



Concentrations of Heavy Metals in Soil and Cassava Leaves Samples in Oil Producing Environment

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Abstract

Oil exploration activities has predisposed several nearby communities in Niger Delta to pollution which could lead to death of living organisms in the environment. This study assessed the arable soils and cassava leaves drawn from around oil exploration sites in six (6) local government areas (Ukwani, Ndokwa East-NE, Ethiope West-EW, Ugheli South-US, Ethiope East-EE, and Ndokwa West-NW) of Delta State. Samples were taken from twelve sampling points (100 meters) from oil exploration sites in each of the above selected communities from soils at a depth of 0-30 and cassava leaves in the farms. Thereafter, three composite samples were formed from each farm as three replicates for both soil and plant. The soil physico-chemical properties, heavy metal constituents and cassava leaves were analysed following standard procedures. Data generated were analysed using ANOVA and means were separated using LSD at 5% significance level. The soil organic matter (OM), electrical conductivity (EC), Al, Th, Pb, Ar, and Cd differed significantly across the LGAs, and ranged from 1.32 ± 0.13 (Ukwani) to 1.95 ± 0.13 (EE), 173.00 ± 12.15 (EE) to 223.00 ± 12.15 (Ukwani), 0.29 ± 0.06 (NE) to 0.51 ± 0.06 (US), 0.10 ± 0.01 (NE) to 0.15 ± 0.01 (Ukwani), 1.02 ± 0.16 (EW) to 1.51 ± 0.16 (Ukwani), 0.40 ± 0.07 (US) to 0.69 ± 0.07 (Ukwani), and 0.94 ± 0.08 (EW) to 1.37 ± 0.08 (NE), respectively. The leaves pH and Ar content differed significantly and ranged from 6.20 ± 0.13 (Ukwani) to 7.33 ± 0.13 (EE) and 0.07 ± 0.01 (EW) to 0.11 ± 0.01 (NW), respectively. The Hg has a significantly strong relationship with Al ($r=0.74$). The Cadmium content of the soil, and leaves Cr and Cd contents were above WHO/FAO permissible levels

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Introduction

Soil contamination with heavy metals has become a major challenge currently mostly in oil producing communities (Hernandez-Soriano and Jimenez-Lopez, 2012 and Li *et al.*, 2024)^[21]. These categories of metals (Cr, Ar, Cd, Pb, Th and Hg) are considered the most dangerous pollutant due to their high level of toxicity and persistence in the body of living things (Guo *et al.*, 2012 and Balali-Mood *et al.*, 2021)^[9, 13]. Human and animal exposure to these heavy metals lead to accumulation and due to their low mobility and longtime persistence in human body it is now a treat in the environment (Adelekan and Abegunde, 2011 and Balali-Mood *et al.*, 2021)^[9]. These metals are considered pollutants because they are found in the wrong place and are increasing concentration gradually due to oil exploration activity and heavy industrialization in the zone (Kinuthia *et al.*, 2020 and Li *et al.*, 2024)^[19, 21]. The metals are redistribution due to human activities in a way which could cause adverse negative effects though, they may occur naturally but, certain concentrations levels may be toxic and subsequently pose health hazard animals and humans life (Iyebor *et al.*, 2020 and Rashid *et al.*, 2023)^[17].

Most soil in Niger-Delta are highly contaminated due to oil spillage and other human activities leading to decreasing. They gradually move to roots and consequently spread to other parts of plants availability of Cultivated farm land and exposure farmers to these metals has negative consequences (Zhou *et al.*, 2017 and Rai *et al.*, 2019). Under this circumstance, pollution assessment by evaluating the concentration of heavy metals in the cultivated farms to guarantee safety becomes imperative. These metals are released into the surrounding through man's activities and the contaminant caused a series of problem facing mankind (Hussein *et al.*, 2017 and Sudarningsih *et al.*, 2023). Therefore, serious attention is requiring to monitor the heavy metal concentration in farming communities where oil activities are taken place. Crops that are Cultivated in areas have the tendency to accumulate the metals and upon consumption can lead to severe health challenges. So, it is better to create awareness to both farmers and consumers of those crops Cultivated on such areas (Hussein *et al.*, 2017 and Sudarningsih *et al.*, 2023).

The local government areas in Delta State where intensive oil exploration activities were taking place therefore, constitute a major source risk to the farmers and their families as the soil they are Cultivating can adsorb high levels of heavy metals continuously and accumulate (Abah *et al.*, 2023)^[1]. Once the heavy metals introduced, they remain for very long time because they are not easily broken down by microbial or chemical means (Khan *et al.*, 2019 and Parvez *et al.*, 2023)^[18, 28]. Report shown that soils are being polluted with heavy metals due oil exploration and exploitation including other human activities in the Niger-Delta Region (Adesuyi *et al.*, 2015)^[4]. The metals are dangerous as they could be transferred into the food chain when crops are Cultivated (Adesuyi *et al.*, 2015)^[4]. The challenges have become a global concern that require regular evaluation of the soil to reveal and establish a database of heavy metal levels.

Incidence of environmental degradation and soil fertility alteration caused by high rate of heavy metal contamination in the Niger-Delta area and other part of oil producing countries were attributed to frequent oil spills (Abioye, 2011 and Nwadiogbu *et al.*, 2024)^[23]. Crude oil is discharge into the agricultural land destroying fertile soil therefore threatening human health and existence that are depending on the soil for survival (Zhang *et al.*, 2024). Heavy dependence on petroleum resources as energy source promoted the high rate of soil contamination in oil producing communities. So, the most critical challenges in our environment today is soil contamination by heavy metals that poses negatively impacts human health ecosystems (Abioye, 2011 and Nwadiogbu *et al.*, 2024)^[23]. Most of the metals occur naturally in soils but as the level increases due to human activities (Abioye, 2011 and Zhang *et al.*, 2024) in location majorly used for farm activities like Ethiope East and West are known for cassava production. It becomes necessary to monitor the heavy metals concentration of cassava cultivated in the oil producing areas. On this premise, it is imperative to assess and inform the public about the concentrations of metals in the farm. Hence, the study determines the contents and distribution of heavy

metals of soils and cassava leaves in selected oil producing local government areas of Delta State, Nigeria.

Materials and Methods

Description of Study site

The experiment was conducted in six oil producing locations across six local government areas of Delta State, in the Niger-Delta Area of Nigeria. The oil exploration host communities are located below;

1. Egbaoma gas processing plant EGPP, Ebedei limited: located within latitudes 6.2850 and longitudes 6.2120 in Ukwuani Local Government Area of Delta-State, Nigeria.
2. Okpai Gas Plant is located at latitude 5.702 °N and longitude 6.515 °E in Ndokwa East local government area of Delta State.
3. Seplat oil field in Boboroku, Jesse, located in latitude 5.87002494 and longitude 5.69079209 in Ethiope West local government area of Delta State.
4. Utorogu gas plant located at latitude 5.5145 °N and longitude 5.9367 °E in Ugheli South local government area of Delta State.
5. Kokori oil field located at latitude 5.6550 and longitude 6.0770 in Ethiope East local government area of Delta State.
6. Obodougwa oil field located at latitude 6.09 °N and longitude 6.03 °E in Ndokwa West local government area of Delta State.

These regions of Delta State, Nigeria are known for major food crops production majorly cassava, yam, and oil palm. The regions are also a major crude oil producing as a result, it had suffered severe contamination due to oil spillages. The rainfall pattern was bimodal that peak at September and October whereas break in August. The rain starts by March and stop in early November while dry peak from December to February.

Samples Collection and Preparations

Samples were taken from twelve sampling points 100 meters from oil exploration sites in each of the above selected communities from soils at a depth of 0-30 and the cassava leaves in the farms. Thereafter, three composite samples were formed from each farm as three replicates for both soil and plant. The samples were kept in a plastic bag, labeled properly and taken to the Department of Agronomy Laboratory, Delta State University, Abraka where soil samples were spread on white paper to be air dried at room temperature whereas, the plant samples were oven dried.

Parameters evaluated

Soil pH, organic carbon, electrical conductivity and cation exchange capacity were measured in soil while only pH and organic carbon were measured in cassava leaves. Organic carbon was determined using Walkley - Black method (2013) whereas pH, EC including CEC were measured with pH meter, EC meter and Atomic Absorption Spectrometer, respectively. Heavy metals analysed in both samples were

Hg, Cr, Al, Th, As, Pb and Cd with Atomic Absorption Spectrophotometric procedure (AOAC, 2000)^[7].

Experimental design and statistical analysis

A simple randomized design with three replications was utilized in the sampling procedure, and data collected were analysed using analysis of variance, while differences in location means on the heavy metal contents were separated using least significant differences at 5% level of significance. A simple correlation analysis was also utilized in comparing the relationships between the heavy metal present in the soil and plant samples.

Results

Results obtained showed that the highest organic matter content was observed in the oil exploration site around Ethiope East LGA ($1.95\pm 0.13\%$) was significantly higher than the content found in Ukwani LGA ($1.32\pm 0.13\%$), but it was statistically similar to the rest LGAs (Table 1). The EC content in Ukwani LGA ($223\pm 12.15\%$) was significantly higher than Ugheli South ($181\pm 12.15\%$) and Ethiope East ($173.0\pm 12.15\%$). The highest aluminum content in the soil was found in Ugheli South (0.51 ± 0.06 mg/kg) and it was significantly higher than Ndokwa East (0.29 ± 0.06 mg/kg) and Ethiope West (0.31 ± 0.06 mg/kg). The Thorium content found in Ndokwa West (0.16 ± 0.01 mg/kg) was significantly Ndokwa East (0.10 ± 0.01 mg/kg) and Ethiope East (0.10 ± 0.01 mg/kg). The Lead content found in Ukwani LGA (1.51 ± 0.16) was statistically higher than Ethiope West (1.02 ± 0.16) and Ethiope East (1.14 ± 0.16). The Arg content

observed in Ukwani LGA (0.69 ± 0.07) was statistically higher than the rest LGAs except Ndokwa East (0.41 ± 0.07) and Ndokwa West (0.39 ± 0.07). Then the Cd content discovered in Ndokwa East (1.37 ± 0.08) was significantly higher than Ukwani LGA (1.04 ± 0.08) and Ethiope West LGA (0.94 ± 0.08).

Table 2 showed the relationship amongst the soil chemical properties. The pH has a weak and non-significant correlation with all other parameters examined, with negative relationship with OC, Al and Ar. The OC had a weak correlation with all the parameters except Al that they had a positively moderate relationship ($r=0.64$). The EC had a positively moderate relationship with Hg ($r=0.54$), but had a weak relationship with the rest parameters, of which the relationship with Cr, Al and Cd were negative. The CEC had a positively moderate relationship with Hg ($r=0.54$), negatively moderate with Cr ($r=-0.55$), and positively strong relationship with Pb ($r=0.7$). He had a weak relationship with Cr, Al, Th, Pb, Arg, and Cd, respectively. Cr had weak relationship with Al, Th, Pb, Arg, and Cd, respectively. Al had weak relationship with Th, Pb, and Arg, but a negatively moderate relationship with Cd ($r=-0.55$). Pb had a moderate relationship with Arg ($r=0.50$) and weak relationship with Cd. Then, Arg had a positively weak relationship with Cd.

Table 3 showed that the level of the heavy metals obtained in the soils of the study areas were under the safe level amount in relation to the World Health Organization (WHO) and Food and Agriculture Organization (FAO) permissible limits. However, only the Cadmium (Cd) level was above the WHO and FAO permissible level.

Table 1: Physic-chemical properties of soils collected from oil exploration sites in six local government areas of Delta State, Nigeria

Location	pH	OC	EC	CEC	Hg	Cr	Al	Th	Pb	Ar	Cd
		%		Mgkg	Mg/kg						
Ukwani	6.1a	1.32b	223a	11.7a	0.13a	6.88a	0.37ab	0.15a	1.51a	0.69a	1.04cd
NE	6.3a	1.57ab	195ab	10.4a	0.09a	6.01a	0.29b	0.10c	1.04ab	0.41b	1.37a
EW	6.3a	1.77a	205ab	10.9a	0.09a	5.99a	0.31b	0.13ab	1.02b	0.55ab	0.94d
US	6.2a	1.94a	181b	10.3a	0.11a	5.88a	0.51a	0.12abc	1.14ab	0.40b	1.20abc
EE	6.2a	1.95a	173b	10.8a	0.09a	4.64a	0.40ab	0.11bc	1.14b	0.39b	1.29ab
NW	6.5a	1.69ab	187ab	10.7a	0.08a	6.90a	0.41ab	0.16a	1.14ab	0.49ab	1.07abc
LSD(0.05)	0.47	0.39	36.11	3.85	0.06	2.39	0.18	0.03	0.49	0.2	0.25
SE	0.16	0.13	12.15	1.3	0.02	0.81	0.06	0.01	0.16	0.07	0.08

Means with same alphabets down the groups are not significantly different from each other at 5% level of

significance. LSD: Least significance differences, SE: Standard error

Table 2: Correlation matrix of physic-chemical elements of soil drawn from near oil exploration sites in six local government areas of Delta State, Nigeria

	Ph	OC	EC	CEC	Hg	Cr	Al	Th	Pb	Ar	Cd
ph	1										
OC	-0.05	1									
EC	0.09	-0.33	1								
CEC	0.05	-0.01	0.39	1							
Hg	0.11	-0.14	0.54	0.54	1						
Cr	0.07	-0.2	-0.11	-0.55	-0.38	1					
Al	-0.13	0.64	-0.13	0.19	0.23	-0.14	1				
Th	0.01	-0.36	0.01	0.18	0.09	0.19	0.09	1			
Pb	0.1	-0.23	0.38	0.70	0.47	-0.25	0.27	0.31	1		
Arg	-0.23	-0.21	0.38	0.44	0.21	0.22	0.03	0.35	0.5	1	
Cd	0.28	0.12	-0.07	0.15	0.19	-0.4	0.05	-0.55	0.07	0.37	1

Table 3: Status of heavy metals level of soils collected oil exploration sites in six local government areas of Delta State WHO/FAO

Location	Cr	Ar	Cd	Pb	Hg	Al
Ukwani	Safe	Safe	Unsafe	Safe	Safe	Safe
NE	Safe	Safe	Unsafe	Safe	Safe	Safe
EW	Safe	Safe	Unsafe	Safe	Safe	Safe
US	Safe	Safe	Unsafe	Safe	Safe	Safe
EE	Safe	Safe	Unsafe	Safe	Safe	Safe
NW	Safe	Safe	Unsafe	Safe	Safe	Safe
WHO/FAO	100	30	0.8	85	0.5	2

The cassava leaves obtained from Ethiope East had the highest pH (7.33 ± 0.13) which was significantly higher than the rest LGAs (Table 4). The cassava leaves obtained from Ndokwa West (0.11 ± 0.01) had the highest Arg content which was significantly higher than Ethiope West, but was statistically similar to the rest LGAs. However, the OC, Hg, Cr, Al, Th, Pb, and Cd contents assessed did not vary significantly across the Local Government Areas.

Table 5 showed that the pH value of the leaf samples harvested from different oil producing LGAs of Delta State had a weak relationship with the organic matter and heavy metals assessed. The organic carbon content had a weak relationship with all the heavy metals assessed except Cd that it had a negatively moderate relationship with ($r = -0.52$). The

He had a weak relationship with all heavy metals assessed except Al that a strong and significant relationship exists ($r = 0.74$). The Cr had a weak relationship with all the other heavy metals except Th where they share a negatively moderate relationship ($r = -0.6$). Al had a weak relationship with Th, Pb, Ar, and Cd. The Pb content had a weak relationship with Ar and Cd, while the relationship between Ar and Cd was negatively weak.

Table 6 showed that the level of the heavy metals obtained in the cassava leaves collected from the study areas were under the safe level amount in relation to the WHO and FAO permissible limits. However, only the Chromium (Cr) and Cadmium (Cd) levels were above the WHO and FAO permissible level.

Table 4: The pH, organic matter and heavy metals constituent of cassava leaves collected from oil exploration sites in six local government areas of Delta State, Nigeria

Location	pH	OC	Hg	Cr	Al	Th	Pb	Ar	Cd
		%	-----mg/kg-----						
Ukwani	6.20c	53.3a	0.04a	5.09a	0.15a	0.08a	0.35a	0.10ab	24.6a
NE	6.40bc	53.2a	0.04a	5.06a	0.15a	0.08a	0.33a	0.08ab	33.5a
EW	6.25bc	52.9a	0.04a	4.56a	0.16a	0.08a	0.28a	0.07b	37.1a
US	6.60b	51.6a	0.05a	5.36a	0.17a	0.09a	0.25a	0.09ab	45.8a
EE	7.33a	53.5a	0.04a	5.69a	0.13a	0.06a	0.26a	0.10ab	43.0a
NW	6.23b	56.9a	0.04a	5.33a	0.16a	0.08a	0.28a	0.11a	38.8a
LSD(0.05)	0.38	14.4	0.02	1.47	0.06	0.05	0.16	0.04	27.8
SE	0.13	4.86	0.01	0.49	0.02	0.02	0.05	0.01	9.34

Means with same alphabets down the groups are not significantly different from each other at 5% level of

significance. LSD: Least significance differences, SE: Standard error

Table 5: Correlation matrix of chemical elements of cassava leaves drawn from near oil exploration sites in six local government areas of Delta State, Nigeria

	Ph	OC	Hg	Cr	Al	Tho	Pb	Ar	Cd
ph	1								
OC	-0.2	1							
Hg	-0.02	0.27	1						
Cr	0.42	-0.02	-0.02	1					
Al	-0.28	0.33	0.74*	-0.37	1				
Th	-0.25	-0.01	0.15	-0.6	0.3	1			
Pb	-0.1	-0.05	0.18	0.11	-0.09	-0.35	1		
Arg	0.18	0.11	-0.27	-0.03	0.11	0.06	-0.33	1	
Cd	0.37	-0.52	0.09	-0.09	0.04	0.17	-0.21	-0.11	1

Table 6: Status of heavy metals level of cassava leaves collected oil exploration sites in six local government areas of Delta State relative to WHO/FAO

Location	Cr	Ar	Cd	Pb	Hg	Al
Ukwani	Unsafe	Safe	Unsafe	Safe	Safe	Safe
NE	Unsafe	Safe	Unsafe	Safe	Safe	Safe
EW	Unsafe	Safe	Unsafe	Safe	Safe	Safe
US	Unsafe	Safe	Unsafe	Safe	Safe	Safe
EE	Unsafe	Safe	Unsafe	Safe	Safe	Safe
NW	Unsafe	Safe	Unsafe	Safe	Safe	Safe
WHO/FAO	1.3	0.3	0.02	2	0.5	0.2

Discussion

The anthropogenic activities of man for decades has contributed largely to the menace of soil pollution worldwide (Ashraf *et al.*, 2019) ^[8]. In this study, the selected local government areas of Delta State, Nigeria is described as an oil rich zones where oil exploration activities are carried out daily (Onojake *et al.*, 2014; Ataikiru *et al.*, 2017) ^[27]. However, these exploration activities contribute to the release of heavy metals to the surrounding soils and plant habitats (Okon and Ogba, 2018) ^[26]. The heavy metals are elements with atomic masses above 20 which is usually needed in trace concentrations in the soil (Li *et al.*, 2019). However, the excessive deposition of these elements above the World Health Organization (WHO) and Food and Agricultural Organization (FAO) in the surrounding environment due to the oil exploration activities presents a serious challenge to farming activities in these communities of which the majority of the population depends on the proceeds from subsistence farming (Ojobor *et al.*, 2022 and Ossai *et al.*, 2025) ^[25], and the awareness of the presence of heavy metals is necessary for remediation actions (Akpeji *et al.*, 2021) ^[6].

The findings of this study revealed a spartial variation in the organic matter content of the assessed soils with the least organic matter content observed around the oil exploration site in Ethiope East LGA. The presence of high organic matter content encourages microbial activities in the soil and the decomposition of some heavy metals thereby making the soil suitable for cassava production (Neina, 2019) ^[22]. However, if these contaminants are not curbed earlier, their concentrations in the soil will eventually degrades the soil organic matter properties and render the soil unfit for agricultural purposes (Agbogidi *et al.*, 2006) ^[5].

Ukwani LGA had the highest electrical conductivity, Th, Pb, and Ar. Although, all the LGAs fell below the danger levels of the heavy metals. However, the Cd content observed in all the LGAs were above the WHO/FAO permissible level. Department of Petroleum Resources (2018) ^[11], had earlier stated the the permissible level of Cd in the soil should not exceed 0.8 mg/kg which is also in line with WHO/FAO, and Tubotu and Agbaire (2022) had also reported that the content of Cd present Burutu and Ogburu communities of Niger Delta exceeds the WHO/FAO permissible level and attributes the high amount to oil exploration in the area. Lead (Pb) and Cadmium (Cd) are known to be toxic to living organisms and has no biologic function (Siddiquee *et al.*, 2015). A similar value of Cd content in Delta Area has earlier been reported by Bankole *et al.* (2024) ^[10] as they attributed the high content to oil exploration activities in Niger Delta communities.

Ugheli South has the highest Al content, although the Al level in all the study area were below the WHO/FAO unsafe level, which means the exploration activities in the areas is yet to pose danger to farm activities. However, safety precautions in the exploration activity in Ugheli South needs to be put in place to avoid quick attainment of Al danger level. This is important as excess Al in the soil lowers the availability of phosphorus, decreases root respiration making the plant root to depend on higher amount of essential nutrients like Ca, Mg, K, P, and Fe (Foy, 1992) ^[12]. However, results obtained showed a moderate relationship between all the parameters in the soil, except the CEC and the Pb where the relationship existing between them is strong. This is because high content of CEC reduces the leaching rate of Pb in the soil (Yong *et al.*, 2016).

The major side effect of the presence of these heavy metals in the soil is on the inhibitory growth, development and eventual output of agricultural produce like cassava, as it affects the soil pH, and availability of other essential elements in the soil (Guijarro *et al.*, 2021), and the subsequent detection of these metals above the world permissible level in the processed food deters buyers and drastically reduce the monetary returns from the sales. This is because, crops grown in the environs of oil exploration end up assimilating these heavy metals from the soil and through air pollution. This is evident in the variation in the pH values of the cassava leaves across the six (6) local government areas where oil exploration is taking place (Saikia *et al.*, 2023). Although, there were variation in the Ar content in the plant samples across the LGAs. Except for Cr and Cd, the values of all other heavy metals in the plants remain within the WHO/FAO permissible level (Obasi *et al.*, 2019) ^[24]. The Hg and Al had a strong relationship between them, and this is because both heavy metals act in acidic corrosions in the air (Saleem *et al.*, 2022).

Conclusion

Cassava farming is a major source of income for majority of farmers around Delta State, Nigeria. However, the production is constrained by oil exploration activities in the State through the release of heavy metals to the soils and cassava produce. This study has shown that the level of Cd in the soils of the six environments were above the World Health Organization and Food and Agriculture, while the levels of Cd and Cr levels of cassava leaves drawn from the six local government areas of Delta State were above the WHO/FAO safe level. Thus, since most of the heavy metals are still below the WHO/FAO permissible level, the oil exploration companies

have to commence the remediation of the contaminated surroundings early to avoid majority of the elements going above the safe level and thus bring the level of the Cr and Cd within safe level in the exploration environment.

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