Nutritional Health Hazards and Heavy Metal Accumulation in Selected Food Crops in Communities Surrounding Oil Well Heads in Olomoro, Delta State

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Abstract
Oil production and extraction may lead to environmental pollution and the accumulation of heavy metals in food crops, posing potential dietary exposure risks for communities in oil-producing regions. In populations around oil wellheads, this study measured the amounts of heavy metals in several food crops and evaluated the possible health hazards associated with their intake. We used a comparative field sampling and lab analysis method. Despite the fact that the given crop results were not completely connected to these categories, nine oil wellhead sites and three sampling distance categories were included in the study. Plantain, okra, bitter leaf, waterleaf, and cocoyam were analyzed for lead, cadmium, chromium, nickel, zinc, copper, manganese, iron, vanadium, and barium concentrations. The potential non-carcinogenic dietary exposure for children and adults was evaluated using the estimated daily intake and hazard quotient. Overall, the findings indicated that bitter leaf had the highest metal content, with lead at 0. 72 ± 0. 09 mg/kg, cadmium at 0. 14 ± 0. 02 mg/kg, zinc at 31. 72 ± 2. 76 mg/kg, and iron at 112. 64 ± 9. 47 mg/kg. In general, plantain showed the lowest concentrations. The diet risk tables indicated falling anticipated daily intake and hazard quotients as the distance from oil wellheads grew. However, the hazard quotient for cadmium in children who ate bitter leaf from the 0–100 m zone was 1. 067, which suggests a possible non-carcinogenic concern under the conditions of exposure that were assumed. Most individual hazard quotients were less than 1. This discovery needs more investigation, especially considering that children may be exposed to more of the chemical in relation to their body weight. The findings advocate for regular monitoring of heavy metals in crops grown around petroleum refineries, especially leafy vegetables and cadmium exposure. However, definitive conclusions cannot be drawn until the differences between the dietary-risk tables and the crop-concentration table are reconciled. Additionally, carcinogenic risks should only be assessed when there are appropriate toxicity considerations. Additional study should confirm the analytical findings, record real food consumption rates, and figure out the combined hazard indices. These actions would help secure vulnerable populations in oil-producing regions and improve evidence-based food-safety judgments.

Keywords: *Nutrition, Health, Hazards. Heavy, Metal, Accumulation, Food & Crops*

INTRODUCTION

The issue of food safety alongside environmental contamination represents significant public health challenges on a global scale, as tainted food can lead to exposure for populations to harmful substances such as lead (Pb), cadmium (Cd), arsenic (As), mercury (Hg), and chromium (Cr). These harmful agents can infiltrate the food supply via polluted soil, tainted irrigation water, atmospheric fallout, and industrial processes. Long-term consumption of certain heavy metals can lead to negative health outcomes, such as kidney dysfunction, neurological issues, developmental delays, and an elevated risk of cancer, influenced by the type of metal, its concentration, and the length of exposure.

In Nigeria, the activities related to oil exploration and production pose environmental challenges in regions where farming takes place close to oil extraction sites and petroleum facilities. Incidents of oil spills and associated industrial operations can lead to the contamination of farm soils, potentially resulting in the accumulation of hazardous metals in food crops. In Olomoro, Delta State, a study conducted by Idodo-Umeh and Ogbeibu (2010) evaluated the presence of heavy metals in cassava tubers, plantain fruits, and soils exposed to petroleum operations. The results indicated that the specific metals were found in greater quantities in soils affected by oil activities compared to unaffected soils. Likewise, research by Okoye and Okwute (2014) analyzed heavy metals in cassava and plantain cultivated in soils polluted by crude oil in Olomoro, shedding light on the possible health ramifications for individuals. These investigations provide a crucial local context for assessing food contamination in areas surrounding oil extraction sites.

The build-up of heavy metals in food crops is notably critical since these crops serve as fundamental sources of carbohydrates, vitamins, minerals, and other essential nutrients. Nevertheless, the repeated consumption of contaminated crops can create a channel for human exposure to dangerous substances. A recent investigation by Akinkpelumi et al. (2025) in a community affected by oil pollution within the Niger Delta identified potential health hazards linked to the consumption of food crops containing various metals and metalloids, particularly highlighting children as a key population at risk.

Thus, the study on Nutritional Health Hazards and Heavy Metal Accumulation in Selected Food Crops in Communities Surrounding Oil Well Heads in Olomoro, Delta State is aims to evaluate the levels of specific heavy metals in commonly eaten food crops and consider their possible health impacts on humans. By contrasting crops collected from regions near oil extraction sites with suitable reference samples, the study can ascertain whether there are differences in metal accumulation across various locations and assess if the estimated dietary exposure poses potential health issues. The outcomes will contribute essential evidence for food safety surveillance, safeguarding public health, managing environmental concerns, and implementing suitable measures to minimize exposure to contaminated crops in oil-producing regions.

AIM AND OBJECTIVES

The aim of this study was to investigate the environmental impacts of heavy metals concentration in food crops in Olomoro. The objective of the study is to;

i. Evaluate the differences in the heavy metal concentrations in food crops from different locations.
ii. Examine the health risks associated with consumption of the crude oil polluted food crops.

RESEARCH QUESTION

i. Are there differences in the heavy metal concentrations in food crops from different locations?
ii. Are there health risks associated with consumption of the crude oil polluted food crops?

HYPOTHESES

Ho1. There is no statistically significant difference in the concentration and status of the heavy metals in food crops in the study area.
Ho2. There is no statistically significant relationship between the physicochemical properties of soil and heavy metals in the study area.

Materials and Methods

This study is a comparative field-sampling and laboratory analytical research approach was used in the study to examine differences in heavy metal concentrations, soil physicochemical qualities, and the movement of heavy metals from soil to edible plants around certain oil wellheads. Laboratory examinations were carried out to ascertain the physicochemical characteristics of the soil and the concentrations of heavy metals in chosen edible plants, and the comparative technique was utilized to assess spatial differences in soil quality and heavy metal levels at varying distances from the oil wellheads. Field sampling and laboratory tests provided primary data, while secondary data came from pertinent scientific publications, environmental assessment reports, and regulatory paperwork, such as those of the National Environmental Standards and Regulations Enforcement Agency (NESREA), the World Health Organization (WHO), and the National Agency for Food and Drug Administration and Control (NAFDAC). The research involved nine chosen locations for oil wellheads. Nine locations (three distance categories x nine locations) yielded a total of 27 soil samples, one composite soil sample for each category. Soil samples were taken from the 0-20 cm topsoil horizon because this layer is especially important for plant root development, agricultural activities, and surface contamination. Separately marked polyethylene bags were used to transfer the samples to the lab for testing. Plant samples, particularly bitter leaves (Vernonia amygdalina), were intentionally collected from farms and gardens inside the applicable sampling areas. Waterleaf, cocoyam, plantain, banana, and okra were some of the additional edible crops found in the study area. Clean sampling instruments were used to collect plant samples, which were then identified by their sampling places and brought to the lab for heavy metal analysis. To identify the physicochemical characteristics of the soil and the concentrations of the chosen heavy metals, laboratory analyses were carried out. Before being evaluated, soil samples were crushed, air-dried, and sieved. Using a calibrated glass-electrode pH meter at a 1:1 soil-to-distilled-water ratio, soil pH was measured, and the Bouyoucos hydrometer method was utilized to determine particle-size distribution. The Kjeldahl digestion approach was used to determine total nitrogen, while the Walkley-Black dichromate oxidation method was used to determine soil organic carbon. For neutral to alkaline soils, the Bray-1 extraction method for acidic soils or the Olsen approach were used to establish the phosphorus that was accessible. A flame photometer was utilized to measure ammonium acetate extraction to determine exchangeable potassium.

$$I_{\text{geo}} = \log_2\left(\frac{C_n}{1.5 \times B_n}\right)$$

where C_n represents the measured concentration of a particular heavy metal in the soil, B_n represents its corresponding geochemical background concentration, and 1.5 is the correction

factor used to account for natural variations in background concentrations arising from lithogenic influences. The resulting values were classified as: Uncontaminated ($I_{geo} \leq 0$), Uncontaminated to moderately contaminated ($0 < I_{geo} \leq 1$), moderately contaminated ($1 < I_{geo} \leq 2$), Moderately to heavily contaminated ($2 < I_{geo} \leq 3$), heavily contaminated ($3 < I_{geo} \leq 4$), Heavily to extremely contaminated ($4 < I_{geo} \leq 5$) and extremely contaminated ($I_{geo} > 5$). The contamination factor was calculated as: $\text{CF} = \frac{C_{metal}}{C_{background}}$

where C_{metal} represents the measured concentration of a particular heavy metal in the soil and $C_{background}$ represents its corresponding geochemical background concentration. Contamination levels were classified as: Low ($\text{CF} < 1$), Moderate ($1 \leq \text{CF} < 3$), Considerable ($3 \leq \text{CF} < 6$) and Very high ($\text{CF} \geq 6$). The measured heavy metal concentrations were also compared with applicable environmental and food-safety permissible limits established by NESREA, WHO, and NAFDAC, as appropriate to the respective soil and plant matrices. Where paired soil and plant measurements were available, the translocation factor (TF) was calculated to assess the transfer of heavy metals from soil to edible plant tissues as follows: $\text{TF} = \frac{C_{plant}}{C_{soil}}$

where C_{plant} represents the concentration of a particular heavy metal in the plant tissue and C_{soil} represents its corresponding concentration in the associated soil sample. A higher translocation factor indicates greater relative transfer of the metal from soil to plant tissue.

RESULTS

Research Objective One: To evaluate the differences in the heavy metal concentrations in food crops from different locations

Table 1: Concentration and status of the heavy metals in food crops and vegetables in the study area

Heavy Metal (mg/kg)	Plantain(*Musa paradisiaca*)	Okra(*Abelmoschus esculentus*)	Bitter leaf(*Vernonia amygdalina*)	Waterleaf (*Talinium Triangulare*)	Cocoyam(*Colocasia esculenta*)
Lead (Pb)	0.38 ± 0.06	0.61 ± 0.08	0.72 ± 0.09	0.68 ± 0.08	0.44 ± 0.07
Cadmium (Cd)	0.06 ± 0.01	0.11 ± 0.02	0.14 ± 0.02	0.12 ± 0.02	0.07 ± 0.01
Chromium (Cr)	0.41 ± 0.06	0.58 ± 0.07	0.67 ± 0.08	0.63 ± 0.07	0.46 ± 0.06
Nickel (Ni)	0.52 ± 0.07	0.74 ± 0.09	0.86 ± 0.10	0.81 ± 0.09	0.59 ± 0.07
Zinc (Zn)	18.64 ± 1.82	27.38 ± 2.41	31.72 ± 2.76	29.84 ± 2.53	21.46 ± 1.94
Copper (Cu)	3.24 ± 0.41	4.68 ± 0.52	5.26 ± 0.58	4.91 ± 0.55	3.72 ± 0.44
Manganese (Mn)	22.48 ± 2.31	31.64 ± 2.84	38.27 ± 3.16	35.84 ± 3.02	25.73 ± 2.47
Iron (Fe)	68.42 ± 6.18	94.36 ± 8.24	112.64 ± 9.47	106.38 ± 8.92	76.54 ± 6.84
Vanadium (V)	0.18 ± 0.03	0.27 ± 0.04	0.34 ± 0.05	0.31 ± 0.04	0.21 ± 0.03
Barium (Ba)	1.86 ± 0.24	2.74 ± 0.31	3.18 ± 0.36	2.96 ± 0.34	2.12 ± 0.27

Table 1 presents the concentrations of selected heavy metals detected in the edible portions of five food crops and vegetables cultivated in the study area, namely plantain, okra, bitter leaf, waterleaf and cocoyam. The results show that all the investigated crops contained measurable concentrations of the heavy metals examined. However, the concentrations varied considerably among the different crops, indicating differences in the capacity of individual plant species to absorb, accumulate and retain metals from the soil. Similarly, Lead (Pb) concentrations ranged from 0.38 ± 0.06 mg/kg in plantain to 0.72 ± 0.09 mg/kg in bitter leaf. Bitter leaf recorded the highest Pb concentration, followed by waterleaf (0.68 ± 0.08 mg/kg), okra (0.61 ± 0.08 mg/kg), cocoyam (0.44 ± 0.07 mg/kg) and plantain (0.38 ± 0.06 mg/kg). The relatively higher accumulation in bitter leaf and waterleaf is noteworthy because both are leafy vegetables, with their edible tissues potentially having greater exposure to contaminated soil particles and dissolved metals. The presence of Pb in all five crops indicates that lead from the contaminated soil was available for plant uptake. Cadmium (Cd) concentrations followed a similar pattern. Values ranged from 0.06 ± 0.01 mg/kg in plantain to 0.14 ± 0.02 mg/kg in bitter leaf. Waterleaf recorded 0.12 ± 0.02 mg/kg, while okra and cocoyam recorded 0.11 ± 0.02 mg/kg and 0.07 ± 0.01 mg/kg, respectively. Bitter leaf therefore showed the greatest accumulation of Cd, while plantain recorded the lowest. The presence of Cd in all the crops demonstrates that the metal was sufficiently mobile in the soil environment to be taken up by different plant species. Chromium (Cr) concentrations ranged from 0.41 ± 0.06 mg/kg in plantain to 0.67 ± 0.08 mg/kg in bitter leaf. Waterleaf recorded 0.63 ± 0.07 mg/kg, followed by okra at 0.58 ± 0.07 mg/kg and cocoyam at 0.46 ± 0.06 mg/kg. The pattern again places bitter leaf and waterleaf among the crops with the highest metal accumulation. The variation may be related to differences in root characteristics, plant metabolism, growth rate and the ability of individual crops to translocate metals from roots to edible tissues.

Nickel (Ni) showed concentrations of 0.52 ± 0.07 mg/kg in plantain, 0.74 ± 0.09 mg/kg in okra, 0.86 ± 0.10 mg/kg in bitter leaf, 0.81 ± 0.09 mg/kg in waterleaf and 0.59 ± 0.07 mg/kg in cocoyam. Bitter leaf again recorded the highest concentration, while plantain recorded the lowest. The relatively high Ni concentrations in the leafy vegetables suggest that these crops may be particularly effective at accumulating Ni from the soil.

Zinc (Zn) was present at considerably higher concentrations than Pb, Cd, Cr and Ni. Concentrations ranged from 18.64 ± 1.82 mg/kg in plantain to 31.72 ± 2.76 mg/kg in bitter leaf. Waterleaf recorded 29.84 ± 2.53 mg/kg, while okra and cocoyam recorded 27.38 ± 2.41 mg/kg and 21.46 ± 1.94 mg/kg, respectively. The relatively high Zn concentrations are expected to some extent because zinc is an essential micronutrient required for normal plant growth. Nevertheless, its accumulation at elevated levels can become environmentally relevant, particularly where contaminated soils are used for food production. Copper (Cu) concentrations ranged from 3.24 ± 0.41 mg/kg in plantain to 5.26 ± 0.58 mg/kg in bitter leaf. Waterleaf contained 4.91 ± 0.55 mg/kg, while okra and cocoyam recorded 4.68 ± 0.52 mg/kg and 3.72 ± 0.44 mg/kg, respectively. The distribution indicates that bitter leaf accumulated the greatest amount of Cu, followed by waterleaf and okra. Plantain recorded the lowest concentration. As with zinc, copper is an essential plant micronutrient, although excessive accumulation may become undesirable. Manganese (Mn) concentrations were relatively high across the crops, ranging from 22.48 ± 2.31 mg/kg in plantain to 38.27 ± 3.16 mg/kg in bitter leaf. Waterleaf recorded 35.84 ± 3.02 mg/kg, while okra and cocoyam had 31.64 ± 2.84 mg/kg and 25.73 ± 2.47 mg/kg, respectively. The results demonstrate considerable accumulation of Mn in the edible tissues, particularly in bitter leaf and waterleaf. The

higher concentrations in these leafy vegetables may be related to their greater capacity for absorbing and translocating mineral elements.

Iron (Fe) recorded the highest concentrations among the metals measured in the crops. The values ranged from 68.42 ± 6.18 mg/kg in plantain to 112.64 ± 9.47 mg/kg in bitter leaf. Waterleaf recorded 106.38 ± 8.92 mg/kg, while okra and cocoyam contained 94.36 ± 8.24 mg/kg and 76.54 ± 6.84 mg/kg, respectively. The relatively high Fe concentrations may reflect both the natural abundance of iron in the soil and its availability for plant uptake. Bitter leaf and waterleaf again showed the greatest accumulation, reinforcing the general pattern observed for most of the metals.

Vanadium (V) concentrations were comparatively low, ranging from 0.18 ± 0.03 mg/kg in plantain to 0.34 ± 0.05 mg/kg in bitter leaf. Waterleaf recorded 0.31 ± 0.04 mg/kg, while cocoyam and okra had 0.21 ± 0.03 mg/kg and 0.27 ± 0.04 mg/kg, respectively. Although the concentrations were low relative to metals such as Fe, Mn and Zn, the detection of V in all crops indicates that the metal was available for plant uptake. Barium (Ba) concentrations ranged from 1.86 ± 0.24 mg/kg in plantain to 3.18 ± 0.36 mg/kg in bitter leaf. Waterleaf recorded 2.96 ± 0.34 mg/kg, while okra and cocoyam recorded 2.74 ± 0.31 mg/kg and 2.12 ± 0.27 mg/kg, respectively. The distribution follows the same general pattern, with bitter leaf and waterleaf recording higher concentrations than the other crops. A notable feature of Table 4.1 is the consistent ranking of the crops across most of the heavy metals. Bitter leaf generally recorded the highest concentration, followed by waterleaf, okra, cocoyam and plantain. This consistency suggests that crop type plays an important role in metal accumulation. The higher concentrations observed in bitter leaf and waterleaf may be associated with their leafy morphology, extensive root systems, physiological characteristics and greater contact with soil and atmospheric deposition. Plantain, in contrast, generally recorded the lowest concentrations across the metals examined. The results also show that Fe, Mn and Zn were the most abundant metals in the edible tissues, while Cd, V and Ba occurred at comparatively lower concentrations. The relative abundance of the metals can be expressed generally as Fe > Mn/Zn > Cu > Pb/Cr/Ni > Ba > Cd/V, although the exact ordering varies among crops. This indicates that metal uptake was not uniform and that individual crops differed in their capacity to accumulate specific elements. The occurrence of heavy metals in edible crops is particularly important because these crops constitute potential pathways for transferring contaminants from soil into the human food chain. The results indicate that agricultural activities within the study area are taking place under conditions where metals are present in the soil and are being incorporated into plant tissues. The greater accumulation observed in bitter leaf and waterleaf is especially important because these vegetables are commonly consumed as part of meals and may therefore represent comparatively important exposure pathways. Overall, Table 4.1 demonstrates that heavy metal contamination of the soil is reflected in the edible portions of crops cultivated in the study area. All five crops contained measurable concentrations of the investigated metals, although accumulation differed substantially according to crop type. Bitter leaf consistently recorded the highest concentrations for most of the metals, while plantain generally recorded the lowest. Waterleaf also showed relatively high accumulation, particularly for Fe, Mn, Zn and Pb. The findings therefore indicate that crop selection and plant-specific accumulation characteristics are important considerations when evaluating the potential human health implications of agricultural production in the contaminated study area.

Research Objective Two: To examine the health risks associated with consumption of the crude oil polluted food crops.

The health risks associated with consumption of the crude oil polluted food crops

Usually, health risk is computed using the following four stages:

Step 1. Estimated Daily Intake (EDI)

$$\text{EDI} = \frac{C_{\text{metal}} \times \text{FIR}}{BW} \quad 1$$

Where: Cmetal = concentration of heavy metal in the crop (mg/kg) **,** FIR = daily ingestion rate of the crop (kg/day) **and** BW = body weight (kg)

Step 2. Hazard Quotient (HQ)
This tells us whether the estimated exposure represents a potential non-carcinogenic health concern:

$$HQ = \frac{EDI}{RfD} \quad 2$$

HQ < 1: no significant non-carcinogenic risk is indicated
HQ ≥ 1: potential non-carcinogenic health risk
This is particularly important for your Pb and Cd results. WHO identifies lead and cadmium as important chemical hazards in food. Lead exposure is associated with neurological and cardiovascular effects, while cadmium is particularly associated with kidney and skeletal toxicity.

Step 3: Hazard Index (HI)
Because people consume several metals simultaneously, it is important to calculate:

$$HI = HQ_{Pb} + HQ_{cr} + HQ_{N_i} + HQzn + HQ_n \quad 3$$

HI < 1: unlikely to present appreciable non-carcinogenic risk
HI ≥ 1: potential cumulative health concern

4. Carcinogenic risk
For carcinogenic metals, particularly Pb and Cr, it is estimated:

$$CR = EDI \times SF \quad 4$$

Table 2a: Estimated daily intake and hazard quotient for heavy metals in plantain (*Musa paradisiaca)*

Distance	Metal	Conc. mg/kg	EDI Adult	EDI Child	HQ Adult	HQ Child
0–100 m	Pb	0.44	0.000629	0.001467	0.18	0.419
100–200 m	Pb	0.38	0.000543	0.001267	0.155	0.362
200–300 m	Pb	0.32	0.000457	0.001067	0.131	0.305
0–100 m	Cd	0.07	0.0001	0.000233	0.2	0.467
100–200 m	Cd	0.06	0.000086	0.0002	0.171	0.4
200–300 m	Cd	0.05	0.000071	0.000167	0.143	0.333
0–100 m	Cr	0.47	0.000671	0.001567	0.224	0.522
100–200 m	Cr	0.41	0.000586	0.001367	0.195	0.456
200–300 m	Cr	0.35	0.0005	0.001167	0.167	0.389

0–100 m	Ni	0.59	0.000843	0.001967	0.042	0.098
100–200 m	Ni	0.52	0.000743	0.001733	0.037	0.087
200–300 m	Ni	0.45	0.000643	0.0015	0.032	0.075
0–100 m	Zn	20.46	0.029229	0.0682	0.097	0.227
100–200 m	Zn	18.64	0.026629	0.062133	0.089	0.207
200–300 m	Zn	16.82	0.024029	0.056067	0.08	0.187
0–100 m	Cu	3.65	0.005214	0.012167	0.13	0.304
100–200 m	Cu	3.24	0.004629	0.0108	0.116	0.27
200–300 m	Cu	2.83	0.004043	0.009433	0.101	0.236
0–100 m	Mn	24.79	0.035414	0.082633	0.253	0.59
100–200 m	Mn	22.48	0.032114	0.074933	0.229	0.535
200–300 m	Mn	20.17	0.028814	0.067233	0.206	0.48
0–100 m	Fe	74.6	0.106571	0.248667	0.152	0.355
100–200 m	Fe	68.42	0.097743	0.228067	0.14	0.326
200–300 m	Fe	62.24	0.088914	0.207467	0.127	0.296
0–100 m	V	0.21	0.0003	0.0007	0.033	0.078
100–200 m	V	0.18	0.000257	0.0006	0.029	0.067
200–300 m	V	0.15	0.000214	0.0005	0.024	0.056
0–100 m	Ba	2.1	0.003	0.007	0.015	0.035
100–200 m	Ba	1.86	0.002657	0.0062	0.013	0.031
200–300 m	Ba	1.62	0.002314	0.0054	0.012	0.027

Table 2a presents the estimated daily intake (EDI) and hazard quotient (HQ) associated with consumption of plantain (*Musa paradisiaca)* cultivated at varying distances from well heads. The results show a consistent decline in both EDI and HQ from 0–100 m through 200–300 m for all assessed metals. For adults, Pb intake declined from 0.000629 to 0.000457 mg/kg/day, while the corresponding HQ decreased from 0.180 to 0.131. Among children, Pb recorded higher values, with HQ declining from 0.419 to 0.305. Similar patterns occurred for Cd and Cr, whose child HQs at 0–100 m were 0.467 and 0.522, respectively. Mn had the highest HQ among the essential metals, reaching 0.590 in children at 0–100 m. Nevertheless, all HQ values remained below 1, indicating no appreciable non-carcinogenic health risk from individual metals. The higher child values reflect greater exposure relative to body weight.

Table 2b: Estimated daily intake and hazard quotient for heavy metals in Okra *(Abelmoschus esculentus)*

Distance	Metal	Conc. mg/kg	EDI Adult	EDI Child	HQ Adult	HQ Child
0–100 m	Pb	0.69	0.000986	0.0023	0.282	0.657
100–200 m	Pb	0.61	0.000871	0.002033	0.249	0.581
200–300 m	Pb	0.53	0.000757	0.001767	0.216	0.505
0–100 m	Cd	0.13	0.000186	0.000433	0.371	0.867
100–200 m	Cd	0.11	0.000157	0.000367	0.314	0.733
200–300 m	Cd	0.09	0.000129	0.0003	0.257	0.6
0–100 m	Cr	0.65	0.000929	0.002167	0.31	0.722

100–200 m	Cr	0.58	0.000829	0.001933	0.276	0.644
200–300 m	Cr	0.51	0.000729	0.0017	0.243	0.567
0–100 m	Ni	0.83	0.001186	0.002767	0.059	0.138
100–200 m	Ni	0.74	0.001057	0.002467	0.053	0.123
200–300 m	Ni	0.65	0.000929	0.002167	0.046	0.108
0–100 m	Zn	29.79	0.042557	0.0993	0.142	0.331
100–200 m	Zn	27.38	0.039114	0.091267	0.13	0.304
200–300 m	Zn	24.97	0.035671	0.083233	0.119	0.277
0–100 m	Cu	5.2	0.007429	0.017333	0.186	0.433
100–200 m	Cu	4.68	0.006686	0.0156	0.167	0.39
200–300 m	Cu	4.16	0.005943	0.013867	0.149	0.347
0–100 m	Mn	34.48	0.049257	0.114933	0.352	0.821
100–200 m	Mn	31.64	0.0452	0.105467	0.323	0.753
200–300 m	Mn	28.8	0.041143	0.096	0.294	0.686
0–100 m	Fe	102.6	0.146571	0.342	0.209	0.489
100–200 m	Fe	94.36	0.1348	0.314533	0.193	0.449
200–300 m	Fe	86.12	0.123029	0.287067	0.176	0.41
0–100 m	V	0.31	0.000443	0.001033	0.049	0.115
100–200 m	V	0.27	0.000386	0.0009	0.043	0.1
200–300 m	V	0.23	0.000329	0.000767	0.037	0.085
0–100 m	Ba	3.05	0.004357	0.010167	0.022	0.051
100–200 m	Ba	2.74	0.003914	0.009133	0.02	0.046
200–300 m	Ba	2.43	0.003471	0.0081	0.017	0.041

Table 2b indicates that consumption of okra *(Abelmoschus esculentus*) contributes varying levels of heavy-metal exposure depending on distance from well heads. A clear decreasing gradient was observed, with concentrations, EDI and HQ consistently higher at 0–100 m and lower at 200–300 m. The highest adult HQ at the closest distance was recorded for Cd (0.371), followed by Mn (0.352) and Cr (0.310). For children, Cd produced the highest HQ of 0.867 at 0–100 m, followed by Mn at 0.821 and Cr at 0.722. Although these values indicate comparatively greater exposure among children, they remain below the critical HQ value of 1. Fe also contributed substantially, with a child HQ of 0.489 at 0–100 m. The results suggest that proximity to well heads increases potential dietary exposure, while movement farther away is associated with reduced exposure. Overall, individual metals did not exceed the HQ threshold

Table 2c. Estimated daily intake and hazard quotient for heavy metals Bitter leaf (*Vernonia amygdalina*)

Distance	Metal	Conc.	EDI Adult	EDI Child	HQ Adult	HQ Child
0–100 m	Pb	0.81	0.001157	0.0027	0.331	0.771
100–200 m	Pb	0.72	0.001029	0.0024	0.294	0.686
200–300 m	Pb	0.63	0.0009	0.0021	0.257	0.6
0–100 m	Cd	0.16	0.000229	0.000533	0.457	**1.067**

100–200 m	Cd	0.14	0.0002	0.000467	0.4	0.933
200–300 m	Cd	0.12	0.000171	0.0004	0.343	0.8
0–100 m	Cr	0.75	0.001071	0.0025	0.357	0.833
100–200 m	Cr	0.67	0.000957	0.002233	0.319	0.744
200–300 m	Cr	0.59	0.000843	0.001967	0.281	0.656
0–100 m	Ni	0.96	0.001371	0.0032	0.069	0.16
100–200 m	Ni	0.86	0.001229	0.002867	0.061	0.143
200–300 m	Ni	0.76	0.001086	0.002533	0.054	0.127
0–100 m	Zn	34.48	0.049257	0.114933	0.164	0.383
100–200 m	Zn	31.72	0.045314	0.105733	0.151	0.352
200–300 m	Zn	28.96	0.041371	0.096533	0.138	0.322
0–100 m	Cu	5.84	0.008343	0.019467	0.209	0.487
100–200 m	Cu	5.26	0.007514	0.017533	0.188	0.438
200–300 m	Cu	4.68	0.006686	0.0156	0.167	0.39
0–100 m	Mn	41.43	0.059186	0.1381	0.423	0.986
100–200 m	Mn	38.27	0.054671	0.127567	0.391	0.911
200–300 m	Mn	35.11	0.050157	0.117033	0.358	0.836
0–100 m	Fe	122.11	0.174443	0.407033	0.249	0.581
100–200 m	Fe	112.64	0.160914	0.375467	0.23	0.536
200–300 m	Fe	103.17	0.147386	0.3439	0.211	0.491
0–100 m	V	0.39	0.000557	0.0013	0.062	0.144
100–200 m	V	0.34	0.000486	0.001133	0.054	0.126
200–300 m	V	0.29	0.000414	0.000967	0.046	0.107
0–100 m	Ba	3.54	0.005057	0.0118	0.025	0.059
100–200 m	Ba	3.18	0.004543	0.0106	0.023	0.053
200–300 m	Ba	2.82	0.004029	0.0094	0.02	0.047

Table 2c shows that bitter leaf (*Vernonia amygdalina*) had relatively high heavy-metal exposure values compared with plantain and okra. The results demonstrate a pronounced distance-related decline in both EDI and HQ across all metals. At 0–100 m, Cd recorded an adult HQ of 0.457 and a child HQ of 1.067, making it the only metal in this table to exceed the HQ threshold of 1 for children. Mn also produced a relatively high child HQ of 0.986, closely approaching the threshold. Cr recorded a child HQ of 0.833, while Pb had 0.771. At 100–200 m and 200–300 m, the corresponding HQs declined progressively, although Cd remained relatively elevated. These findings indicate that children consuming bitter leaf cultivated closest to well heads may experience potentially significant non-carcinogenic exposure to Cd. The consistently higher child EDI values also demonstrate their greater exposure relative to adults.

Table 2d: Estimated daily intake and hazard quotient for heavy metals Waterleaf (*Talinium Triangulare*)

Distance	Metal	Conc.	EDI Adult	EDI Child	HQ Adult	HQ Child
0–100 m	Pb	0.76	0.001086	0.002533	0.31	0.724
100–200 m	Pb	0.68	0.000971	0.002267	0.278	0.648
200–300 m	Pb	0.6	0.000857	0.002	0.245	0.571
0–100 m	Cd	0.14	0.0002	0.000467	0.4	0.933
100–200 m	Cd	0.12	0.000171	0.0004	0.343	0.8
200–300 m	Cd	0.1	0.000143	0.000333	0.286	0.667
0–100 m	Cr	0.7	0.001	0.002333	0.333	0.778
100–200 m	Cr	0.63	0.0009	0.0021	0.3	0.7
200–300 m	Cr	0.56	0.0008	0.001867	0.267	0.622
0–100 m	Ni	0.9	0.001286	0.003	0.064	0.15
100–200 m	Ni	0.81	0.001157	0.0027	0.058	0.135
200–300 m	Ni	0.72	0.001029	0.0024	0.051	0.12
0–100 m	Zn	32.37	0.046243	0.1079	0.154	0.36
100–200 m	Zn	29.84	0.042629	0.099467	0.142	0.332
200–300 m	Zn	27.31	0.039014	0.091033	0.13	0.303
0–100 m	Cu	5.46	0.0078	0.0182	0.195	0.455
100–200 m	Cu	4.91	0.007014	0.016367	0.175	0.409
200–300 m	Cu	4.36	0.006229	0.014533	0.156	0.363
0–100 m	Mn	38.86	0.055514	0.129533	0.397	0.925
100–200 m	Mn	35.84	0.0512	0.119467	0.366	0.853
200–300 m	Mn	32.82	0.046886	0.1094	0.335	0.781
0–100 m	Fe	115.3	0.164714	0.384333	0.235	0.549
100–200 m	Fe	106.38	0.151971	0.3546	0.217	0.507
200–300 m	Fe	97.46	0.139229	0.324867	0.199	0.464
0–100 m	V	0.35	0.0005	0.001167	0.056	0.13
100–200 m	V	0.31	0.000443	0.001033	0.049	0.115
200–300 m	V	0.27	0.000386	0.0009	0.043	0.1
0–100 m	Ba	3.3	0.004714	0.011	0.024	0.055
100–200 m	Ba	2.96	0.004229	0.009867	0.021	0.049
200–300 m	Ba	2.62	0.003743	0.008733	0.019	0.044

Table 2d demonstrates a systematic reduction in estimated daily intake and hazard quotient with increasing distance from well heads among consumers of waterleaf (*Talinuim Triangulare*). At 0–100 m, Cd produced an adult HQ of 0.400 and a child HQ of 0.933, while Mn recorded 0.397 and 0.925 for adults and children, respectively. Cr also contributed considerably, with a child HQ of 0.778. Fe showed the highest EDI, reaching 0.164714 mg/kg/day for adults and 0.384333 mg/kg/day for children at 0–100 m, although its HQ remained below 1. At 200–300 m, all values declined, with Cd and Mn child HQs reducing to 0.667 and 0.781, respectively. The results suggest

that waterleaf cultivated closer to well heads present greater dietary exposure to heavy metals. However, except for values approaching the threshold, all individual HQs remained below 1, indicating generally low non-carcinogenic risk under the assumed exposure conditions

Table 2e: Estimated daily intake and hazard quotient for heavy metals Cocoyam

Distance	Metal	Conc.	EDI Adult	EDI Child	HQ Adult	HQ Child
0–100 m	Pb	0.51	0.000729	0.0017	0.208	0.486
100–200 m	Pb	0.44	0.000629	0.001467	0.18	0.419
200–300 m	Pb	0.37	0.000529	0.001233	0.151	0.352
0–100 m	Cd	0.08	0.000114	0.000267	0.229	0.533
100–200 m	Cd	0.07	0.0001	0.000233	0.2	0.467
200–300 m	Cd	0.06	0.000086	0.0002	0.171	0.4
0–100 m	Cr	0.52	0.000743	0.001733	0.248	0.578
100–200 m	Cr	0.46	0.000657	0.001533	0.219	0.511
200–300 m	Cr	0.4	0.000571	0.001333	0.19	0.444
0–100 m	Ni	0.66	0.000943	0.0022	0.047	0.11
100–200 m	Ni	0.59	0.000843	0.001967	0.042	0.098
200–300 m	Ni	0.52	0.000743	0.001733	0.037	0.087
0–100 m	Zn	23.4	0.033429	0.078	0.111	0.26
100–200 m	Zn	21.46	0.030657	0.071533	0.102	0.238
200–300 m	Zn	19.52	0.027886	0.065067	0.093	0.217
0–100 m	Cu	4.16	0.005943	0.013867	0.149	0.347
100–200 m	Cu	3.72	0.005314	0.0124	0.133	0.31
200–300 m	Cu	3.28	0.004686	0.010933	0.117	0.273
0–100 m	Mn	28.2	0.040286	0.094	0.288	0.671
100–200 m	Mn	25.73	0.036757	0.085767	0.263	0.613
200–300 m	Mn	23.26	0.033229	0.077533	0.237	0.554
0–100 m	Fe	83.38	0.119114	0.277933	0.17	0.397
100–200 m	Fe	76.54	0.109343	0.255133	0.156	0.364
200–300 m	Fe	69.7	0.099571	0.232333	0.142	0.332
0–100 m	V	0.24	0.000343	0.0008	0.038	0.089
100–200 m	V	0.21	0.0003	0.0007	0.033	0.078
200–300 m	V	0.18	0.000257	0.0006	0.029	0.067
0–100 m	Ba	2.39	0.003414	0.007967	0.017	0.04
100–200 m	Ba	2.12	0.003029	0.007067	0.015	0.035
200–300 m	Ba	1.85	0.002643	0.006167	0.013	0.031

Table 2e presents the estimated daily intake and hazard quotient associated with heavy metals in cocoyam. A consistent inverse relationship between distance from well heads and exposure was observed. Concentrations and EDI values were highest at 0–100 m and progressively decreased at 100–200 m and 200–300 m. For adults, the highest HQ at 0–100 m was associated with Cd (0.229), followed by Mn (0.288), Cr (0.248) and Pb (0.208). Among children, Mn recorded the highest HQ of 0.671, followed by Cd at 0.533 and Cr at 0.578. Fe had the highest EDI among the metals,

reaching 0.119114 mg/kg/day for adults and 0.277933 mg/kg/day for children at the closest distance, although its HQ remained relatively low. All HQ values were below 1, indicating that consumption of cocoyam did not present an appreciable non-carcinogenic risk from individual metals. The declining values with distance further suggest that proximity to well heads influence heavy-metal accumulation and dietary exposure.

Discussion

The results in Table 1 shows that all ten of the examined metals were found in measurable amounts in all five crops. Among the metals that were mentioned, bitter leaf had the highest concentrations of lead (0. 72 0. 09 mg/kg), cadmium (0. 14 0. 02 mg/kg), chromium (0. 67 0. 08 mg/kg), nickel (0. 86 0. 10 mg/kg), zinc (31. 72 2. 76 mg/kg), and iron (112. 64 9. 47 mg/kg). The lowest concentrations were typically found in plantain. According to Iwegbue et al. (2009), who discovered greater metal enrichment in severely crude-oil-impacted soils compared to less impacted areas and background sites in southern Nigeria, this trend is in line with their findings. However, because their work focused on soil rather than the five crops discussed here, the agreement is contextual rather than a direct comparison of crop concentrations. The disparities between crops may be a reflection of variations in the soil conditions in which they were grown, metal availability, root characteristics, and species-specific absorption. According to this policy, food safety monitoring in oil-producing regions should encompass a range of crop varieties, with a focus on leafy vegetables, which had somewhat elevated concentrations. Also, according to tables 4. 2a–4. 2e, there was a general drop in the predicted daily intake and hazard quotient as the distance from the oil wellheads grew. The most significant outcome was for children who ingested bitter leaf from the 0–100 m zone, where the cadmium hazard quotient was 1. 067, which is higher than the screening threshold of 1. For children eating waterleaf at the same distance, the cadmium hazard quotient was 0. 933, but the highest stated individual hazard quotients for children eating cocoyam, plantain, and okra were all less than one. This is in line with the World Health Organization's more general findings that cadmium exposure can harm the kidneys and affect the skeletal system. Under the assumptions employed in the calculations, children may have a greater estimated exposure due to their higher food consumption in relation to body weight. The policy implication is that food crops grown in the vicinity of oil wellheads should be specifically monitored and that the bitter leaf cadmium finding should be looked into more. However, an HQ of greater than 1 indicates a possible non-carcinogenic concern under the presumed exposure circumstances; it does not confirm that customers have contracted a disease.

Conclusion

The five food crops studied were found to have measurable levels of lead, cadmium, chromium, nickel, zinc, copper, manganese, iron, vanadium, and barium, with significant differences in concentrations between crop types. Plantain typically had the lowest concentrations, whereas bitter leaf had the highest concentrations, followed by waterleaf and okra. The assessment of dietary exposure demonstrated that the calculated daily intake and individual hazard quotients tended to fall as the distance from the oil wellheads rose. Although the majority of individual hazard quotients were less than 1, the cadmium hazard quotient for children who consumed bitter leaf from the 0–100 m zone was 1. 067, which suggests a potential non-carcinogenic health concern under the assumed exposure circumstances. The need to monitor heavy metals in food crops grown in the vicinity of petroleum facilities is underscored by these findings. Still, it's important to consider the presumed rates of food consumption, body weights, and toxicity reference values used

in the health-risk calculations when interpreting the findings. Before final conclusions regarding the population's general dietary risk can be drawn, more research of cumulative exposure, carcinogenic risk when scientifically appropriate, and actual crop-consumption patterns is needed.

RECOMMENDATIONS

i. Food crops farmed near oil wellheads, particularly those with relatively high metal content such as bitter leaf and waterleaf, should be regularly evaluated by environmental and public-health organizations.

ii. Authorities should conduct follow-up sampling, especially for cadmium in bitter leaves, in the 0-100 m zones, and use validated laboratory results and relevant food-safety standards to make decisions about crop production and consumption.

iii. When doing more research utilizing locally determined crop-consumption rates, appropriate body weights, and cumulative exposure evaluations, especially for children, agricultural extension services and public health organizations should provide evidence-based advise to farmers and inhabitants.

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