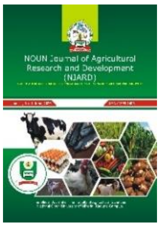
*NOUN Jour. of Agric. Res. & Dev. Vol. 1, No.1, Page 37 - 47*

**p-ISSN: 1595-1405**

**NOUN Journal of Agricultural Research and Development (NJARD)**

***The Official Journal of the Faculty of Agricultural Sciences, National Open University of Nigeria, Kaduna Campus***

Journal homepage: https://journal.agric.nou.edu.ng



**OPEN ACCESS**

**Original Article**

# Assessment of heavy metals concentrations in soils and cassava (*Manihot esculenta*) from crude oil-polluted soils in Akwa Ibom State, Nigeria.

**Sunday *, A.  E, Umoh, F. O. & Udoh O. E.**

*Department of Soil Science, Akwa Ibom State University, Nigeria.*
**Corresponding author: ekpeslincolnjur@gmail.com, Tel: 08062139419*

***Editor:*** *Dr. Sunday N. Obasi*
*National Open University of Nigeria*

***Received:*** *April 10, 2025*
***Accepted:*** *May 15, 2025*

*Peer-review: Externally peer-reviewed*

***Conflict of Interest:*** *The authors have no conflicts of interest to declare*

***Financial Disclosure:*** *The authors declared that this study has received no financial support*

## ABSTRACT

*This study assessed the concentrations and transfer dynamics of selected heavy metals—Iron (Fe), Manganese (Mn), Zinc (Zn), and Copper (Cu)—in soils and cassava (Manihot esculenta) grown in crude oil-polluted areas of Akwa Ibom State, Nigeria. Soil samples were collected at depths of 0–15 cm and 15–30 cm from six locations, alongside corresponding cassava samples. Standard laboratory procedures were employed to determine physicochemical properties and metal concentrations, while transfer factors (TF) and geo-accumulation indices (Igeo) were used to evaluate bioaccumulation and contamination status. Results revealed that the polluted soils were predominantly sandy loam, with elevated pH, organic matter, and electrical conductivity compared to the control (Etinan). Heavy metal concentrations followed the order Fe > Mn > Zn > Cu in both soil and plant tissues. The highest metal accumulation in cassava was recorded for Fe (134.51 mg/kg in Ibeno) and Mn (31.55 mg/kg in Ikot Abasi), while transfer factors indicated moderate to high bioavailability, particularly for Zn and Cu. Geo-accumulation indices suggested moderate to strong contamination in some locations, notably Ikot Abasi and Esit Eket, although all levels remained within permissible limits set by WHO/FAO. The study concludes that while cassava from these oil-impacted areas is currently within safe consumption thresholds, continued monitoring is essential to prevent long-term health risks. It recommends cautious cultivation practices and environmental management in crude oil-exploited zones to safeguard food safety and soil health.*

***Keywords:*** *Crude oil-polluted, Soil concentrations, Transfer factors, Heavy metal, Bioaccumulation.*

## 1.0 Introduction

The environmental impact of oil exploration is an inevitable consequence of modern economic development in the technological age. Nigeria, as noted by Kadafa (2012) is country rich in oil. Whether by design or by chance-making the oil industry the most significant economic sector of Nigeria. This sector has rapidly expanded to become a major driver of economic activity today. Petroleum contributes nearly 90% of export revenues and serves as a crucial raw material for chemical companies (Akachuku, 1995). The high demand for petroleum products, including cooking gas, fuel, gas oil, motor lubricating oil and lots more have increased the rate of environmental pollution and high output of petroleum-related activities, frequently resulting in oil spills, oil well blowouts, tanker accidents, and pipeline leaks (Umoh *et al*., 2024). These mishaps have led to the release of crude oil and refined petroleum products into both terrestrial causing harm aquatic environments (Ellis & Adams, 1997). When these dangerous toxic compounds are present in sufficient amounts it then causing harm to the soil environment and to humans (Chary *et al.*, 2008, Tommy et al., 2021)

Heavy metals particularly Cadmium (Cd) and Lead (Pb) which are found in crude oil, have substantial harmful and hazardous impacts on the environment and human health (Raskin *et al*., 1995). Recent research has shown that many edible plants accumulate these heavy metals in their roots, translocating them to their leaves or shoots, and even to their fruit, which is then consumed by humans or animals (Baker *et al*., 2000). The effect of heavy metal contamination on water bodies, streams, soils and plants is one of the major environmental problems facing oil-bearing communities in Akwa Ibom State. Uduak and Umoh (2022); Adewumi *et al*, (2022) observed high level of Cd, Cu and Pb in some selected oil polluted soils in Eastern Nigeria which they reported to be above the permissible limits by World Health Organization (WHO). It was also observed that Manihot esculenta grown on the soils were high in metal concentration and these may have a harmful effect on the consumers.

Ijah et al., 2018 and Onwugbuta *et al*., (2022) reported a slight increase in clay content in oil polluted soils than unpolluted soil and a slight decreased in pH but increased in organic matter levels. Edem *et al*., (2008) reported that oil spilled on land surfaces disrupt the soil aggregate, lose the aggregate size, decreased infiltration of water and increased run off while Sunday *et al*., (2020) noticed that the leaching potential of nutrient down the soil profiled will increased rapidly due the weak structure of the soil and sandy nature of the parent materials causing nutrient to loss over time; while dissolving metals compound that were bound with soil particles and released into soil solution thus increasing their bioavailability.

Akata *et al*., (2018) reported that Cassava (*Manihot esculeta*) is one of the most important versatile agricultural commodities in Akwa Ibom State. It numerous uses and by-products is a major staple food for rural and urban households, also as raw materials for many industries in the many States. Cassava is a widely accessible and affordable staple crop a reliable source of food for more than 700 million people in the developing countries and Nigeria leads the global market share with about 21 percent of the world's cassava production (FAO/WHO, 2006). Based on the many benefits of these crop and for the safety of the consumers, there is a great need to monitors the rate of pollutions and also making the environment save. Therefore, this study aimed at assessing the concentrations levels of heavy metals in soils and Cassava grown in crude oil polluted soils in selected communities of Akwa Ibom State, Nigeria.

## 2.0 Material and Method

### 2.1 Description of Study Locations

The study was conducted in six locations representing different oil-bearing communities in Akwa Ibom State which lies between Latitudes $4^0$32'N and $5^0$33'N and longitudes $7^0$25'E and $8^0$25'E. It is bounded with Abia State in the North, Cross River State in the southeast and the offshore of the Atlantic Ocean in the south. It has a land mass of 8,412km$^2$ and a shore line of 129km$^2$ long encompassing Akwa Ibom River Basin. There are two main seasons are the wet and dry seasons from January and March Table 1 and Figure 1 show the description of the study site.

### 2.2 Samples Collection and Design

The soil samples were collected from the six locations at 0-15 cm depth and 15-30cm depth and three replications and a total of 36 soil samples were generated, soils sample were air-dried, sieved through a 2mm mesh and used for determination of the physicochemical properties and heavy metals levels. Plant sample were also collected from the six locations and replicated 3 times and totals of 8 plant samples were analysed.

### 2.3 Laboratory Analysis

### 2.3.1 Physicochemical Properties:

The soil sample were used to determine some physical and chemical properties of the study soils using the standard procedures as outlined by Udo *et al.,* (2009). Particle size distribution was determined by the Bouyoucous hydrometer method. Soil pH was determined in 1:2.5 soil: water ratio with a pH meter. Organic carbon was determined by Walkley Black Dichromate Oxidation Method. Organic matter was obtain by multiplying % OC values with a factor 1.72. Total nitrogen (N) was determined by the microkjeldahl method. Available phosphorous (P) was extracted by the Bray 1 extraction method, and the content of P was determined colorimetrically using a Technico AAll auto analyser. Exchangeable bases K, Na, Ca and Mg) were extracted with O. I. N ammonium acetate; K and Na were read with a flame photometer while Ca and Mg were determined through the EDTA titration method. Exchangeable acidity was determined by leaching the soils with I N KCl and titrating the aliquots with 0.01 NaOH. Effective cation exchange capacity (ECEC) was calculated as the sum of exchangeable bases and exchangeable acidity. Base saturation was calculated by dividing the sum of exchangeable bases by ECEC and multiplying by 100.

### 2.3.2 Determination of Heavy Metals in Soil

The soil sample (1g) was weighed into a digested flask. Concentrated nitric acid (20ml) was added and the mixture was digested using hot plate. After digestion it was allow to cool and 30ml of distilled water was added and filtered with human filter paper. The flask and the contents were placed in a standing position on an electric hot plate in a fume cupboard and gently heated to evaporated until 1-2m of the acid was left (near dryness), the color changes to white. This was allowed to cool before leaching the residue with 5ml of $HNO_3$. The filtration was done using an acid filter paper (Whatman No.1) finally made up to 50 ml with de-ionized water. The aliquots were used for the determination of Iron (Fe), Manganese (Mn), Zinc (Zn), Copper (Cu), metals using a Unicam atomic absorption spectrophotometer (AAS) MODEL 939.

Table 1: Description of the Study Locations

| **Parent Materials** | **LGA** | **Community** | **Vegetation Cover** | **Land use Type** | **Coordinates** |
|---|---|---|---|---|---|
| Beach Sand | **Ibono** | Mkpanak | Fresh, Water Swamp, Mangrove | Yam, Maize, Cassavas | 4.6213° N, 7.7360° E |
| Alluvium | Esit Eket | Uquo | Fresh, Water Swamp, Mangrove | Yam, Maize, Cassavas | 4.5524° N, 7.8279° E |
| Alluvium | Mbo | Udung Ulo | Fresh, Water Swamp | Yam, Maize, Cassavas | 4.5000° N, 8.2667° E |
| Alluvium | Eastern Obolo | Atabrikang | Fresh, Water Swamp, Mangrove | Yam, Maize, Cassavas | 4.6878° N, 7.8426° E |
| Alluvium | Ikot Abasi | Ikot Ada Udo | Tropical Rain Forest | Yam, Maize, Cassavas | 4.7469° N, 7.4000° E |
| Coastal Plain Sand | Etinan | Ikot Udobia | Fresh Water | Maize, Cassavas | 4.9719° N, 7.8870° E |

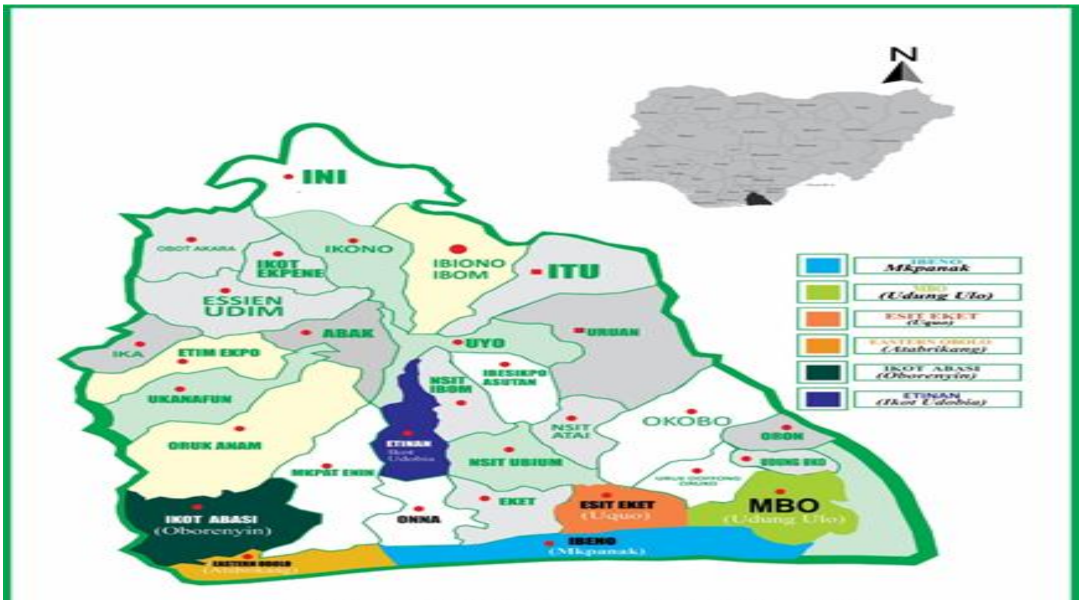


**Figure 1: The Map of Akwa Ibom State showing the location of the study Area**

### 2.3.3 Determination of Heavy Metals in *Manihot esculenta*

The powdered plant sample (2g) was weighed into a crucible and ashed in a furnace at 500˚C-700˚C for 4 hours. It was removed after ashing from the furnace and cooled. The sample (ash) was leached with 5 cm3 of 6 M HCl and was made to 50 $cm^3$ of volume of deionized water. Blank determination was also carried out as in a similar way as described above except for the omission of the sample. The solutions were analyzed for Iron (Fe), Manganese (Mn), Zinc (Zn), Copper (Cu), using Atomic Absorption Spectrophotometer (AAS) Unicam Solaar 969 model.

### 2.3.4 Soil to Plant Transfer Assessment

Soil to plant metal transfer was computed as transfer factor (TF) which was defined by Equation 1.

$$TF = C_{plant} / C_{soil} \quad - \quad - \quad -(1)$$

(Chary *et al.,* 2008)

Where ($C_{plant}$) is the concentration of heavy metals in plants and ($C_{soil}$) is the concentration of heavy metals in soil.

### GEO Accumulation Index ($I_{geo}$)

Methods for calculating pollutant indices (Geo accumulation index) was calculated by computing the base 2logarithm of the measured total concentration of the metals relative to its concentration, using the mathematical relationship.

$I_{geo}= \log_2 (Cn/1.5\ Bn)$ - - (2)

Where; Cn-measure of total concentration of the element

Bn- is the geochemical of the element

1.5 - the constant which introduced to minimize effect.

**Geo-accumulation rating by Muller and Suess, 1979**

Goe- accumulation index > 0 indicated uncontaminated

Goe- accumulation index >0-1 indicated uncontaminated to moderate contamination

Goe- accumulation index >1-2 indicate moderate contamination

Goe- accumulation index >2-3 indicate moderate to strongly contamination

Goe- accumulation index >3-4 indicate strongly contamination

Goe- accumulation index >4-5 indicate strong to very strong contamination

Goe- accumulation index >5 indicate very strong contamination.

**Statistical Analysis**

Data generated from the laboratory were subjected to analysis of variance and means compared using least significant difference at 0.05% ($p < 0.05$) and 1% ($p < 0.01$) probability levels. The Duncan's Multiple Range Test were used. (Gomez and Gomez, 1984).

## 3.0 Results and Discussions

### 3.1 Physiochemical Properties of the soils as affected by crude oil Pollution

The result of the soil properties as affected by crude oil pollution, is presented in Table 2. The sand, silt, and clay fraction were significantly difference among the various locations. The sand content values ranging from Mbo (82.30%) > Ibeno (81.75%) > Esit Eket (81.40%)> Ikot Abasi (80.46%) > Eastern Obolo (78.85%) > Etinan (78.92%). The silt fraction varies as in Eastern Obolo (8.40%)>, Ikot Abasi (6.70%)>, Etinan (6.17%)>, Ibeno (3.95%)>, Esit Eket 3.22%)> Mbo (2.85%). Clay fraction were Esit Eket (15.32%)>, Mbo (14.85%)>, Etinan (14.90%)> Ikot Abasi (12.82%)>, Eastern Obolo (12.75%).

The texture were consistent as loamy sand. The high sand fractions soils may be due to the crude oil present causing aggregation of soil particles to flocculation. This process result in formation of large macrospore leading to downward movement of suspended clay, high sand along with reduction of clay and silt fraction in the soil (Umoh *et al.*, 2024). The study also reveals that the pH were significantly higher in polluted soils than unpolluted soil (Etinan). This finding agreed with the work of Wang *et al.,* (2009) who reported an increase in soil pH in crude oil polluted soils. Extreme soil pH in Etinan can be attributed to the sandy nature of the soil, with a low level of organic matters resulting in a low buffering capacity and low rate of a water infiltration (Umoh *et al.,* 2020). The electrical conductivity (EC) of the study soils were significant differences; Ibeno had the highest EC value of 0.725 $dsm^{-1}$, while Etinan had the lowest at 0.046 $dsm^{-1}$. The Organic carbon (OC) content across the locations was low, with values varying from Eastern Obolo (2.170) >, Esit Eket (2.075) >, Etinan (1.595) >, Ibeno (1.520) >, Ikot Abasi (1.500) >, to Mbo (1.377) >. The Organic Matter (OM) and Total Nitrogen (TN) levels were also low, based on the ratings. Available Phosphorus (Av. P) exhibited significant variation among the locations, with values varies as Esit Eket (15.952) > Eastern Obolo (15.195) > Ibeno (13.295) > Etinan (8.695). The cation exchange capacity of the soil also displayed notable differences across the locations, with the order of abundance being Ca > Mg > K > Na These Calcium (Ca) was the predominant element across the locations, with values ranging from Esit Eket (4.305) > Mbo (4.331) > Etinan (3.596) > Ikot Abasi (2.785) > Eastern Obolo (2.273). Magnesium (Mg) increased in the following order: Esit Eket (1.878) > Etinan (1.861) > Ikot Abasi (1.496) > Mbo (1.330) > Eastern Obolo (1.158). The potassium (K) concentration were Ibeno (1.672) > Ikot Abasi (1.612) > Etinan (1.397) > Mbo (1.345) > Eastern Obolo (1.330) > Esit Eket (1.017). Sodium (Na) concentrations were higher in oil-polluted soils compared to the control soils (Etinan). The effective cation exchange capacity (ECEC) of the soils varied significantly among the locations, ranging from Mbo (9.241) > Esit Eket (8.776) > Etinan (8.365) > Ikot Abasi (8.031) > Eastern Obolo (6.028). The percentage base saturation (BS) was significantly lower in crude oil-polluted soils compared to the unpolluted soil in Etinan (control).

In terms of depth the fraction of sand, silt and clay at 0-15cm were significantly higher than those at 15-30cm. The pH level in the topsoil were also higher than those in the subsoil (4.85>4.75) Electrical conductivity (EC) were lower in 0-15 than 15-30cm (0.02, <0.18). Organic carbon (OC), Organic matter (OM). Total Nitrogen (TN), and Available Phosphorus (Av. P) were significantly higher in the topsoil than in the subsoil may be attributed to the calculation of letter on the surface soil and light retention of nutrients. (Umoh *et al*, 2023; and Sunday *et al*., 2021) Electrical conductivity (EC) of the soil were significantly higher in polluted soil than in the control soils. The difference could be due to hydrophobic nature of crude oil and thus increase the salt levels. The percentages of organic carbon content of the soil increased and were significantly higher at 0-15 cm depth. This may be as a result of the increased in organic matter content and similar observations were obtained by Umoh *et al*., (2023). Hydrocarbon content in crude oil can also increase the level of organic carbon (Osuji *et al*., 2004). These may be attributed to the accommodation of litter over the years (Umoh *et al.,* 2020, Umoh *et al.,* 2023). The effective cation exchange capacity (ECEC), and base saturation (BS) exhibited higher values in the topsoil (0-15cm) compared to the subsoil (15-30cm). The intimation between the locations and soil depth shows that sand, silt and clay fraction at various polluted locations were significantly higher than the control. This observation aligns with the finding of Ideria *et al*., (2013) who reported a higher, silt and clay fraction in the subsoil and compared to high sand content in topsoil. Effective cation exchangeable capacity (ECEC) and base saturation (BS) which measures the fertility status of the soil were moderate varying in the order of $Ca^{2+}$>$Mg^{2+}$>$K^{+}$>$Na^{+}$. (Tommy *et al*., 2021, Itakufok and Umoh, 2022).

## 3.2 Concentration of Heavy Metal in the Soils

The results of heavy metal concentrations in soils are presented in Table 3. The concentration of Iron (Fe) across the various locations were significantly higher than the control soils (Etinan). The concentrations were as follows: Ibeno (142.605) >Ikot Abasi (142.307) > Eastern Obolo (122.872) > and Esit Eket (111.457), compared to Etinan (46.092). Manganese (Mn), with Ikot Abasi had the highest concentration of Mn (52.477) and Zn, compared to the lowest concentration in control (0.927) as showed in figure 2. These values were significantly higher than those at the control site, likely due to the area's status as a core oil-producing community with increasing oil exploitation activities. This finding aligns with the research conducted by Ideria *et al*. (2013), who reported that areas with oil activities consistently exhibit high concentrations of heavy metals. Additionally, the elevated concentrations of heavy metals in soil samples from all study locations (Ibeno, Esit Eket, Mbo, Eastern Obolo, Ikot Abasi) exceed the permissible limits established by World Health Organization (WHO, 2011). In contrast, the heavy metal concentrations from the control site remain within acceptable limits.

This finding indicates that the soil samples from all crude oil study locations in Akwa Ibom State are significantly contaminated with heavy metals, which may pose serious environmental and health risks. The depth of the statistical analysis revealed a significant difference in heavy metal concentrations between the soil depths of 0-15 cm and 15-30 cm ($P < 0.05$). Additionally, iron (Fe), Zincc (Zn), copper (Cu) exhibited high levels of contamination in the topsoil. Manganese (Mn). The concentration of the element at various depths revealed high concentration on the topsoil than the subsoil. This may be attributed to high or accumulation of litters, resulting from crude oil pollution. Esit Eket, Mbo and Eastern Obolo were not significantly different in heavy metal concentration between the two depth (0-15cm – 0-30cm). This variation may be link to soil texture and the degree of retention of elements (Umoh *et al.* 2021).

The interaction between the oil bearing soils were highly significant compared to control (Etinan) and top soils may experiment leeching of element. This finding align with the research conducted by Sunday *et al*. (2020) who reported that the leaching can deplete soil nutrients elements and minerals or redistribute them among various soil layers (topsoil and subsoil) due to excessive rainfall and irrigation. The deposition of heavy metals in contaminated soil can pose significant health risks. This finding supports the conclusions of Benson and Ebong (2005), who indicated that accumulation of heavy metals in soil degrade soil quality, hinder crop development, and result in reduced yield.

## 3.3 Concentration of Heavy Metal (Fe, Mn, Zn, Cu) in the Cassava

The concentrations of heavy metals in cassava leaves are presented in Table 4. The levels of iron (Fe), manganese (Mn), Zincc (Zn), copper (Cu) in cassava leaves were significantly higher than those in the control soils. The concentration of Fe ranged from 134.51 mg/kg in Ibeno > Esit Eket (129.38 mg/kg) > Mbo (107.46 mg/kg) > Ikot Abasi (101.71 mg/kg) > Eastern Obolo (80.33 mg/kg) > Etinan 30.16 mg/kg). Mn in Ikot Abasi (31.55 mg/kg)> Ibeno (24.53 mg/kg)> Eastern Obolo (22.48 mg/kg)> Mbo (17.75 mg/kg)> Esit Eket (14.33 mg/kg)> Etinan (11.70 mg/kg). Zinc (Zn) Ibeno (29.29 mg/kg) > Esit Eket (22.75 mg/kg) > Mbo (19.51 mg/kg)> Eastern Obolo (18.45 mg/kg)> Etinan (7.20 mg/kg). Cu levels ranged from Eastern Obolo (10.95 mg/kg)> Mbo (10.01 mg/kg), Ikot Abasi (4.74 mg/kg)> Ibeno (1.40 mg/kg)> Etinan (1.26 mg/kg. These concentrations were within the safety limits established by the World Health Organization (WHO, 2011). The differences in heavy metals concentrations among the locations are due to the concentration of crude oil accumulation. The result also indicates that Ibono had the highest concentration of Fe and Zn, Ikot Abasi had the highest level of manganese (Mn), and Esit Eket had the highest (Cu). This accumulation of heavy metals varies among the different oil of bearing locations.

Table 2: Soil Physicochemical Properties of the Study Area

| Locations | Sand | Silt | Clay | Tex | pH | EC | OC | OM | TN | AV.P | K | Ca | Mg | Na | EA | ECEC | BS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | % | % | % | | | (dSm$^{-1}$) | % | % | % | ( mgkg$^{-1}$) | $\leftarrow$ | | cmolkg$^{-1}$ | | | $\rightarrow$ | % |
| **Location** | | | | | | | | | | | | | | | | | |
| **Ibeno** | $81.75^{b}$ | $3.95^{d}$ | $14.30^{c}$ | SL | $4.57^{b}$ | $0.725^{a}$ | $1.542^{b}$ | $2.670^{a}$ | $0.895^{c}$ | $13.295^{c}$ | $1.672^{a}$ | $2.350^{d}$ | $1.608^{b}$ | $0.068^{b}$ | $1.388^{b}$ | $7.088^{e}$ | $78.996^{c}$ |
| **Esit Eket** | $81.40^{c}$ | $3.22^{e}$ | $15.32^{a}$ | SL | $5.40^{a}$ | $0.081^{cd}$ | $2.075^{a}$ | $3.576^{a}$ | $0.491^{e}$ | $15.952^{a}$ | $1.017^{d}$ | $4.305^{a}$ | $1.878^{a}$ | $0.270^{a}$ | $1.305^{b}$ | $8.776^{b}$ | $84.958^{a}$ |
| **Mbo** | $82.30^{a}$ | $2.85^{f}$ | $14.85^{b}$ | SL | $5.32^{a}$ | $0.085^{c}$ | $1.377^{c}$ | $2.367^{c}$ | $0.603^{d}$ | $7.505^{e}$ | $1.345^{c}$ | $4.331^{a}$ | $1.330^{c}$ | $0.290^{a}$ | $1.941^{a}$ | $9.241^{a}$ | $78.730^{c}$ |
| **Eastern O.** | $78.85^{e}$ | $8.40^{a}$ | $12.75^{d}$ | SL | $4.50^{b}$ | $0.071^{d}$ | $2.170^{a}$ | $3.729^{a}$ | $1.286^{b}$ | $15.195^{b}$ | $1.330^{c}$ | $2.273^{d}$ | $1.158^{d}$ | $0.300^{a}$ | $0.965^{c}$ | $6.028^{f}$ | $84.368^{ab}$ |
| **Ikot Abasi** | $80.46^{d}$ | $6.70^{b}$ | $12.82^{d}$ | SL | $4.55^{b}$ | $0.046^{e}$ | $1.595^{b}$ | $2.742^{b}$ | $1.508^{a}$ | $8.695^{d}$ | $1.397^{bc}$ | $3.596^{b}$ | $1.861^{a}$ | $0.145^{b}$ | $1.366^{b}$ | $8.365^{f}$ | $83.440^{b}$ |
| **Etinan** | $78.92^{e}$ | $6.17^{c}$ | $14.90^{b}$ | SL | $4.45^{b}$ | $0.156^{b}$ | $1.50^{b}$ | $2.582^{b}$ | $0.653^{d}$ | $6.520^{f}$ | $1.612^{ab}$ | $2.785^{c}$ | $1.496^{b}$ | $0.290^{a}$ | $1.855^{a}$ | $8.031^{d}$ | $77.133^{c}$ |
| **Soil Depth** | | | | | | | | | | | | | | | | | |
| **0 - 15** | $81.72^{a}$ | $5.31^{a}$ | $13.15^{b}$ | SL | $4.84^{a}$ | $0.183^{a}$ | $2.039^{a}$ | $3.511^{a}$ | $0.965^{a}$ | $11.527^{a}$ | $2.055^{a}$ | $3.296^{a}$ | $1.543^{a}$ | $0.228^{a}$ | $1.581^{a}$ | $8.705^{a}$ | $81.777^{a}$ |
| **15 - 30** | $79.51^{b}$ | $5.13^{b}$ | $15.16^{a}$ | SL | $4.75^{a}$ | $0.020^{b}$ | $1.381^{b}$ | $2.378^{b}$ | $0.847^{b}$ | $10.860^{b}$ | $0.735^{b}$ | $3.251^{a}$ | $1.567^{a}$ | $0.225^{a}$ | $1.358^{b}$ | $7.138^{b}$ | $80.768^{b}$ |
| **Location x Soil depth Interaction** | | | | | | | | | | | | | | | | | |
| **IB (0-15cm)** | $83.05^{b}$ | $3.60^{f}$ | $13.35^{e}$ | SL | $4.70^{c}$ | $0.724^{a}$ | $2.270^{b}$ | $3.919^{b}$ | $0.920^{d}$ | $13.810^{c}$ | $2.460^{a}$ | $3.410^{d}$ | $1.623^{b}$ | $0.083^{d}$ | $1.406^{cd}$ | $8.983^{bc}$ | $84.350^{bc}$ |
| **(15-30cm)** | $80.45^{e}$ | $4.30^{e}$ | $15.25^{b}$ | SL | $4.45^{cde}$ | $0.724^{a}$ | $0.815^{g}$ | $1.421^{g}$ | $0.870^{d}$ | $12.780^{d}$ | $0.885^{e}$ | $1.290^{g}$ | $1.593^{bc}$ | $0.053^{d}$ | $1.370^{cd}$ | $5.193^{g}$ | $73.643^{f}$ |
| **EE (0-15cm)** | $82.35^{c}$ | $3.15^{h}$ | $14.50^{c}$ | SL | $5.60^{a}$ | $0.042^{g}$ | $2.270^{b}$ | $3.919^{b}$ | $0.550^{g}$ | $16.785^{a}$ | $1.525^{d}$ | $3.390^{d}$ | $1.533^{b}$ | $0.300^{ab}$ | $1.440^{c}$ | $8.190^{d}$ | $82.410^{cd}$ |
| **(15-30cm)** | $80.45^{e}$ | $3.40^{fg}$ | $16.15^{a}$ | SL | $5.20^{b}$ | $0.121^{c}$ | $1.880^{c}$ | $3.232^{b}$ | $0.433^{h}$ | $15.120^{b}$ | $0.510^{f}$ | $5.220^{a}$ | $2.223^{a}$ | $0.240^{abc}$ | $1.170^{e}$ | $9.363^{b}$ | $87.506^{a}$ |
| **MB (0-15cm)** | $83.45^{a}$ | $2.40^{i}$ | $14.15^{d}$ | SL | $5.30^{b}$ | $0.084^{de}$ | $1.675^{d}$ | $2.880^{d}$ | $0.763^{e}$ | $9.240^{e}$ | $2.115^{bc}$ | $4.280^{b}$ | $1.410^{cde}$ | $0.320^{a}$ | $1.753^{b}$ | $9.880^{a}$ | $82.222^{d}$ |
| **(15-30cm)** | $81.15^{d}$ | $3.31^{h}$ | $15.55^{b}$ | SL | $5.35^{ab}$ | $0.087^{d}$ | $1.080^{f}$ | $1.854^{f}$ | $0.443^{h}$ | $5.770^{g}$ | $0.575^{ef}$ | $4.383^{b}$ | $1.250^{efg}$ | $0.260^{abc}$ | $2.130^{a}$ | $8.603^{cd}$ | $75.236^{f}$ |
| **EO (0-15cm)** | $79.45^{f}$ | $8.40^{a}$ | $12.15^{f}$ | SL | $4.5^{cde}$ | $0.066^{ef}$ | $2.465^{a}$ | $4.236^{a}$ | $1.293^{c}$ | $16.660^{a}$ | $1.820^{cd}$ | $2.213^{f}$ | $1.250^{fg}$ | $0.250^{abc}$ | $1.270^{de}$ | $6.753^{f}$ | $81.767^{d}$ |
| **(15-30cm)** | $78.25^{g}$ | $8.40^{a}$ | $13.35^{e}$ | SL | $4.50^{cde}$ | $0.076^{de}$ | $1.875^{c}$ | $3.223^{c}$ | $1.280^{c}$ | 13.730 | $0.840^{e}$ | $2.333^{f}$ | $1.113^{fg}$ | $0.240^{abc}$ | $0.660^{f}$ | $5.303^{g}$ | $87.506^{a}$ |
| **IA (0-15cm)** | $82.60^{c}$ | $6.00^{c}$ | $11.40^{g}$ | SL | $4.70^{c}$ | $0.038^{g}$ | $1.770^{cd}$ | $3.043^{cd}$ | $1.583^{a}$ | $8.730^{e}$ | $2.000^{c}$ | $3.733^{c}$ | $2.113^{a}$ | $0.150^{bcd}$ | $1.390^{cd}$ | $9.380^{b}$ | $85.350^{b}$ |
| **(15-30cm)** | $78.32^{g}$ | $7.40^{b}$ | $14.25^{cd}$ | SL | $4.40^{de}$ | $0.054^{fg}$ | $1.420^{e}$ | $2.441^{d}$ | $1.433^{b}$ | $8.660^{e}$ | $0.795^{ef}$ | $3.410^{d}$ | $1.610^{b}$ | $0.140^{cd}$ | $1.343^{cd}$ | $7.350^{d}$ | $81.693^{d}$ |
| **ET (0-15cm)** | $79.40^{f}$ | $7.25^{b}$ | $13.35^{e}$ | SL | $4.25^{e}$ | $0.149^{b}$ | $1.785^{cd}$ | $3.070^{c}$ | $0.683^{ef}$ | $6.870^{f}$ | $2.415^{ab}$ | $2.750^{e}$ | $1.380^{def}$ | $0.270^{abc}$ | $2.230^{a}$ | $9.043^{bc}$ | $75.236^{f}$ |
| **(15-30cm** | $78.45^{g}$ | $5.10^{d}$ | $16.45^{a}$ | SL | $4.65^{cde}$ | $0.163^{b}$ | $1.220^{f}$ | $2.095^{f}$ | $0.233^{fg}$ | $6.170^{fg}$ | $0.840^{ef}$ | $2.820^{e}$ | $1.613^{b}$ | $0.310^{a}$ | $1.480^{c}$ | $7.020^{ef}$ | $78.970^{e}$ |

Means with the same letters along the columns are not significantly different at $p \leq 0.05$., IB = Ibeno, EE = Esit Eket, MB = Mbo, EO = Easter Obolo, IA = Ikot Abasi, ET = Etinan SL=Sand Loam,

Table 3: The Level of Heavy Metals in the Polluted Soil

| Locations | Fe | Mn | Zn | Cu |
|---|---|---|---|---|
| | (mgkg$^{-1}$) | (mgkg$^{-1}$) | (mgkg$^{-1}$) | (mgkg$^{-1}$) |
| | | Location | | |
| Ibeno | $142.605^{a}$ | $34.385^{b}$ | $16.342^{c}$ | $3.035^{b}$ |
| Esit Eket | $111.457^{c}$ | $11.942^{d}$ | $14.575^{d}$ | $15.735^{a}$ |
| Mbo | $94.865^{d}$ | $18.852^{c}$ | $19.245^{b}$ | $0.152^{b}$ |
| Eastern Obolo | $122.872^{b}$ | $5.734^{f}$ | $2.202^{f}$ | $0.845^{b}$ |
| Ikot Abasi | $142.307^{a}$ | $52.477^{a}$ | $26.215^{a}$ | $12.172^{a}$ |
| Etinan | $46.092^{e}$ | $8.865^{e}$ | $3.112^{e}$ | $0.927^{b}$ |
| | Soil Depth | | | |
| 0 – 15 cm | $111.484^{a}$ | $21.145^{b}$ | $14.019^{a}$ | $7.447^{a}$ |
| 15 – 30 cm | $108.582^{b}$ | $22.940^{a}$ | $13.211^{b}$ | $3.508^{b}$ |
| | Location X Soil depth Interaction | | | |
| Ibono (0-15cm) | $157.010^{a}$ | $40.010^{c}$ | $18.640^{c}$ | $3.595^{c}$ |
| (15-30cm) | $128.200^{d}$ | $28.760^{d}$ | $14.045^{f}$ | $2.475^{c}$ |
| Esit Eket (0-15cm) | $114.687^{g}$ | $13.900^{g}$ | $12.635^{g}$ | $6.405^{bc}$ |
| (15-30cm) | $108.227^{h}$ | $9.985^{h}$ | $16.515^{e}$ | $25.065^{a}$ |
| Mbo (0-15cm) | $90.815^{j}$ | $16.675^{f}$ | $17.460^{d}$ | $0.155^{c}$ |
| (15-30cm) | $98.915^{i}$ | $21.030^{e}$ | $21.03^{b}$ | $0.150^{c}$ |
| Eastern Obolo (0-15cm) | $125.577^{e}$ | $4.945^{k}$ | $1.475^{k}$ | $0.725^{c}$ |
| (15-30cm) | $120.167^{f}$ | $6.523^{j}$ | $2.930^{i}$ | $0.965^{c}$ |
| Ikot Abasi (0-15cm) | $145.917^{b}$ | $41.505^{b}$ | $31.420^{a}$ | $9.485^{bc}$ |
| (15-30cm) | $138.687^{c}$ | $63.450^{a}$ | $21.010^{b}$ | $14.860^{b}$ |
| Etinan (0-15cm) | $34.890^{l}$ | $9.835^{h}$ | $2.485^{j}$ | $0.685^{c}$ |
| (15-30cm | $57.295^{k}$ | $7.890^{i}$ | $3.740^{h}$ | $1.170^{c}$ |

Means with the same letters along the columns are not significantly different at $p \leq 0.05$.

**3.4 Transfer Factor of heavy metal from soil to Plant**

The transfer factors of heavy metals from soil to plants (Table 5) show significant differences among the locations. Mbo has the highest concentrations of iron (Fe) and copper (Cu), while Etinan (the control site) has the lowest. Eastern Obolo exhibits the highest concentrations of Magnesium (Mg), Zincc (Zn), but these values differ significantly among the oil-bearing soils. This variation may be attributed to oil accumulation, as reported by Essiett *et al.,* (2010), who found similar results. The levels of Fe, Mg, Zn, and Cu were higher at a depth of 0-15 cm. The differences in depth may suggest an increase in organic matter. Umoh *et al*. (2021) reported that high retention of element on top soils can transfer nutrients down the soil profile, which plant roots may have access for elements utilization. The interaction between location and depth indicates that the soil-to-plant transfer factors are within the permissible limits established by the World Health Organization (WHO, 2011). This suggests that people living in all oil-bearing communities are safe to consume cassava.

**3.5 Geo-accumulation index of heavy metals in crude oil polluted soil**

Geo-accumulation Index (Igeo) has been extensively used to assess the degree of metal contamination in soils worldwide (Alshahri and El-Taher, 2018). It quantifies the extent of anthropogenic contamination by comparing the concentrations of various metals that may appear in different ranges within the study area, as proposed by Muller and Suess (1979). The distribution of the Geo-accumulation Index ($I_{geo}$) for heavy metals in the studied soils is presented in Table 7. The findings indicate that Ikot Abasi exhibited the highest concentrations of Cu in both depth (3.21, 3.09) follow by Esit Eket with (2.64, 3.33) as illustrated in Figure 3. These levels indicate strong to very strong contamination, thought not exceeding the permissible limits established by Müller and Suess (1979), Food Agricutural Organisation and World Health Organizsation (2011) (Table 6). The other locations, Mbo and Eastern Obolo, displayed uncontaminated to modest levels of iron (Fe), manganese (Mn), Zincc (Zn), and copper (Cu) suggesting that individuals consuming cassava from those areas are not at any risk, compare to Ikot Abasi and Esit Eket which the concentrations are high but is not above the permissible limits set by Müller and Suess (1979). Etim *et al*. (2016) found similar results, reporting that the soils and edible vegetables in oil-producing area, are contaminated, and may have significant consequences for both human health and the environment.

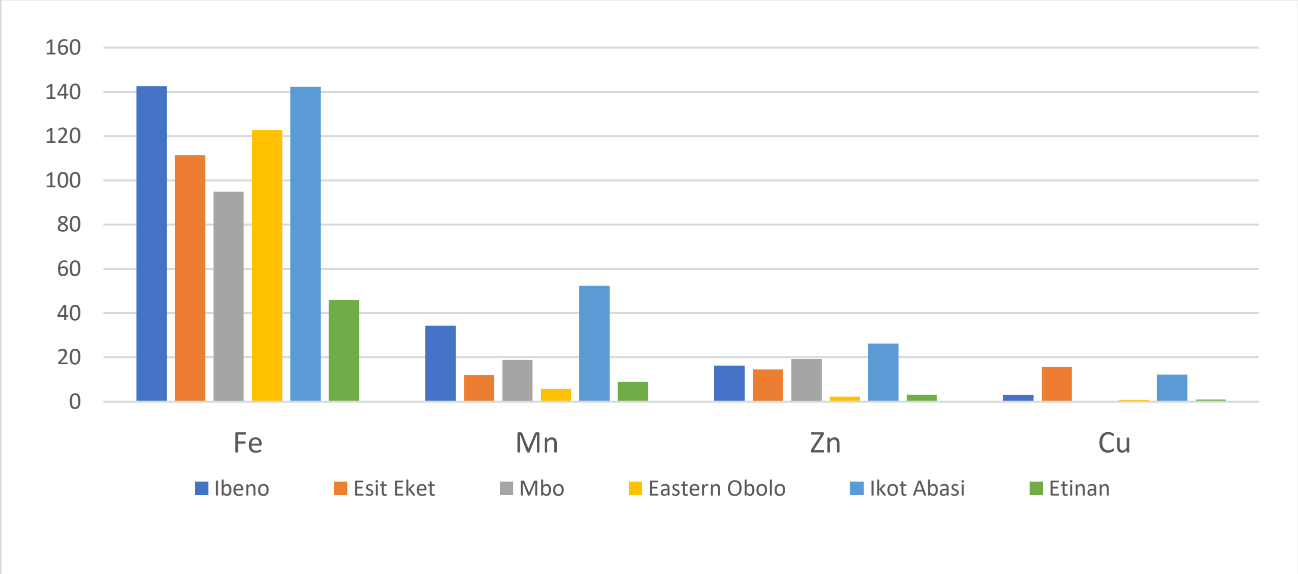


**Figure 2: The Level of heavy metals in the polluted soils**

Table 4: Concentration of Heavy Meatal in Cassava Leaves

| Location | **Fe** | **Mn** | **Zn** | **Cu** |
|---|---|---|---|---|
| | ← | mgkg$^{-1}$ | → | |
| Ibeno | 134.51 | 24.53 | 29.29 | 1.40 |
| Esit Eket | 129.38 | 14.33 | 22.75 | 11.74 |
| Mbo | 107.46 | 17.75 | 19.51 | 10.61 |
| Eastern Obolo | 80.33 | 22.48 | 18.45 | 10.95 |
| Ikot Abasi | 101.71 | 31.55 | 17.65 | 4.74 |
| Etinan | 30.16 | 11.70 | 7.20 | 1.26 |
| P(<0.05) | 17.95 | 0.33 | 0.41 | 3.56 |

Table 5: Transfer Factor of Heavy Metal from Soil to Plant

| | Fe (mgkg$^{-1}$) | Mn (mgkg$^{-1}$) | Zn (mgkg$^{-1}$) | Cu (mgkg$^{-1}$) |
|---|---|---|---|---|
| | | | Location | |
| Ibeno | $0.952^{b}$ | $0.733^{e}$ | $1.828^{c}$ | $0.462^{C}$ |
| Esit Eket | $0.863^{b}$ | $1.232^{c}$ | $1.589^{d}$ | $0.185^{C}$ |
| Mbo | $1.134^{a}$ | $0.954^{d}$ | $1.023^{e}$ | $5.555^{a}$ |
| Eastern Obolo | $0.654^{c}$ | $4.001^{a}$ | $9.401^{a}$ | $1.709^{b}$ |
| Ikot Abasi | $0.715^{c}$ | $0.628^{f}$ | $0.701^{e}$ | $0.187^{c}$ |
| Etinan | $0.695^{c}$ | $1.337^{b}$ | $2.415^{b}$ | $0.133^{c}$ |
| | | | Soil Depth | |
| 0 - 15 | $0.846^{a}$ | $1.534^{a}$ | $3.410^{a}$ | $1.420^{a}$ |
| 15 - 30 | $0.825^{a}$ | $1.428^{b}$ | $2.243^{b}$ | $1.324^{a}$ |
| | | | Location x Soil depth Interaction | |

| | | | | |
|---|---|---|---|---|
| IB (0-15cm) | 0.856$^{cde}$ | 0.613$^{f}$ | 1.572$^{g}$ | 0.376$^{c}$ |
| (15-30cm) | 1.049$^{abc}$ | 0.853$^{f}$ | 2.085$^{d}$ | 0.547$^{c}$ |
| EE (0-15cm) | 0.838$^{de}$ | 1.307$^{e}$ | 1.800$^{f}$ | 0.226$^{c}$ |
| (15-30cm) | 0.888$^{bcd}$ | 1.434$^{c}$ | 1.377$^{g}$ | 0.143$^{c}$ |
| MB (0-15cm) | 1.183$^{a}$ | 1.065$^{e}$ | 1.11$^{h}$ | 5.567$^{a}$ |
| (15-30cm) | 1.086$^{ab}$ | 0.844$^{f}$ | 0.928$^{i}$ | 5.543$^{a}$ |
| EO (0-15cm) | 0.639$^{fg}$ | 4.545$^{a}$ | 12.507$^{a}$ | 1.951$^{b}$ |
| (15-30cm) | 0.668$^{efg}$ | 3.457$^{b}$ | 6.257$^{b}$ | 1.466$^{b}$ |
| IA (0-15cm) | 0.696$^{defg}$ | 0.760$^{f}$ | 0.561$^{j}$ | 0.146$^{c}$ |
| (15-30cm) | 0.733$^{def}$ | 0.497$^{g}$ | 0.840$^{k}$ | 0.168$^{c}$ |
| ET (0-15cm) | 0.864$^{cde}$ | 1.190$^{c}$ | 2.900$^{c}$ | 0.168$^{c}$ |
| (15-30cm | 0.526$^{g}$ | 1.484$^{c}$ | 1.930$^{d}$ | 0.099$^{c}$ |

Means with the same letters along the columns are not significantly different at p≤0.05., IB = Ibeno, EE = Esit Eket, MB = Mbo, EO = Easter Obolo, IA = Ikot Abasi, ET = Etinan

Table 6: WHO / FAO Guideline for Metal in Foods and Plant.

| S/N | Metals | WHO / FAO |
|---|---|---|
| 1 | Fe | 400 - 500 |
| 2 | Mn | 200 |
| 3 | Zn | 20 - 100 |
| 4 | Cu | 2.5 |

*Source: WHO/ FAO 2011*

**Table 7:** *Geo-accumulation Indices of Heavy Metals in Crude Oil Polluted Soils*

| Location | Depth | Fe | Mn (mgkg$^{-1}$) | Zn | Cu |
|---|---|---|---|---|---|
| **Ibeno** | 0-15 | 1.59 | 1.44 | 2.32 | 1.81 |
| | 15-30 | 0.58 | 1.28 | 1.32 | 0.50 |
| **Esit Eket** | 0-15 | 1.13 | -0.09 | 1.76 | 2.64 |
| | 15-30 | 0.33 | -0.24 | 1.56 | 3.33 |
| **Mbo** | 0-15 | 0.80 | 0.18 | 2.23 | -2.75 |
| | 16-30 | 0.20 | 0.83 | 1.91 | -3.55 |
| **Eastern Obolo** | 0-15 | 1.26 | -1.58 | -1.34 | -0.50 |
| | 15-30 | 0.48 | -0.86 | -0.94 | -0.86 |
| **Ikot Abasi** | 0-15 | 1.48 | 1.49 | 3.08 | 3.21 |
| | 15-30 | 0.69 | 2.42 | 1.91 | 3.09 |

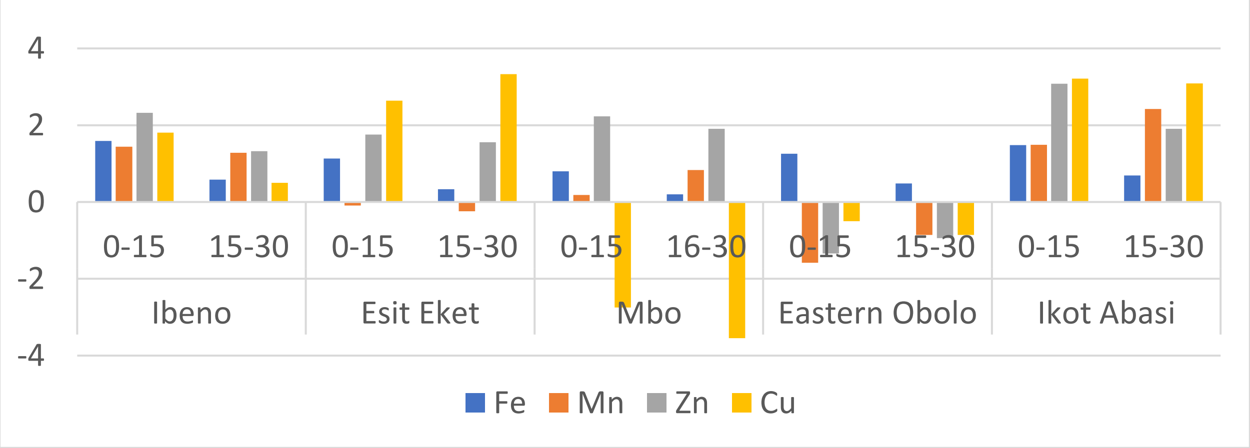


Figure 3: Geo-accumulation indices of heavy metals in crude oil polluted soils

## 4.0 Conclusion

The results indicate, that crude polluted soils exhibited a high sand with low silt and clay content compared to the control soils, and was classifying as sandy loam in texture. The pH, organic carbon (OC), and organic matter (OM%) percentage were higher in polluted soils. The base saturation was high. The abundance of heavy metals in the soils were ranked as follows: Fe > Mn > Zn > Cu. The transfer factors of heavy metals from soil to cassava plant varied in this order: Eastern Obolo (14.6 mg/kg) > Zn (9.40 mg/kg) > Mn (4.00 mg/kg), > Cu (5.56 mg/kg) > Fe (1.13 mg/kg). The levels of heavy metals were moderately to strongly elevated but remained within WHO/FAP permissible limits. Therefore, farmers should therefore refrain from cultivating cassav in oil-polluted soils that is above the permissible limit to prevent health issues.

## References

Adewumi A. J, Ogundele O. D. and Adeseko A.A., (2022). Heavy Metals in Soils around a Major Cement Factory in Southern Nigeria: Ecological and Human Health Risks. *Nigerian Journal of Environmental Sciences and Technology*, 6(2), 283-294. https://doi.org/10.36263/nijest.2022.02.0352

Akachuku C.O. and Ekwenye, U.N. (1995). Impact of Petroleum Industry on Nigeria Ecosystems, Paper presented at the 4th Annual Scientific. 12(1), 124–132.

Akata O. R, Akpan E. A, Umoh F. O, Ndaeyo N. U.; (2018). Effect of poultry manure and Ash rate on the growth and yield performance of cassava (Manihot esculenta crantz) And soil chemical properties; *AKSU Journal of Agriculture and food Sciences*. 1 (1): 132-140.

Alshahri F. El-Taher, A. (2018). Assessment of heavy and trace metals in surface soli nearby an oil refinery. Saudi Arabia, using geo accumulation and pollution indices.

Baker A. J, Megrath, SP, Reeves, M, Smith J. A (2000). Metal accumulator review of the ecology and physiology of a biological resource for phytoremediation of metal polluted soils. 1124-34.

Benson N, Ebong G, (2005). Heavy metals in vegetables commonly grown in a tropical garden Ultisol. Journal Sustainable Tropical Agricultural Resources. 16:77-80

Chary N. S., Kamala, C. T. & Raj, D. S. S (2008). Assessing the risk of heavy metal from consuming food grown on sewage irrigated soil and food chain transfer Ecotoxicology and Environmental Safety 69 (3) 513-524.

Edem P. E, Udom S. A, Anoka, O. A (2008), Levels of toxic elements in soils of abandoned Waste dump site, African Journal of Biotechnology, 5(3), 1241-1243

Essiett U A. Effiong G. S. Ogbemudia F O. Bruno E. J (2010). Heavy metal concentrations in plants growing in crude oil contaminated soil in Akwa Ibom State, South-Eastern Nigeria. African Journal of Pharmacy and Pharmacology 4(7):465-470

Etim A. O. Ekpo, F. E, Okeke, A. I (2016) Assessment of Heavy metals concontrations in soils and Edible Vegetable Grown in Core Crude Oli Producing communities of Ibeno, Akwa Ibom State, Nigeria. International Journal of Environmental Science and Toxicology Research. 4(1) 1-6

Gomez R. A and Gomez A. A (1984). Statistical procedures for Agriculture Research. New York: USA, John Willey and Sons. p. 680.

Kadafa A. A. (2012). "Environmental Impacts of Oil Exploration and Exploitation in the Niger Delta of Nigeria." *Global Journal of Science Frontier Research* 3 (4) 217-223.

Muller P. J and Suess, E. (1979). Productivity, Sedimentation rate and sedimentary organic matter in the oceans. I. Organic Carbon presentation, Deep Sea Res. 26, 1347.

Onwugbuta N. E, Ugbomeh, A. P, Anaero-Nweke, G. N and Bobmanuel, K. N (2022) Assessment of Heavy metals in soils and Manihot esculenta of some seleted communities in Niger Delta. *International Journal of Advance Research in Biological Science.* 9 (12) : 74-96.

Raskin I (1995). Phytoremediation: A Novel Strategy for the Removal of Toxic Metals from the Environment Using Plants. *Nature Biol. Technol.,* 13: 468 - 474.

Sunday A. E., Umoh, F. O, Sifon M. U (2020) Assessment of phosphorus leaching potentials on soil from diverse parent material in Akwa Ibom State. Proceeding of the 44th Conferenced of Soil Science Society of Nigeria on Climate Smart soil management, Soil health / Quality and Land management synergies for sustainable ecosystem services. 44: 486-492.

Umoh F. O, Essien, O. A, Utin, U. E and Udom P. U (2020). Influence of tillage systems on selected soil physical and chemical properties on coastal plain sands in south eastern Nigeria. *Nigeria Journal of Agricultural Technology.* 17: 39 - 43.

Umoh F. O, Monday, B. S, Ijah, C. J, Etukudo, N. E and Ekwere, O. J (2024). Effect of oil pollution on soil properties and performance of maize (Zea Mays) grown on soil derived from coastal plain sand in Obio Akpa, Akwa Ibom State. *Direct Research Journal of Agriculture and food Science.* 12(1): 107 – 117.

Umoh F. O, Udoh Udowo O. M and Sunday A. E (2023). Assessing the availability of exchangeable Calcium (Ca), magnesium (Mg) and Potassium (K) in Oil palm (Elacis guineesis) Plantation grown on coastal plain sand soils of Akwa Ibom State. Proceeding of the 47th Annual conference of Soil Science Society of Nigeria. 47: 90-99

WHO (2006) World Health Organization. Switzerland: Geneva; Trace Elements in Human Nutrition and Health. 21-29.

WHO (2011) Join FAO / WHO food Standards program codex committee on contaminate in food, Fifth session 64-89.