg/kg	0.98	0.40	1.15	0.8433	0.797	0.40	0.7617

Table 2: Socio-Economic Information of the Residents

Table 3: Frequency of sickness among respondents.

No of Times	Frequency	Per cent (%)
Once in a month	28	36.8
Twice in a month	21	27.6
Thrice in a month	10	13.2
More than thrice in a month	4	5.3
No Idea	13	17.1
Total	76	100.0
Sex	**Frequency**	**Percent (%)**
Male	45	59.2
Female	31	40.8
Total	76	100.0
Age	**Frequency**	**Percent**
0-18	5	6.6
19-35	37	48.7
36-50	29	38.2
51 and above	5	6.6
Total	76	100.00
Marital Status	**Frequency**	**Per cent (%)**
Single	39	51.3
Married	36	47.4
Others	1	1.3
Total	76	100
Education	**Frequency**	**Per cent (%)**
Primary Education	1	1.3
Secondary Education	20	26.3
Tertiary Education	55	72.4
Total	76	100

Table 4: The impact of the oil and gas spillage on soil

Impacts of soil pollution	Frequency	Per cent (%)
Corrosion of metals	3	3.9
Contaminated Food & Water	10	13.15
Stunted growth of plants	53	69.79
Soil Erosion and Degradation	10	13.15
Total	76	100

Table 5: Awareness of the impacts of pollution on environmental resources

Impacts on crop and plant	Frequency	Per cent (%)
No Damage	3	3.9
Partial Damage	47	61.8
Total Damage	26	34.3
Total	76	100
Impacts on Food and Water	Frequency	Per cent (%)
No Damage	6	7.9
Partial Damage	49	64.5
Total Damage	21	27.6
Total	76	100
Impacts on livestock and Animals	Frequency	Per cent (%)
No Damage	3	3.9
Partial Damage	44	57.9
Total Damage	29	38.1
Total	76	100

Table 6: WHO permissible limits for heavy metals in plant and soil.

Elements	*Target value of soil (mg/kg)	***Permissible value of plant (mg/kg)
Cd	0.8	0.02
Zn	50	0.60
Cu	36	10
Cr	100	1.30
Pb	85	2
Ni	35	10

*Target values are specified to indicate desirable maximum levels of elements in unpolluted soils. Source: Denneman and Robberse 1990; Ministry of Housing, Netherlands 1994
***Source: WHO (1996),

DISCUSSION OF LABORATORY RESULTS

The pH scale ranges from 0 to 14, with 7 being neutral. A pH value below 7 indicates acidic soil, while a pH above 7 indicates alkaline soil. The correct balance is when the soil pH is between 5.5 and 7.5. In higher rainfall areas, the natural pH of soils typically ranges from 5 to 7, while in drier areas, the range is 6.5 to 9 (Queensland Laboratories, 2023). The pH of samples from the study area ranged from 3.26 to 7.0, with a mean value of 5.26. The average pH across the study area is therefore below the recommended limit, with samples 2, 5, and 6 being highly acidic. Highly acidic soil can create nutrient imbalances by reducing the availability of certain essential nutrients. Acidic soil conditions can increase the solubility of elements like aluminum, manganese, and iron, which can be toxic to plants in excessive amounts, while reducing the availability of macronutrients like phosphorus, potassium, and calcium. This can lead to nutrient deficiencies and hinder plant growth and development. W.H. Elmer and R.L. Tubbs. (2005).

Sodium (Na):
Sodium within the study area ranges from 21.1 ppm to 74.98 ppm, with a mean ppm across the study area of 39.69, which is within the WHO acceptable limit of ≤100 ppm (table 6). Sodium has been found to have antimicrobial properties that can help suppress some soil-borne pathogens and fungal diseases. This can contribute to reduced disease incidence in certain crops or in specific soil conditions.

Potassium (K)
Potassium (K) concentrations within the study area range from 23.46 ppm to 105.57 ppm, with a mean ppm across the study area of 56.62. Potassium (K) levels in the soil were within the WHO acceptable limit of ≤100 ppm, except for sample 1, which slightly exceeded this limit with a value of 105.57 ppm (table 6). Potassium is a vital nutrient for plant growth and development. When potassium levels are sufficient or slightly higher in the soil, it can promote healthy plant growth, improve crop quality, and enhance overall yield. Potassium is known to play a crucial role in various plant physiological processes, including enzyme activation, photosynthesis, and carbohydrate metabolism. However, high potassium levels in some crops, such as fruits and vegetables, can lead to reduced shelf life and post-harvest quality. Excess potassium can contribute to issues like softening, rapid decay, and reduced storage potential.

Calcium (Ca):
Calcium within the study area ranges from 128 ppm to about 1442 ppm, with a mean ppm across the study area of 826.78. The mean levels of Ca in the soil were above the WHO acceptable limit of ≤100 ppm. Excessive calcium levels may reduce the availability of other essential cations, such as potassium and magnesium, affecting their uptake by plants and potentially causing nutrient deficiencies (Marschner, 2011). In some cases, high calcium levels combined with other factors such as arid climates or poor drainage can contribute to soil salinity issues. Saline soils have increased levels of soluble salts, including calcium salts, which can negatively impact plant growth and limit agricultural productivity (Gupta & Gupta, 2000). Also, in acidic soils, excessive calcium can exacerbate aluminum toxicity. The excess calcium in the study area can be attributed to certain oil spill response and cleanup activities, such as using calcium-based amendments like lime to aid in remediation efforts. This could potentially result in elevated calcium levels, but it would be a consequence of the cleanup activities rather than the spillage itself.

Magnesium (Mg):
Magnesium within the study area ranges from 59 ppm to 510 ppm, with a mean ppm across the study area of 288.15 ppm. The mean level of Mg in the soil was beyond the WHO acceptable limit of ≤100 ppm. Excessive magnesium levels in soil can lead to nutrient imbalances. High magnesium levels can interfere with the uptake and utilization of other essential cations, such as potassium and calcium, potentially causing nutrient deficiencies or imbalances in plants (Marschner, 2011). In acidic soils, excessive magnesium can increase soil acidity, potentially affecting nutrient availability and plant growth. This is particularly relevant when magnesium is present in the form of highly soluble magnesium sulfate (Marschner, 2011). The excess magnesium levels in soil can be influenced by factors such as the underlying geology, weathering of minerals, and fertilizer application practices.

Exchangeable Cation Exchange Capacity (ECEC):
It is a measure of the soil's ability to retain and exchange cations (positively charged ions) with the surrounding solution. It is an important property of soils that influences their fertility and nutrient availability. Brady & Weil (2008) The standard or optimal exchangeable cation exchange capacity (ECEC) concentration in a healthy soil can vary depending on several factors, such as soil type, climate, and intended land use. However, a general range for the ECEC concentration in healthy soils is typically between 10 and 40 milliequivalents per 100 grams of soil (meq/100g). ECEC within the study area ranges from 12.1 meq/100g to 14.78 meq/100g, with a mean ppm across the study area of 12.78. meq/100g. Soils with a higher ECEC tend to have a greater capacity to retain and store essential plant nutrients, such as potassium (K^+), calcium (Ca^{2+}), magnesium (Mg^{2+}), and ammonium (NH_4^+). Brady & Weil (2008) This helps in supplying nutrients to plants, especially during periods of high demand. ECEC also provides an indication of the soil's ability to hold and exchange cations, which is crucial for nutrient availability. Soils with higher ECEC have a greater capacity to retain and release cations, allowing for better nutrient uptake by plant roots. ECEC is often correlated with soil fertility because it indicates the soil's nutrient-holding capacity. Soils with a higher ECEC are generally more fertile, as they can supply a greater pool of nutrients to plants, promoting healthy growth and high crop yields. Alloway (2012).

Exchangeable Acidity (EA):
Exchangeable acidity in soil refers to the concentration of exchangeable hydrogen (H^+) or aluminum (Al^{3+}) ions in the soil, which can impact soil pH and nutrient availability. The desirable range for exchangeable acidity in healthy soils is typically around 1 to 5 meq/100g. Exchangeable acidity within the study area ranges from 0.25 ppm to 13.50 ppm, with a mean ppm across the study area of 12.1 ppm, which is beyond the acceptable limit. However, sample 4 is 4.66 ppm, which is within an acceptable range. Brady & Weil (2008) In highly acidic soils, high levels of exchangeable aluminum can be toxic to plants. Aluminum toxicity can damage root systems, impair nutrient uptake, and hinder overall plant growth. Lal, (2021). This is particularly problematic for sensitive crops that are intolerant of aluminum. Acidic soils can cause the leaching and loss of essential cations like calcium, magnesium, and potassium, leading to nutrient

deficiencies. Additionally, excessive acidity can increase the solubility of toxic elements like aluminum, which can be detrimental to plant growth and development. Alloway (2012).

Lead (Pb):
The mean levels of Pb in soil were within the WHO acceptable limit of ≤100 ppm. Lead (Pb) hardly provides for any biological roles if consumed. Lead (Pb) has carcinogenic effects (Jaishankar et al., 2014). Lead (Pb) damages chlorophyll, where its toxicity arises from its ability to replace cations including Na+, Ca2+, Mg2+, and Fe2+ (Harmanescu et al., 2011). Lead (Pb) also induces cardiovascular diseases, reduces cognitive development, and induces tumor induction and hypertension (Harmanescu et al., 2011).
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Cadmium (Cd):
Cadmium within the study area ranges from 0.26 ppm to 0.50 ppm, with a mean ppm across the study area of 0.34 ppm. The mean levels of Cd in the soil were within the WHO acceptable limit of ≤3 ppm. In very low concentrations, cadmium can stimulate plant growth and enhance photosynthesis, which can lead to increased biomass production. Cadmium can improve the uptake and translocation of essential nutrients in plants, such as iron, zinc, and manganese. Cadmium (Cd) is a toxic heavy metal that can have detrimental effects on soil health, plant growth, and human health if present in high concentrations.

Iron (Fe):
Iron within the study area ranges from 321.86 ppm to 994.04 ppm, with a mean ppm across the study area of 991.04. Iron concentration in humid soil for plant growth is around 20 to 100 parts per million (ppm) or milligrams per kilogram (mg/kg). The Fe concentration in the soil is beyond an acceptable limit. Soils with high iron concentrations or poor drainage can lead to iron toxicity. Excessive iron can cause oxidative stress in plants, damaging cellular structures and inhibiting metabolic processes. Iron toxicity symptoms include leaf bronzing or darkening, stunted growth, and reduced root development. Brady and Weil, (2008).

Copper (Cu):
Copper within the study area ranges from 10.1 ppm to 180.43 ppm, with a mean ppm across the study area of 10.1 ppm. The mean levels of Cu in the soil were within the WHO acceptable limit of ≤100 ppm. Copper (Cu) is an essential nutrient, but excess intake of Cu causes hepatic damage, headaches, acute esophageal aches, diarrhea, and vomiting (Harmanescu et al., 2011; Jaishankar et al., 2014; Rahman et al., 2014). Copper plays a crucial role in various enzymatic reactions within plants. It is involved in electron transfer processes, including photosynthesis and respiration. Copper is also necessary for the synthesis of certain proteins and plant growth regulators, contributing to overall plant metabolism and growth (Alloway, 2013). Copper has antimicrobial properties and can help control fungal and bacterial pathogens, reducing disease incidence and severity. Copper-based treatments are particularly effective against certain foliar diseases (Rai et al., 2018).

Zinc (Zn):
Zinc within the study area ranges from 98.76 ppm to 122.6 ppm, with a mean ppm across the study area of 98.26 ppm. The mean levels of zinc in the soil were within the WHO acceptable limit of ≤100 ppm. The mean levels of Zn in the soil were within the WHO acceptable limit of ≤300 ppm. Contamination of soil by zinc (Zn) is caused by mining and smelting of metal, atmospheric depositions, and agricultural and industrial activities (Rahman et al., 2014). Zinc (Zn) induces disruption of the immune system and consequently reduces immune function (Harmanescu et al., 2011).

Total Petroleum Hydrocarbons (TPH):
It is a term used to describe a wide range of organic compounds found in petroleum products. TPH in the soil ranges from 11.30 to as high as 226.34. TPH analysis in soil serves as an important indicator of petroleum hydrocarbon contamination. It can help identify areas where oil spills, leaks, or other petroleum-related activities have occurred (IOGP). (2018). TPH analysis provides information about the potential risks associated with petroleum hydrocarbon contamination in soil. It helps evaluate the extent and severity of contamination, which assists in assessing potential impacts on human health, ecosystems, and groundwater resources (figure 12, 13, 14 and 15). This information is crucial for making informed decisions regarding land use and remediation strategies. TPH in soil can have adverse effects on the environment. Petroleum hydrocarbons, particularly those with high molecular weights, are persistent and can accumulate in the soil, potentially leading to long-term contamination. Barriuso, Benoit & Gabrielle, (2008). This can affect soil quality, microbial activity, plant growth, and the overall ecological balance of the area. Exposure to TPH-contaminated soil can pose risks to human health. Certain petroleum hydrocarbons, such as polycyclic aromatic hydrocarbons (PAHs), can be toxic and carcinogenic. Direct contact with contaminated soil or inhalation of volatile components can lead to adverse health effects, depending on the level and duration of exposure. US EPA. (1999).
3.3.2 Questionnaire Administered

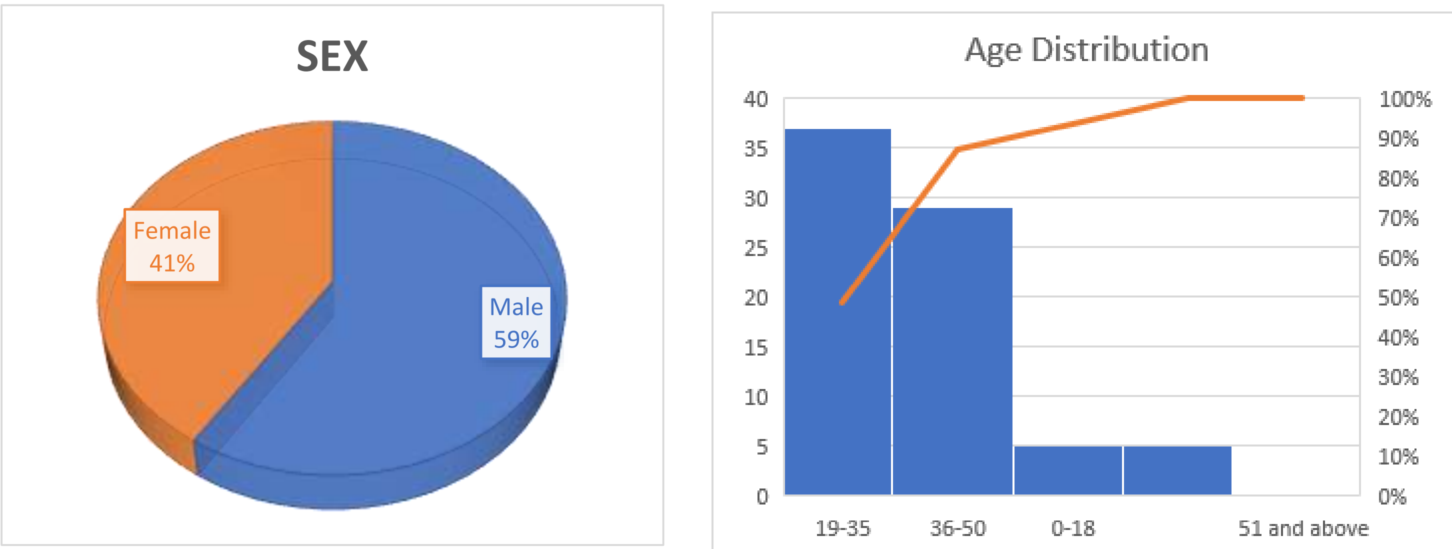

Figure 9: Statistic of gender and age group

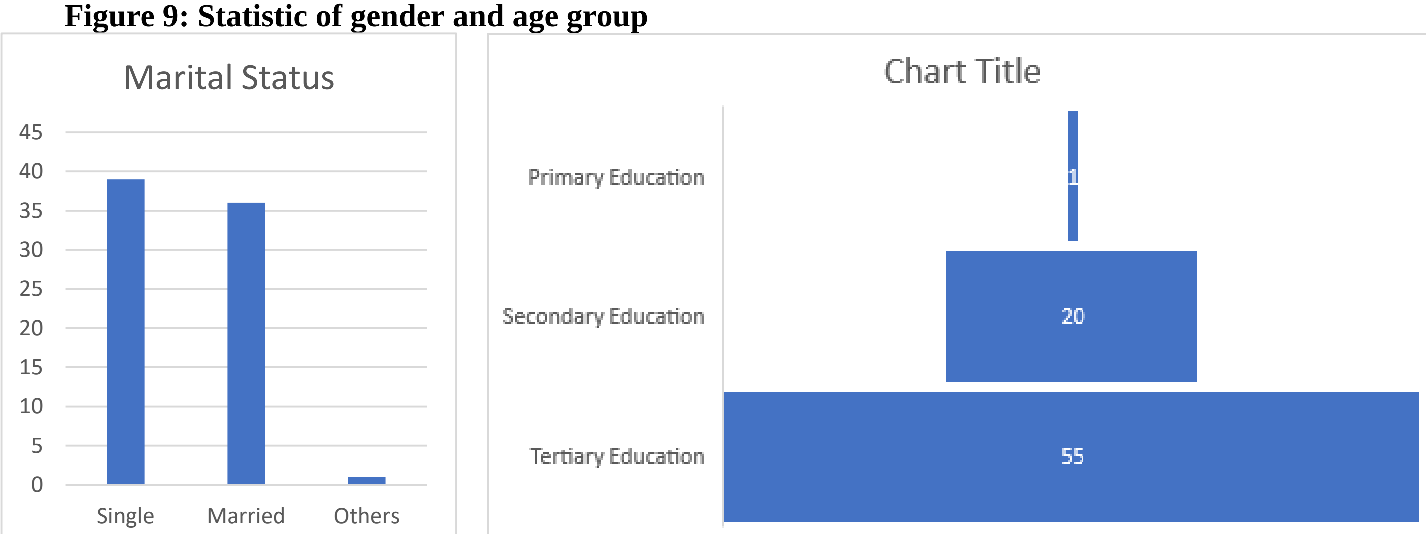

Figure 10: Socio-Economic Information of the Residents

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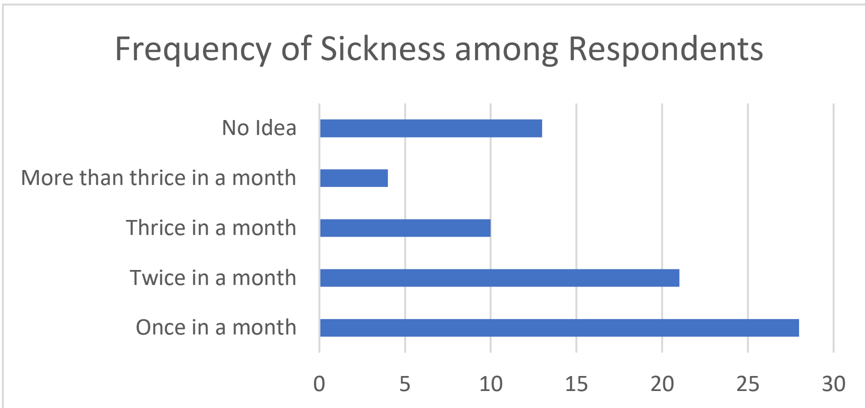

Figure 11: Frequency chart of sickness among respondents

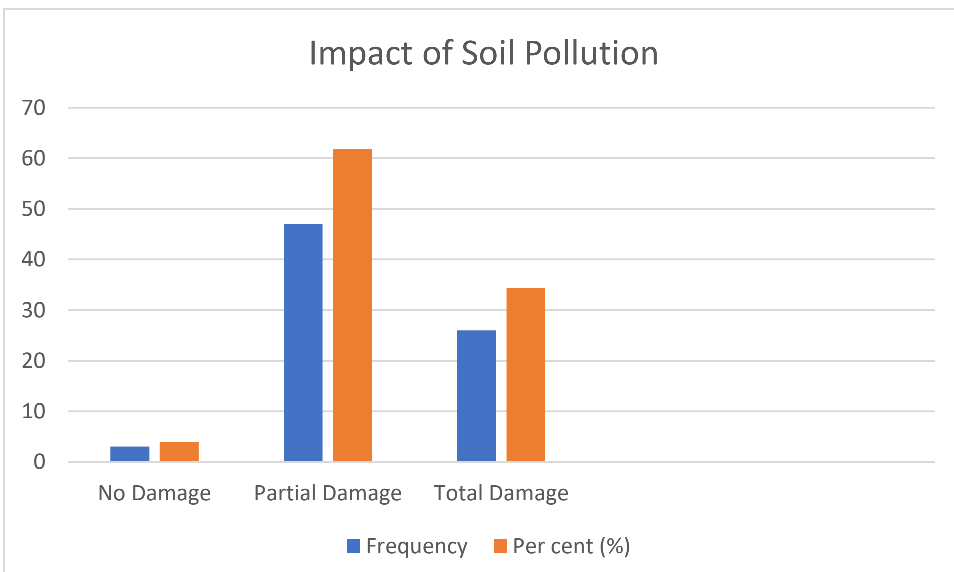

Figure 12: Shows the impacts of soil pollution

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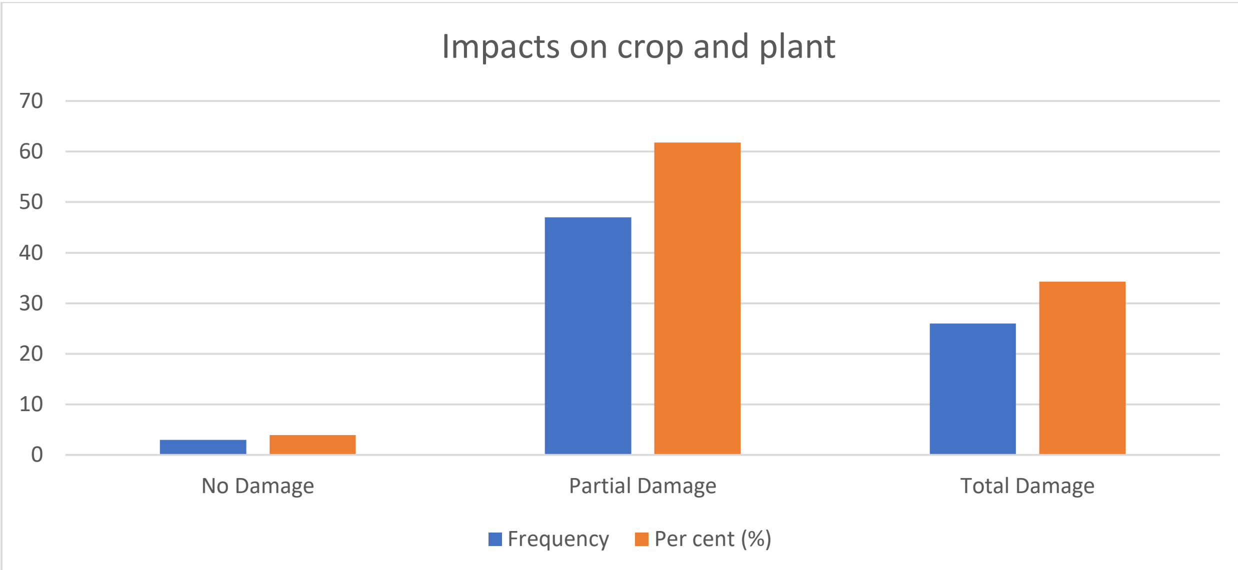

Figure 13: Impacts on crop and plant

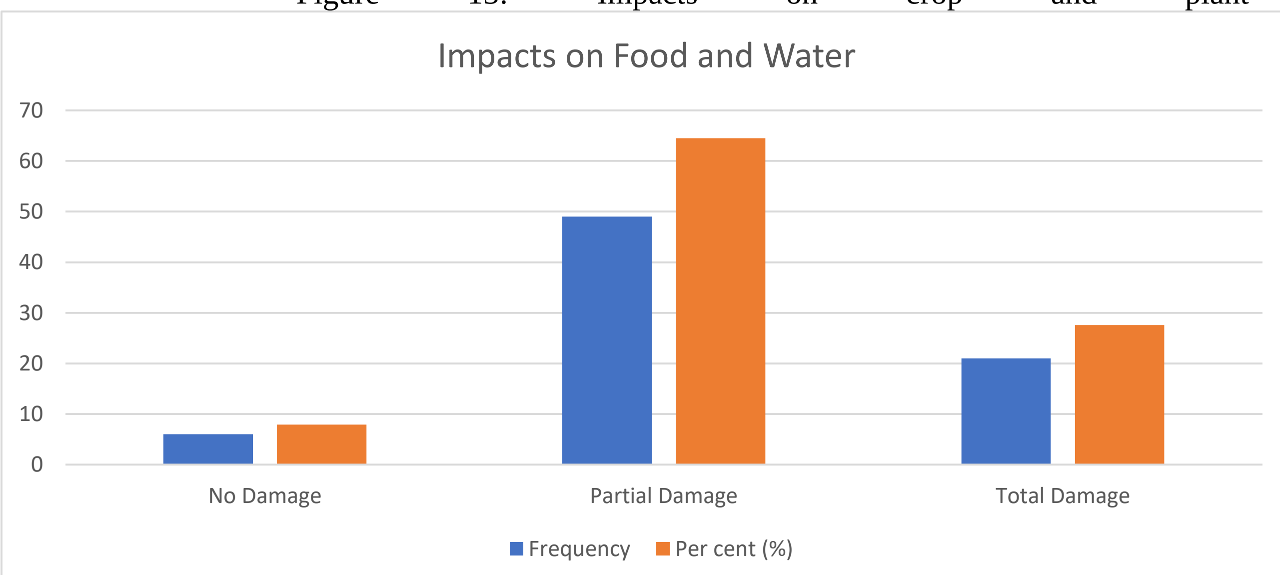

Figure 14: Impacts on Food and Water

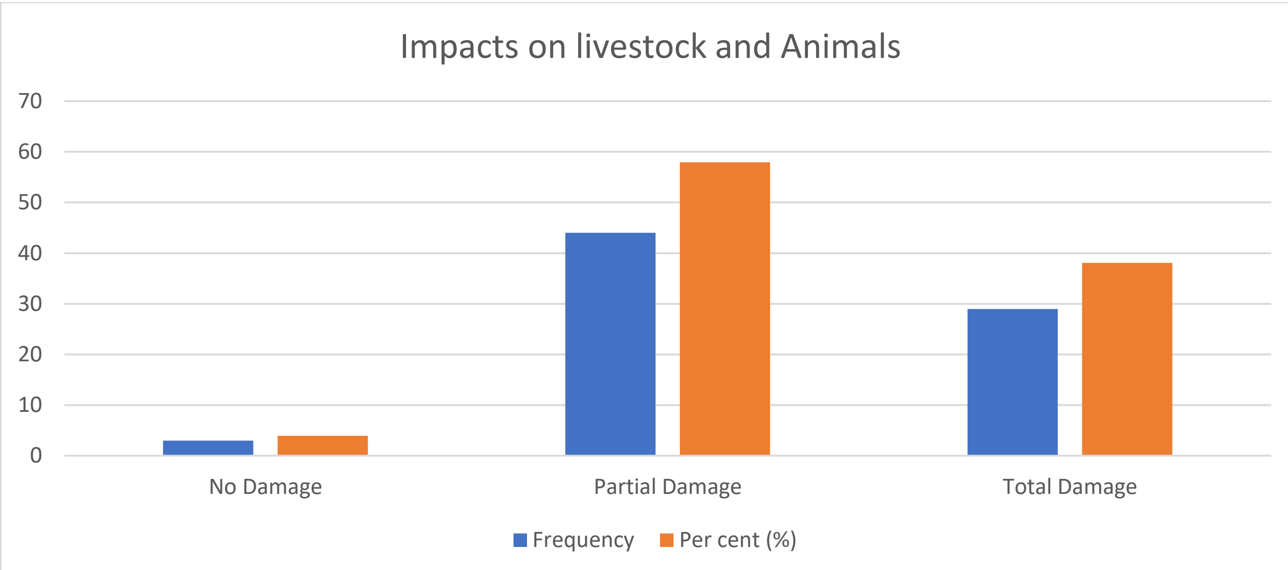

Figure 15: Impacts on livestock and Animals

The study by Crayton & Naher (2022) reported a high impact of oil spillage on agricultural produce, crop yield, and fish production due to resultant poor soil fertility and damage to water bodies. Pollution of the oil-producing communities' basic amenities through oil spillage has led to abandonment of their infrastructure (Crayton & Naher, 2022) and contamination of their drinking water (Olalekan et al., 2018). In addition, the oil spill affected the community's social environment, leading to setbacks in their occupation, income, and education (Brown & Tari, 2015; Albert et al., 2019). Contaminated soil can impact agriculture, as it can inhibit plant growth and reduce crop yields. Plants may absorb toxic substances from the soil, affecting their quality and safety for consumption. Communities relying on agriculture as a primary source of livelihood may suffer economic losses. Contaminated soil can devalue land and property, impacting the economic well-being of individuals and the community as a whole. Tourism and other industries relying on a healthy environment may also suffer. Efforts to prevent spills, implement proper safety measures, and hold responsible parties accountable can help mitigate the impacts of soil contamination from oil and gas spillage (figure 12 and table 4). Additionally, effective monitoring, prompt cleanup, and comprehensive remediation strategies are crucial in minimizing the long-term effects on host communities and the environment.

CONCLUSION

The research work conducted on the environmental impacts assessment and evaluation of oil and gas spillage on soil in parts of Warri, Delta State, Nigeria, provides valuable insights into the soil characteristics and contamination levels in the study area. The findings highlight several important points. The pH levels in the study area ranged from highly acidic to slightly acidic. Highly acidic soil can have negative effects on nutrient availability and hinder plant growth. It is important to address soil acidity to promote healthy plant development. The sodium levels in the soil were within the acceptable limit set by the World Health Organization (WHO). Sodium can have antimicrobial properties and contribute to reducing disease incidence in certain crops or specific soil conditions. Potassium levels were generally within the acceptable limit, except for one sample that slightly exceeded it. Excessive calcium levels can reduce the availability of other essential cations and contribute to soil salinity issues, negatively impacting plant growth and agricultural productivity. Magnesium levels in the soil exceeded the acceptable limit set by the WHO. Excessive magnesium can interfere with the uptake and utilization of other essential cations, potentially causing nutrient imbalances in plants. The Exchangeable Cation Exchange Capacity (ECEC) levels in the study area were within the acceptable range. Soils with higher ECEC have a greater capacity to retain and release essential plant nutrients, promoting healthy growth and high crop yields. The exchangeable acidity levels in the soil were generally beyond the acceptable limit, indicating the presence of high levels of exchangeable hydrogen or aluminum ions. Acidic soils and excessive exchangeable aluminum can be toxic to plants and hinder nutrient availability. Lead (Pb) and cadmium (Cd) levels were within the acceptable limits set by the WHO. However, it is important to note that these heavy metals (table 1) have toxic effects on human health and the environment, and continuous monitoring is crucial to ensure their levels remain within safe limits. Total petroleum hydrocarbons (TPH) in the soil indicated the presence of petroleum hydrocarbon contamination, potentially from oil spills or other petroleum-related activities. TPH contamination can have adverse effects on soil quality, plant growth, and human health. The study reported a high impact of oil spillage on agricultural produce, crop yield, and livestock (Table 5) production due to poor soil fertility and damage to water bodies. Pollution of the oil-producing communities' basic amenities through oil spillage has led to abandonment of their infrastructure and contamination of their drinking water. In addition, the oil spill affected the community's social environment, leading to setbacks in their occupation, income, and education. Overall, the research work highlights the need for remediation and mitigation strategies to address soil acidity, excessive nutrient levels, exchangeable acidity, and petroleum hydrocarbon contamination. Continuous monitoring and regular assessment of soil quality are crucial for sustainable land use and the protection of human health and the environment in areas affected by oil and gas spillage.

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