



**BIOACCUMULATION OF HEAVY METALS, HYDROCARBONS
AND CANCER RISK OF *Manihot esculenta* AND *Telfairia
occidentalis* FROM AGRICULTURAL SOILS OF Ogoniland,
NIGERIA**

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Abstract

This study investigates the bioaccumulation efficiency and associated health risks of polycyclic aromatic hydrocarbons (PAHs), total petroleum hydrocarbons (TPHs), and heavy metals by *Manihot esculenta* and *Telfairia occidentalis* cultivated in K-Dere and Bera, Ogoni using Bioaccumulation factor (BAF) and incremental lifetime cancer risk (ILCR) index. Levels of Heavy metal in the soil were determined using atomic absorption spectrometry, while PAHs and TPHs were analyzed using Fourier Transformed Infrared (FTIR). The results revealed that PAHs were undetected in both study locations, TPHs levels were higher in K-Dere (41.255 ± 3.16 mg/kg) than the Bera (33.484 ± 3.00 mg/kg) below the WHO/DPR limit of 50.0 mg/kg, evidencing petroleum contamination. Elevated levels of heavy metals: Fe (26.13 ± 2.12 mg/kg), > WHO limit (22 mg/kg). Cr (0.385 ± 0.001 mg/kg) < WHO standards in K-Dere. PAHs were undetectable in both *Manihot esculenta* and *Telfairia occidentalis*, TPHs > US EPA (0.2 mg/kg). BAFs for all metals analyzed were below 1, except for Cr in *Telfairia occidentalis* from K-Dere (24.5). The Σ ILCR showed that combined effects of Pb, Ni, Cr, exposure through *Telfairia occidentalis* may elicit cancer effect of 1 in every 100 adults (Σ ILCR = 5.24×10^{-2}). Increased level of heavy metals in leafy vegetables and its corresponding high bioaccumulation indicate high probability of metal-induced cancer effect on the exposed population. *Telfairia occidentalis* can be explored as a native plant for phytoremediation to remediate heavy metals contaminated soils.

Keywords: *Manihot esculenta*, *Telfairia occidentalis*, Hydrocarbons, Metals, Bioaccumulation factor, Cancer, Ogoniland

INTRODUCTION

Oil exploration and exploitation have significantly contributed to Nigeria's economy, driving rapid development (Idodo-Umeh and Ogbeibu 2010). However, the environmental impact of these activities, particularly in the Niger Delta, have not received the attention they deserve (Idodo-Umeh, 2002). In oil-producing areas such as Ogoniland, frequent crude oil spills and gas flaring are major anthropogenic

sources of heavy metals, polycyclic aromatic hydrocarbons (PAHs), and total petroleum hydrocarbons (TPHs) contamination in terrestrial habitats (Digha et al. 2017).

Nigerian crude oil is known to contain various heavy metals, including Aluminum (Al), Zinc (Zn), Arsenic (As), Barium (Ba), Iron (Fe), Lead (Pb), Cobalt (Co), Copper (Cu), Chromium (Cr), Manganese (Mn), Nickel (Ni), and Vanadium (V) (Idodo-Umeh and Ogbeibu 2010). Bioaccumulation, the gradual buildup of these contaminants in living organisms over time, is a critical concern, especially when it involves edible plants. The toxicity of ingested heavy metals and petroleum hydrocarbons has long been recognized as a significant health risk (LeCoultrre, 2001). Numerous environmental studies have documented the bioaccumulation of heavy metals and petroleum hydrocarbons in the edible tissues of vegetables (LeCoultrre, 2001). Some species of *Brassica* (cabbage) are high accumulators of heavy metals in the edible parts of the plants (Adeniyi and Afolabi 2002) and this can be an important exposure pathway for people who consume vegetables grown in heavy metal contaminated soil (Bambara et al. 2023). These contaminants mostly do not degrade or may slowly degrade and are known to build up in the body of human consumers via biomagnification.

Telfairia occidentalis and *Manihot esculenta* are staple foods in Ogoni communities and considered one of the fundamental parts of the Nigerian daily diet. Thus, it is essential to provide periodic information regarding the accumulation of these contaminants in agricultural soils and plants for the local authorities and consumers. Despite the importance of health and safety data, there is a notable shortage of documented reports on the bioaccumulation potential, biomagnification and potential human health risks associated with these contaminants in the study area. Thus, the focus of this study is to investigate heavy metals, PAHs and TPHs contamination in K-Dere Ogoni land. Specifically, the study had the following objectives: investigate the level of heavy metals, PAHs and TPHs in oil spill contaminated soil in K-Dere, investigate the level of heavy metals, PAHs and TPHs in *Telfairia occidentalis* and *Manihot esculenta* tissues from K-Dere and Bera, investigate the bioaccumulation of heavy metals, PAHs and TPHs *Telfairia occidentalis* and *Manihot esculenta* harvested from K-Dere and analyze the potential carcinogenic effect due to consumption of *Telfairia occidentalis* and *Manihot esculenta* in K-Dere and Bera, in Ogoni.

MATERIALS AND METHODS

Description of the Study Area

The study was conducted using the soil, pumpkin *Telfairia occidentalis* and cassava *Manihot esculenta* of the people of K-Dere community (latitude 4,663889 N and longitude 7.277209 N) and Bera community (latitude 4,684029 N and longitude 7.276742 N) both in Gokana local government area of, Rivers State, Nigeria.

Gokana LGA is one of the major LGA in Rivers state. Rivers state is situated in the Niger Delta region and is bordered by the Atlantic Ocean to the south. It shares borders with Abia State to the north, Imo and Bayelsa States to the west, and Akwa Ibom State to the east. The economy of Rivers State is largely driven by oil and gas activities. The state is home to significant oil reserves and has several oil refineries and petrochemical industries. Besides the oil sector, agriculture, commerce, and services contribute to the state's economic activities.

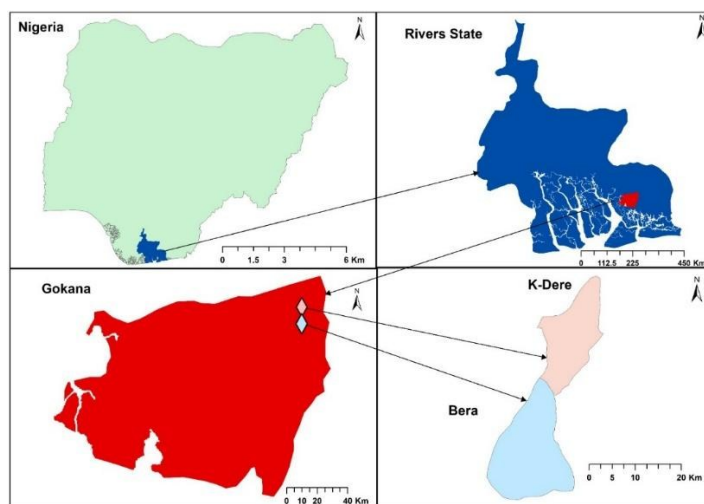


Figure 1: Map of the Study Areas.

Sample Collection

Four random composite soil samples were collected from 20 cm depth into clean polythene bags and kept in a cooler. 10 tubers of cassava tubers from different farm lands were uprooted manually and over 20 leaves of pumpkin were plucked from 10 different parent plants. All samples were kept in a cooler and carried to the laboratory where they were preserved in the refrigerator at a temperature of less than 4 °C until the analysis was carried out. Soil samples were homogenized with a clean glass rod and oven-dried at 85 °C to constant weight. Any lump present was broken up with a clean glass rod in order to expose the inside for drying and all plant materials were removed. The oven dried soil sample was thoroughly ground into powdery form and sieved through 650 µm stainless sieve.

Extraction and Analysis of Heavy Metals

10 grams of the sieved dry soil was weighed into acid-washed 250mL polythene extraction bottles and 100mL of extraction solution (0.005M HCL and 0.0125M HNO_3) was added and shaken for 1 hour on a mechanical shaker. The solution was filtered through Whatman No. 42 filter paper. Blank samples were prepared using the same procedure with deionized water instead of soil solution. Analysis of Fe, Pb, Cr, Ni Zn and Cu were carried out with atomic absorption spectrometer (BUCK SCIENTIFIC, MODEL 210VGP) fitted with solar software in accordance with ASTM (1999) and US EPA (2019) analytical methods.

Extraction and Analysis of PAHs and TPHs

US EPA (2019) analytical methods were utilized. In this method, 5 grams of soil was weighed into a clean 50ml glass vial with a Teflon cap. 1 gram of anhydrous sodium sulphate was added to remove moisture and the mixture was thoroughly mixed with a clean spatula. 20mL of tetrachloroethene ($\text{Cl}_2\text{C}=\text{CCl}_2$) was added to the mixture, corked and properly shaken to ensure mixture homogeneity. The cork was removed and the mixture was placed in a water bath sonicator and sonicated for 30 min. The mixture was filtered through a glass wool. An additional 10 mL of tetrachloroethene was added and the process was repeated as above to obtain extraction efficiency. 1g of deactivated florosil was added to

remove all polar compounds (that might interfere with PAHs and TPHs determination) and filtered through a 0.45 µm solvent resistant membrane filter to remove all particulate matter. Tetrachloroethene was scanned as a blank. The filtered solution was analyzed using Fourier Transformed Infrared (FTIR) Spectrophotometer fitted with Winfirst software and values were expressed in mg/kg.

Extraction and Analysis of Heavy Metals in Pumpkin and Cassava

The pumpkin (*Telfairia occidentalis*) and cassava (*Manihot esculenta*) samples were brought out of the refrigerator and kept in clean polythene bags and allowed to attain room temperature. The epicarps of the pumpkin leaves and piliferous layers of the cassava tubers *Manihot esculenta* were carefully removed. The pumpkin leaves, the piliferous layers and the cortex of cassava were cut into pieces and oven-dried at 85 °C to constant weight. The dried samples were ground into powdery form and labeled. 1g of each ground sample was weighed into 100mL beaker. 5mL concentrated nitric acid and 2ml perchloric acid were added and heated in a fume cupboard to almost dryness. Then, 10ml of deionized water was added and the solution was properly stirred and filtered with Whatman filter paper No 42. Blank samples were prepared using the same procedure with deionized water instead of *Telfairia occidentalis* or cassava *Manihot esculenta* samples. The filtrate of each sample was aspirated into the flame of AAS along with standard solution in accordance with ASTM (1999) and US EPA (2019) analytical methods.

Evaluation of Bioaccumulation Factor

Bioaccumulation factor (BAF) represents the ratio of the concentration of a chemical substance in the tissue of an exposed organism to its concentration in all environmental media. This was evaluated according to US EPA (2003a) as follows:

$$BAF = C_t / C_e \dots \text{Egn.1}$$

Where C_t = concentration of chemical in the specified tissue, C_e = concentration of chemical in the environment.

A BAF greater than 1 indicates efficient bioaccumulation, meaning the plant's contaminant concentration exceeds that in the soil, while a BAF less than 1 suggests the plant accumulates the contaminant at a lower concentration than its soil concentration.

Carcinogenic Risk Analysis

Potential cancer risks from exposure to metals in fluted pumpkin and cassava were calculated using the ILCR. ILCR is characterized as the incremental (individual) lifetime likelihood of developing any form of cancer due to continuous exposure to a carcinogen over seventy years. This was evaluated (Eqn. 2) in line with the (US EPA 2014) index:

$$ILCR = CDI * CSF \dots \text{Egn.2}$$

Where ILCR = Individual Lifetime Cancer Risk, CDI = Chronic daily intake, CSF = Cancer slope factor.

$$CDI = \frac{EDI * EFr * EDR}{\text{ATr}} \dots \text{Egn.3}$$

ATr

Where EDI = Estimated daily intake of individual carcinogenic substance (mgkg⁻¹ day⁻¹), EFr = Exposure frequency for target population residents = 350days per year (US EPA, 2014), EDr =

Exposure duration for target population residents = 26years (US EPA, 2014), ATr = Averaging time; the period over which the exposure is averaged = [365years x 70years].

Chronic Daily Intake (CDI) is a measure of the average consumption of a contaminant *Telfairia occidentalis* and *Manihot esculenta* over an individual's standard lifetime of 70yrs (US EPA, 2014). It relates the EDI of a target contaminant to the population age. It is expressed as $\text{mgkg}^{-1} \text{day}^{-1}$.

RESULTS AND DISCUSSION

Results

Table 1 compares the concentrations of PAHs, TPHs, and heavy metals in soil from two locations: K-Dere and a Bera. PAHs were observed below detection levels (BDL) in both locations. TPHs are higher in (41.255 mg/kg) than in (33.484 mg/kg). Fe, Cr, Zn, and Cu concentrations are also higher in, indicating potential contamination, particularly with iron. Lead is only detected in, while Ni was not detected in samples from both locations. The data suggests a higher degree of contamination with chemicals of environmental and health concern at K-Dere.

Table 1: Concentration of PAHs, TPHs and heavy metals (mg/kg) in soil from K-Dere and Bera, Gokana, Rivers State.

Chemical parameters	(K-Dere)	(Bera)	WHO Standard
PAHs	* -	* -	1.00
TPHs	41.255±3.16	33.484±3.00	50.0
Fe	26.13±2.12	13.854±1.20	22
Pb	* -	2.069±0.02	0.3
Cr	0.385±0.001	* -	0.5
Ni	* -	* -	67.9
Zn	11.736±0.97	6.493±0.09	99.4
Cu	5.119±0.08	3.926±0.03	73.3

*Concentrations found below detection limit, BDL (-)

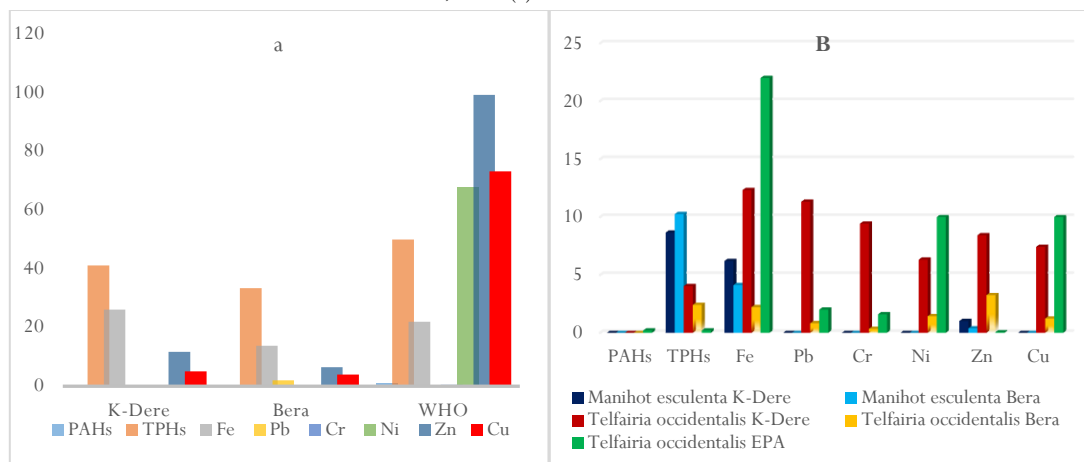


Figure 2. Levels of Hydrocarbons and Heavy Metals (mg/kg) in Soil (a) and Pumpkin (b) from K-Dere and Bera, Gokana, Rivers State.

The levels of PAHs, TPHs, and heavy metals in cassava and vegetable samples from K-Dere and Bera (Table 2) shows PAHs below detection levels (BDL) across all samples. There is evidence of higher TPHs in cassava (Bera: 10.25 ± 0.60 mg/kg) > K-Dere: 8.65 ± 0.52 mg/kg) than in vegetables (K-Dere: 4.03 ± 0.09 mg/kg > Bera: 2.41 ± 0.04 mg/kg). The levels of metals were observed in the order of Fe > Pb > Cr > Zn > Cu > Ni. These findings indicate substantial evidence of uptake and retention of contaminants in vegetable samples from K-Dere.

Table 2: Concentration of PAHs, TPHs and heavy metals (mg/kg) in cassava and vegetable sample

Chemical parameters	(K-Dere)	(Bera)	(K-Dere)	(Bera)	EPA Permissive Level
	Cassava		Vegetable		
PAHs	BDL	BDL	BDL	BDL	0.2
TPHs	8.65 ± 0.52	10.25 ± 0.60	4.03 ± 0.09	2.41 ± 0.04	0.2
Fe	6.201 ± 0.50	4.118 ± 0.80	12.321 ± 0.06	2.223 ± 0.001	22
Pb	BDL	BDL	11.321 ± 0.05	0.832 ± 0.0006	2.0
Cr	BDL	BDL	9.431 ± 0.03	0.342 ± 0.0004	1.6
Ni	BDL	BDL	6.321 ± 0.04	1.432 ± 0.002	10
Zn	1.017 ± 0.051	0.381 ± 0.030	8.421 ± 0.009	3.253 ± 0.007	0.06
Cu	BDL	BDL	7.421 ± 0.007	1.234 ± 0.001	10

BAF for PAHs, TPHs, and heavy metals in cassava and vegetable samples from K-Dere and Bera (Table 3) points to evidence of potential uptake and retention of TPHs by cassava than pumpkin. Conversely, vegetables accumulate more heavy metals than cassava.

Table 3: Bioaccumulation factor (BAF) of PAHs, TPHs and heavy metals of cassava and vegetable samples from study area.

Chemical parameters	(K-Dere)	(Bera)	(K-Dere)	(Bera)
	Cassava		Vegetable	
PAHs	-	-	-	-
TPHs	0.209	0.306	0.098	-
Fe	0.237	0.297	0.40	-
Pb	-	-	-	0.40
Cr	-	-	24.5	-
Ni	-	-	-	-
Zn	0.087	0.059	-	0.50
Cu	-	-	-	0.31

* Not applicable (-)

Table 4 presents the Individual Lifetime Cancer Risks (ILCR) and cumulative cancer risks ($\sum$ ILCR) for consuming pumpkin and cassava from K-Dere and Bera. The results show that consumption of pumpkin from K-Dere has greater probability of eliciting cancer (ILCR) values for heavy metals signifying a

substantial cancer risk from consuming *Telfairia occidentalis* in K-Dere. In contrast, the ILCR for heavy metals in *Manihot esculenta* are negligible.

Table 4: Individual lifetime cancer risks (ILCR) and cumulative cancer risks (Σ ILCR) for consumption of vegetables and Cassava from two study areas.

	Study Area	Pb	Cr	Ni	Σ ILCR	RCR (US EPA, 2024)
<i>Telfairia occidentalis</i>	(K-Dere)	4.6×10^{-2}	3.8×10^{-3}	2.6×10^{-3}	5.24×10^{-2}	1.0×10^{-6}
	(Bera)	3.0×10^{-4}	1.4×10^{-4}	6.0×10^{-4}	1.0×10^{-3}	
<i>Manihot esculenta</i>		-	-	-	-	
		-	-	-	-	

*Reference cancer risk (RCR) * Not applicable (-)

DISCUSSION

Concentration of Hydrocarbons in Soil from K-Dere and Bera

Undetectable levels of PAHs were observed in both study locations (K-Dere and Bera), indicating minimal petroleum pollution, efficient low distribution of contaminants to the farm lands or natural degradation. Levels of TPHs (41.255 ± 3.16 mg/kg) in K-Dere were higher Bera (33.484 ± 3.00 mg/kg), likely due to K-Dere's history of petroleum-related activities. These levels of PAHs and TPHs are within safe limits of US EPA (2005) (1.00 mg/kg for PAHs and 50.0 mg/kg for TPHs). Previous studies by Alinnor and Nwachukwu (2013) reported in soil and groundwater samples showed higher TPH levels between 1534.66 to 1651.00 mg/kg.

Heavy Metals in Soil from K-Dere and Bera

This study evaluated the concentrations of selected heavy metals (Fe, Pb, Cr, Ni, Zn, and Cu) in agricultural soils from K-Dere and Bera in Ogoniland, Nigeria. Results were compared with the United States Environmental Protection Agency (US EPA, 2005) standards to assess potential for bioaccumulation, ecological and human health risks.

Iron (Fe) concentrations in K-Dere (26.13 ± 2.12 mg/kg) exceeded the EPA permissible limit of 22 mg/kg, suggesting anthropogenic input from oil-related activities. In contrast, Bera soils recorded acceptable levels (13.854 ± 1.20 mg/kg). Despite the elevated values in K-Dere, iron concentrations remained significantly lower than those reported in previous studies involving effluent retention pit areas (Nduka and Aigberaa, 2018). High iron levels cause Fe overload in humans, potentially causing organ damage (Tchounwou et al. 2012).

Lead (Pb) was undetectable in K-Dere but exceeded the EPA standard in Bera (2.069 ± 0.02 mg/kg), indicating localized contamination, potentially from legacy lead-based materials. The presence of Pb in Bera raises health concerns due to its neurotoxic effects, especially in children (Najeeb et al. 2014).

Chromium (Cr) levels in K-Dere were within safe limits (0.385 ± 0.001 mg/kg), while Bera showed undetectable levels. These concentrations were substantially lower than those found in heavily polluted

Ogoni soils, possibly due to natural attenuation or less severe contamination. Okon and Ogba (2018) reported higher Cr (1.70, 1.71, 1.862 and 2.16mg/kg) in sub-surface soils from Ogoniland.

Nickel (Ni) was below detection limits in both locations, well under the EPA standard of 67.9 mg/kg. This indicates a low risk of Ni-related toxicity and minimal industrial or geogenic input.

Zinc (Zn) and Copper (Cu) were found at higher concentrations in K-Dere (11.736 ± 0.97 mg/kg for Zn; 5.119 ± 0.08 mg/kg for Cu) compared to Bera (6.493 ± 0.09 mg/kg for Zn; 3.926 ± 0.03 mg/kg for Cu). Although within regulatory limits, these levels may be influenced by the use of agrochemicals or industrial emissions.

These findings indicate variable levels of contamination in the study areas, with K-Dere showing higher concentrations of most metals, likely due to oil exploration activities. The data underline the need for continued environmental monitoring and management to mitigate potential risks to soil health, agriculture, and human populations.

Hydrocarbons in Edible Plants

Findings obtained from this study (Table 2) revealed that both *Manihot esculenta* and *Telfairia occidentalis* sampled from both locations showed PAHs concentrations below detection levels (BDL) and within the WHO (2012) permissible level of 0.2 mg/kg. This indicates negligible environmental contamination and exposure effects by PAHs suggesting that the risk of PAH-related health issues, such as cancer, is low for consumers of these crops. *Manihot esculenta* from Bera has a higher TPHs concentration (10.25 ± 0.60 mg/kg) compared to K-Dere (8.65 ± 0.52 mg/kg), *Telfairia occidentalis* from K-Dere exhibit higher levels (4.03 ± 0.09 mg/kg) than those from Bera (2.41 ± 0.04 mg/kg). TPHs in both cassava and pumpkin samples exceed the WHO (2012) level of 0.2 mg/kg. The mean of TPHs in this study was lower than those reported by Al-Baldawi *et al.* (2015), with a reported average TPHs concentration in *Scirpus grossus* tissue in range of 19.86 - 91.36 mg/kg in the roots and 16.14 - 223.56 mg/kg in stems and leaves. The higher TPHs levels in K-Dere *Telfairia occidentalis* (Figure 2b) are likely due to the root system, which makes it more susceptible to absorbing petroleum hydrocarbons present in the topsoil. Hydrocarbon exposure is concerning due to the potential for chronic health effects such as liver and kidney damage and increased cancer risk.

Heavy Metal Concentrations in Edible Plants

The investigation of heavy metal concentrations in cassava and fluted pumpkin from K-Dere and Bera indicate elevated levels of Fe in both crops from K-Dere, with *Telfairia occidentalis* recording 12.321 ± 0.06 mg/kg and *Manihot esculenta* (6.201 ± 0.50 mg/kg), compared to lower concentrations in Bera. These values, though below the WHO (2012) threshold of 22 mg/kg, suggest contamination from oil infrastructure in K-Dere.

Pb levels in *Telfairia occidentalis* from K-Dere were significantly higher (11.321 ± 0.05 mg/kg) than the WHO limit of 2.0 mg/kg, indicating serious contamination and health risk. Cr was undetectable in *Manihot esculenta* but reached 9.431 ± 0.03 mg/kg in *Telfairia occidentalis* (K-Dere), well above the 1.6 mg/kg WHO threshold.

Ni was undetected in cassava but found in pumpkin at 6.321 ± 0.04 mg/kg in K-Dere and 1.432 ± 0.002 mg/kg (Bera), both within safe WHO limits. Zn and Cu were more concentrated in Pumpkin

than in cassava across both locations, with Zn reaching 8.421 ± 0.009 mg/kg and Cu 7.421 ± 0.007 mg/kg in K-Dere.

All metals, except Pb and Cr, remained within permissible limits, though the marked difference in metal accumulation between plant species underscores the higher uptake potential of *Telfairia occidentalis*. This observation supports prior findings that leafy vegetables, particularly those with large surface areas and shallow roots, accumulate more metals than tuber crops (Tocco, 2025 and Zhou *et al.*, 2016). Plants with a larger total root surface area or a highly branched and fibrous root system typically have a greater capacity for metal sequestration from the soil solution (Hussain *et al.*, 2021). On the other hand, leafy vegetables, levels of metals can also via foliar uptake from atmospheric depositions (e.g., from traffic or industrial emissions) and represents a significant, and sometimes dominant, accumulation pathway, often showing a stronger correlation with atmospheric deposition than soil concentration (Bi *et al.*, 2018; Luo *et al.*, 2021). In addition, large leaf surface areas of some leafy crops, by definition, present a large surface area exposed to atmospheric particulates and dust, which can carry heavy metals (Luo *et al.*, 2021).

The findings highlight the need for ongoing monitoring and potential public health interventions in contaminated agricultural zones.

Bioaccumulation Factor (BAF)

Investigation of bioaccumulation factors (BAF) of TPHs and Fe, Pb, Cr, Zn, Ni, Cu in two staple crops: *Manihot esculenta* (cassava) and *Telfairia occidentalis* (fluted pumpkin) commonly cultivated in contaminated soils of K-Dere and Bera, Ogoniland highlight variations in metal uptake between crops and across locations, with implications for environmental monitoring and food safety.

TPH BAFs were consistently below 1 in both crops, indicating limited uptake from soil. However, *Manihot esculenta* (0.209) demonstrated a slightly higher TPHs accumulation than *Telfairia occidentalis* (0.098) in K-Dere samples (Table 3, Figure 2b) possibly due to root morphology or biochemical physiology.

Fe also showed BAFs <1 in both crops and locations, with *Telfairia occidentalis* in K-Dere exhibiting the highest uptake (0.40). These values remain well below WHO (1998) 200 mg/kg guideline, suggesting minimal health risk.

Pb presented a BAF of 0.40 in *Telfairia occidentalis* from Bera, surpassing the WHO (1998) safety threshold of 0.3. While this BAF is below 1, it signals potential for uptake and retention from heavy metal contaminated soils.

Cr showed a notable exception, with a high BAF of 24.5 ± 0.8 in *Telfairia occidentalis* from K-Dere, well above WHO's acceptable limit of 2.3. This observation is lower than the work of Abbas *et al.*, (2023) on bioaccumulation and mobility of heavy metals in the soil-plant system and health risk assessment of plant irrigated by wastewater with values ranging from 31.00-34.25. This highlights significant Cr bioaccumulation, likely due to elevated soil bioavailability from industrial pollutants, posing a serious food safety risk.

Zn and Cu BAFs remained below 1 in most cases. However, Cu in *Telfairia occidentalis* from K-Dere exceeded unity (1.45 ± 0.09), indicating notable accumulation. Despite being under WHO's 20 mg/kg threshold, this calls for attention to possible sources like agrochemical use or atmospheric deposition.

The findings revealed that *Telfairia occidentalis* exhibited higher bioaccumulation potential across most metals compared to *Manihot esculenta*. These differences underscore the influence of crop type, soil

properties, and environmental factors on heavy metal uptake. The study recommends continuous monitoring and public awareness to mitigate risks of toxic metal exposure through food crops in oil-polluted regions.

Carcinogenic Risk Evaluation

The individual lifetime cancer risks (ILCR) and cumulative cancer risks (Σ ILCR) for consumption of pumpkin and cassava from two study areas (Table 4) reveal significant differences between the two study areas (K-Dere and Bera) and between the consumption of cassava and Pumpkin. ILCR values of 1.0×10^{-2} , 1.0×10^{-3} , and 1.0×10^{-4} indicate 1 in 100, 1 in 1,000, and 1 in 10,000 probability of an individual developing cancer over a lifetime due to exposure to carcinogens.

The ILCR values for Pumpkin consumption in K-Dere are considerably higher than in Bera (Table 4). The population of both communities are still unsafe as ILCR and Σ ILCR for pumpkin were above the safe consumption threshold. The risks due to Pb, Cr, and Ni violated the RCR of 1.0×10^{-6} .

In K-Dere, the ILCR for Pb (1.06×10^{-4}), Cr (5.23×10^{-3}) and Ni (6.38×10^{-3}) indicate higher potential of cancer effect (ILCR of 1: 10,000; 1,000) chances of consumers of pumpkin to develop Pb-Cr-Ni-induced cancer. The combined cancer risk due to intake of all studied carcinogenic metals (Σ ILCR) in K-Dere was observed to be 5.24×10^{-2} (Table 4). This reveals a probability of cancer development of 1 in every 100 people consuming pumpkin. This risk level is far above the acceptable threshold and indicates severe high risk of heavy metal exposure from contaminated staple foods. Lower probabilities of 1:10,000 cancer effects in the adult population to develop cancer from Pb, Cr, and Ni (3.0×10^{-4} , 1.4×10^{-4} and 6.0×10^{-4}) exposure via pumpkin were observed in Bera. While there are histories of oil pollution including spills arising from transportation and smaller-scaled historic hydrocarbon activities in Bera, the increased danger of heavy metals could come from other practices including use of pesticides and fertilizers during crop cultivation.

Results obtained from this study have revealed that cancer risk due to consumption of cassava *Manihot esculenta* from both study areas (Table 4) is negligible and may likely pose no significant health risk. The elevated cancer risk associated with pumpkin consumption in K-Dere can be attributed to the bioaccumulation of heavy metals such as Pb, Cr, and nickel, which were found in higher concentrations in pumpkin than in the soil (Table 3). Therefore, the populations of K-Dere whom are exposed to pumpkin over a 70 years period has high tendency to developing cancer due to combined effects of carcinogenic heavy metals intake.

CONCLUSION

The levels of petroleum hydrocarbons observed in this study were significantly below the EGASPIN/WHO target value of 50.0 mg/kg. These low soil concentrations of TPHs (K-Dere: 41.255 mg/kg; Bera: 33.484) and undetectable PAHs concentrations may be evidence of remediation. The study observed poor ability of cassava tubers to take up and retain hydrocarbons and metals and greater tendency of pumpkin to bioaccumulate hydrocarbons than heavy metals. This observation proves the potential efficacy of leafy vegetables in remediation of heavy metals' contaminated soil while portraying negative health implications for edible leafy vegetables.

The Incremental Lifetime Cancer Risk (ILCR) assessment further substantiates these concerns. The ILCR for Pb, Cr, Ni and Σ ILCR due to the consumption of *Telfairia occidentalis* from K-Dere are pose possible

cancer risk of 1 in 100, 1 and 1000 in K-Dere population and her environs. Therefore, it is strongly advised that consumption of pumpkin be reduced while further monitoring is encouraged.

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