Physicochemical Assessment of Oil-Impacted Soils in Idu Ekpeye Community, Ahoada West, Rivers State, Nigeria

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Abstract
This study evaluates the physicochemical properties of oil-polluted farmlands in Idu Ekpeye Community, Ahoada West Local Government Area, Rivers State, Nigeria. Comparative analyses were performed on three polluted sites (Oloya, Uyalena, and Iloh farmlands) and a control site (Uyanye-Enweozu farmland). The results showed significantly reduced pH levels in polluted sites (4.75, 4.19, and 4.32, respectively) compared to the control (5.43). Electrical conductivity peaked at 253 µS/cm in Oloya, indicating increased ionic content. Chloride concentrations were elevated in Oloya (107.77 mg/kg) and Iloh (99.26 mg/kg), compared to the control (53.88 mg/kg). Sulphate values were highest in Oloya (10,500 mg/kg), followed by Iloh (8,400 mg/kg), while the control recorded 7,750 mg/kg. Total hydrocarbon content was significantly high in Uyalena (1,864 mg/kg) and Oloya (381.33 mg/kg), while the control was negligible (-0.0045 mg/kg). Iron (Fe) concentrations ranged from 2,832.81 mg/kg (Oloya) to 10,844.38 mg/kg (Iloh), with the control at 6,433.59 mg/kg. Other metals like Zinc (Zn), Manganese (Mn), Nickel (Ni), Copper (Cu), and Lead (Pb) also showed spatial variability, with Pb being absent in the control but reaching 5.00 mg/kg in Oloya and Uyalena. The results reveal that oil pollution significantly alters soil chemistry, posing ecological and agricultural threats.

Keywords: *Oil pollution, Soil quality, Heavy metals, Hydrocarbon contamination, Physicochemical parameters, Idu Ekpeye, Ahoada West, Environmental impact.*

Introduction

The increasing exploration and exploitation of petroleum resources in the Niger Delta region of Nigeria have led to extensive environmental degradation, particularly in agricultural landscapes. Soil contamination due to crude oil spills remains a critical issue, affecting soil quality, plant productivity, and ecosystem health (Okonkwo et al., 2021; Adesodun & Mbagwu, 2020). Idu Ekpeye community in Ahoada West Local Government Area is one of the regions severely impacted by artisanal refining and crude oil-related pollution. Crude oil comprises a complex mixture of hydrocarbons and trace metals that significantly alter the physical and chemical integrity of soils (Chikere et al., 2022). These contaminants disrupt nutrient cycling, reduce microbial biomass, increase soil acidity, and lead to the bioaccumulation of toxic elements (Eze et al., 2020). Several studies have shown that oil contamination leads to elevated levels of chloride, sulphate, heavy metals, and petroleum hydrocarbons, all of which pose risks to plant life and human health (Nduka et al., 2023; Udeogu et al., 2019).

Physicochemical parameters such as pH, electrical conductivity (EC), total hydrocarbon content (THC), and heavy metals like iron (Fe), zinc (Zn), manganese (Mn), and lead (Pb) are useful indicators of soil health and pollutant impact (Ogundele et al., 2021). Monitoring these parameters is essential for assessing the extent of soil degradation and for developing appropriate remediation strategies. In the Idu Ekpeye area, the persistence of artisanal refining and pipeline vandalism has compounded environmental challenges, resulting in the chronic exposure of farmlands to petroleum hydrocarbons (Ogbonda et al., 2021; Aluko & Ayodele, 2018). Despite this, limited site-specific studies exist that quantify the physicochemical alterations in soils across different farmlands within this community.

This study, therefore, aims to evaluate the physicochemical properties of soils from selected farmlands in Idu Ekpeye—specifically comparing polluted sites (Oloya, Uyalena, and Iloh) to a control site (Uyanye-Enweozu). The study focuses on key parameters such as pH, EC, chloride, sulphate, THC, and selected heavy metals (Fe, Zn, Mn, Ni, Cu, and Pb), to determine the spatial variability of oil pollution and its environmental implications. By providing updated and site-specific data, this research contributes to a broader understanding of crude oil's impact on soil health and supports the development of targeted environmental management policies in the Niger Delta region.

Materials and Methods

Study Area

The study was conducted in Idu Ekpeye Community, located in Ahoada West Local Government Area, Rivers State, Nigeria. This region lies within the Niger Delta basin, a hotspot for oil exploration and artisanal refining activities. The area is characterized by tropical rainforest vegetation, high annual rainfall (over 2,500 mm), and loamy soil suitable for farming. Due to ongoing petroleum-related activities, the region faces significant environmental challenges including soil and water contamination.

Sample Collection

Four farmland locations were selected for this study:

1. Uyanye-Enweozu farmland – Control (unimpacted site)
2. Oloya farmland – Oil-impacted
3. Uyalena farmland – Oil-impacted
4. Iloh farmland – Oil-impacted

Soil samples were collected at a depth of 0–15 cm using a stainless-steel soil auger. Composite samples were formed by combining three sub-samples from each farmland and thoroughly homogenized. Samples were stored in clean, labeled polyethylene bags and transported to the laboratory for analysis.

Laboratory Analysis

All soil analyses followed standard methods and protocols. Samples were air-dried, sieved (2 mm mesh), and analyzed for the following physicochemical properties:

pH measurement

Measured in a 1:2.5 soil-to-water suspension using a digital pH meter (APHA, 2017).

Electrical Conductivity (EC) measurement

Measured in µS/cm using a conductivity meter (Jackson, 2015).

Chloride (Cl^-) measurement
Determined by argentometric titration with silver nitrate (AOAC, 2019).

Sulphate (SO_4^{2-}) measurement
Quantified using turbidimetric methods (ASTM, 2018).

Total Hydrocarbon Content (THC) measurement
Analyzed via UV spectrophotometry after extraction with n-hexane, following APHA (2017) guidelines.

Heavy Metals (Fe, Zn, Mn, Ni, Cu, Pb) measurement
Digested using aqua regia and quantified using Atomic Absorption Spectrophotometry (AAS) according to standard methods (U.S. EPA, 2016).

Quality Control and Statistical Analysis
All glassware and sampling tools were properly cleaned and rinsed with deionized water. Reagent blanks, standard solutions, and duplicates were used for quality assurance. Data were statistically analyzed using descriptive statistics to compute mean values. Results were compared between the control and polluted farmlands.

Results
The physicochemical properties of soils from the control and oil-impacted farmlands in Idu Ekpeye community are presented in the tables below.

Table 1: Soil pH and Electrical Conductivity (EC)

Location	pH	EC (µS/cm)
Uyanye-enweozu farmland (Control)	5.43	41.70
Oloya farmland	4.75	253.00
Uyalena farmland	4.19	88.40
Iloh farmland	4.32	36.60

Table 2: Anions Concentration (mg/kg)

Location	Chloride (Cl-)	Sulphate (SO_4^{2-})
Uyanye-enweozu farmland (Control)	53.88	7750
Oloya farmland	107.7	10500
Uyalena farmland	51.05	5600
Iloh farmland	99.26	8400

Table 3: Total Hydrocarbon Content (THC)

Location	Chloride (Cl-)
Uyanye-enweozu farmland (Control)	**-0.0045**
Oloya farmland	381.33
Uyalena farmland	1864.00
Iloh farmland	423.73

Table 4: Heavy Metal Concentrations (mg/kg)

Location	Fe	Zn	Mn	Ni	Cu	Pb
Uyanye-enweozu farmland (Control)	6433.59	86.52	143.68	12.50	25.93	0.00
Oloya farmland	2832.81	78.01	346.20	12.50	11.11	5.00
Uyalena farmland	5003.91	78.01	157.74	7.50	3.70	5.00
Iloh farmland	10844.38	143.12	13.89	10.00	3.70	3.33

These tables summarize the significant changes observed in soil physicochemical characteristics due to petroleum hydrocarbon pollution in the area.

Discussion

The observed physicochemical parameters from the soils of Idu Ekpeye community farmlands reveal marked deviations from the control site, suggesting serious environmental impacts resulting from petroleum hydrocarbon contamination. These alterations in soil quality have significant implications for soil health, agricultural productivity, and ecological sustainability.

Soil pH

Soil pH values in the oil-polluted sites ranged from 4.19 to 4.75, significantly lower than the control (5.43). Acidification of soil in hydrocarbon-contaminated environments is a common phenomenon due to the breakdown of hydrocarbons into acidic intermediates and the microbial oxidation of sulfur compounds (Adewuyi & Asomugha, 2022; Ubuoh et al., 2021). Acidic soils can hinder nutrient availability, inhibit microbial activity, and reduce crop productivity (Amusan et al., 2019). Low pH values in the polluted soils could impair root development, alter metal solubility, and negatively affect plant physiological functions.

Electrical Conductivity (EC)

The highest EC (253 µS/cm) was recorded in Oloya farmland, indicating a considerable increase in soluble salt concentration relative to the control (41.70 µS/cm). Elevated EC in petroleum-impacted soils is often attributed to increased ionic strength from the leaching of salts and other breakdown products (Ite et al., 2023). According to Anoliefo et al. (2020), high EC can adversely affect plant osmotic balance and interfere with water uptake, leading to plant stress and reduced agricultural yield. The variation in EC among the sites also reflects the heterogeneous nature of contamination and differences in soil drainage and organic matter decomposition.

Chloride and Sulphate

Both chloride and sulphate concentrations were elevated in oil-impacted sites, especially in Oloya (Cl^- = 107.77 mg/kg; SO_4^{2-} = 10500 mg/kg). Chloride accumulation in contaminated soils can originate from flaring residues and degraded hydrocarbons (Nwankwoala & Amadi, 2021). Sulphate increase, on the other hand, may be linked to microbial oxidation of sulphur-containing hydrocarbons and drilling wastes (Eze et al., 2023). These anions, when elevated, can lead to soil salinization and acidity, contributing to reduced fertility and microbiota imbalance (Ghazali et al., 2022).

Total Hydrocarbon Content (THC)

The control site recorded a negligible THC value (-0.0045 mg/kg), while Uyalena farmland had the highest THC at 1864 mg/kg. This stark contrast underlines the severity of hydrocarbon pollution in the region. High THC levels suggest recent or chronic exposure to crude oil, leading to the buildup of toxic organic residues in the soil (Okoh et al., 2019). According to Ekpo et al. (2022), high THC impairs microbial activity and disrupts nutrient cycling, resulting in long-term degradation of soil structure and function. The persistence of hydrocarbons can also inhibit seed germination, alter enzyme activities, and diminish crop yield (Olawoyin et al., 2020).

Iron (Fe)

Iron concentrations ranged from 2832.81 mg/kg in Oloya to 10844.38 mg/kg in Iloh farmland, with the control recording 6433.59 mg/kg. The elevated Fe levels in the polluted soils may be due to the oxidation of ferrous to ferric iron in acidic conditions, typical of hydrocarbon-affected soils (Akinola et al., 2021). Excess Fe can be phytotoxic, particularly under anaerobic conditions where it becomes more soluble and interferes with phosphorus uptake and other micronutrient balances (Akpokodje et al., 2022).

Iron is an essential micronutrient for both plants and animals, playing vital roles in chlorophyll synthesis and various enzymatic processes (Obasi & Nduka, 2022). However, excessive Fe levels in soil, as observed in Iloh farmland (10,844.38 mg/kg), can induce phytotoxicity, leading to chlorosis, stunted growth, and inhibited root elongation in crops. For humans, elevated iron intake from crops grown in Fe-rich soils can result in gastrointestinal distress, liver damage, and in extreme cases, hemochromatosis (Afolabi & Oladoja, 2022). Accumulated iron in food chains can destabilize trophic relationships and impact soil microbial biodiversity.

Zinc (Zn)

Zinc is required in small quantities for protein synthesis and growth regulation in plants, but excessive amounts can disrupt photosynthesis, reduce seed germination, and impair root development. Iloh farmland recorded 143.12 mg/kg, significantly higher than the control. Chronic exposure to Zn through consumption of contaminated crops can lead to vomiting, cramps, and impaired immune responses in humans (Akintunde, Oyekunle, & Popoola, 2023). Additionally, Zn bioaccumulation in herbivores can affect metabolic pathways and reproductive functions, thus threatening ecological balance.

Zinc levels were relatively high in Iloh farmland (143.12 mg/kg) compared to the control (86.52 mg/kg). Zn, although an essential micronutrient, becomes toxic at elevated concentrations, causing oxidative stress and inhibiting enzymatic systems in plants (Chibuike & Obiora, 2021). Hydrocarbon pollution has been reported to mobilize heavy metals including Zn due to altered pH and microbial activity (Chukwu et al., 2020).

Manganese (Mn)

Manganese is another micronutrient necessary for plant metabolism, especially in photosynthesis and nitrogen assimilation. However, in Uyalena and Iloh farmlands, Mn levels were drastically low (15.74 and 13.89 mg/kg respectively) compared to the control (143.68 mg/kg), which could indicate disrupted Mn cycling due to oil pollution. In plants, Mn deficiency leads to interveinal chlorosis and poor fruit development. In humans, low Mn levels impair skeletal development and fertility, while overexposure (in contaminated areas) may result in neurotoxicity, linked to Parkinson-like symptoms (Nwachukwu & Eze, 2021). The control site had significantly higher Mn (143.68 mg/kg) than the polluted sites, especially Iloh (13.89 mg/kg). This suggests possible immobilization or leaching of Mn under hydrocarbon-stressed conditions. Studies by Omoregie et al. (2022) showed that reduced Mn in polluted soils is often a result of redox imbalances and microbial suppression, affecting enzyme functions critical to plant metabolism.

Nickel (Ni), Copper (Cu), and Lead (Pb)

Nickel levels were relatively consistent across farmlands, ranging from 7.5 to 12.5 mg/kg. Although required in trace amounts for enzymatic functions in plants, elevated Ni interferes with nutrient uptake, causing necrosis and wilting. In humans, Ni exposure through food leads to skin dermatitis, lung fibrosis, and increased cancer risk (Chikere, Okpokwasili, & Chikere, 2022). Ni is also a potent mutagen, and its bioaccumulation in aquatic and terrestrial food webs could disrupt predator-prey dynamics and biodiversity. Nickel and copper concentrations were lower in polluted soils than in the control, likely due to chemical binding or microbial precipitation (Essien et al., 2020). Copper concentrations were highest in the control farmland (25.93 mg/kg) but dropped drastically in polluted farmlands. Cu deficiency impairs lignin synthesis and plant disease resistance, while toxicity (when excessive) can damage root membranes and photosynthetic tissues. For humans, Cu imbalance can result in liver and kidney dysfunction. Chronic ingestion through polluted crops can cause Wilson's disease or gastrointestinal distress (Korie & Akpokodje, 2022). Cu, when mobilized in the environment, can also affect aquatic life by inhibiting fish gill function. Lead is a non-essential and highly toxic metal. The control site had no detectable Pb, while polluted sites recorded levels from 3.33 to 5.00 mg/kg. Pb disrupts plant physiological functions by affecting enzymatic activities, causing chlorosis, reduced biomass, and oxidative stress. In humans, Pb ingestion is associated with neurodevelopmental disorders in children, renal failure, hypertension, and anemia in adults (Ugochukwu & Ertel, 2022). Through trophic transfer, Pb accumulation in animals and humans poses long-term health risks, making it a critical contaminant of concern in the food chain. However, Pb was absent in the control but present in polluted sites, peaking at 5.00 mg/kg in Oloya and Uyalena farmlands. Lead contamination in crude oil-polluted soils is a recognized concern due to its non-biodegradable nature and potential to bioaccumulate (Osuji & Egbuson, 2021). Even at low levels, Pb interferes with enzymatic processes, root elongation, and poses serious human health risks through the food chain (Ojo & Udosen, 2023).

Summary of Key Environmental Impacts Identified:
Soil acidification and loss of pH buffering capacity.
Salinization and increase in EC, impairing water/nutrient uptake.
Accumulation of hydrocarbons and toxic metals, altering microbial and enzymatic soil functions.
Potential risk to food safety, plant productivity, and groundwater contamination.
The results corroborate findings from other Niger Delta studies that link artisanal refining and oil spills to drastic degradation in soil quality (Emuedo et al., 2021; Duru & Ezirim, 2023). Restoration of these farmlands would require integrated remediation strategies such as bioremediation, phytoremediation, and soil amendment to restore fertility and ecological balance (Chikere et al., 2022; Abii et al., 2023).

Conclusion

The physicochemical assessment of oil-impacted farmlands in Idu Ekpeye Community, Ahoada West, Rivers State, reveals significant environmental degradation attributable to crude oil contamination. Parameters such as pH, electrical conductivity, chloride, sulphate, total hydrocarbon content (THC), and heavy metals (Fe, Zn, Mn, Pb) exhibited substantial deviations from the control site, confirming the presence of hydrocarbon pollutants and associated geochemical disruptions.
Acidic soil pH and elevated EC levels indicate a chemically stressed environment that impairs plant root functioning and microbial health. The pronounced concentrations of sulphate, chloride, and heavy metals (especially Fe, Pb, and Zn) in contaminated farmlands further corroborate the impact of oil pollution, potentially leading to bioaccumulation in crops and subsequent public health concerns. Moreover, the exceptionally high THC values underscore the persistence of hydrocarbons, pointing to both acute and chronic contamination.
These findings not only highlight the deteriorating quality of agricultural soils in the region but also underscore the urgent need for environmental monitoring, regulatory enforcement, and the implementation of soil remediation strategies to restore productivity and ensure food safety.

Recommendations

Based on the outcomes of this study, the following recommendations are proposed:
1. Remediation Strategies:
Bioremediation and Phytoremediation should be prioritized using indigenous microbial strains and hyperaccumulator plants to degrade hydrocarbons and stabilize heavy metals (Chikere et al., 2022; Abii et al., 2023). Application of organic amendments such as compost, biochar, and animal manure to buffer soil pH, enhance microbial activity, and immobilize metals (Gbenro et al., 2021).
2. Governmental and Policy Intervention:
Immediate regulatory intervention is necessary to curb artisanal crude oil refining and illegal discharges into the environment (Duru & Ezirim, 2023).
Development of a community-based environmental monitoring framework in partnership with local stakeholders and environmental agencies.
3. Agricultural Restoration:
Encourage crop rotation and the cultivation of tolerant crops during remediation periods to sustain food production while soil conditions improve (Olowokere et al., 2020).
Periodic soil testing and nutrient management to restore fertility and monitor contaminant levels.
4. Public Health and Environmental Education:

Initiate awareness campaigns on the dangers of farming on contaminated lands and consumption of crops grown in polluted soils.

Provision of alternative livelihoods for communities engaging in artisanal refining to reduce environmental abuse.

5. Further Research:

Long-term ecotoxicological studies to assess the impact of contaminants on soil fauna, groundwater quality, and crop uptake.

Advanced geospatial mapping of contaminated sites in Ekpeye land to prioritize areas for intervention.

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