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Assessment of Heavy Metal Concentrations in Food Samples of Oil and Non-Oil Producing Communities in Rivers State, Nigeria

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Authors' contributions

This work was carried out in collaboration between both authors. Author ECI designed the study, wrote the protocol, and the first draft of the manuscript. Author CTK managed the literature searches. Both authors read and approved the final manuscript.

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ABSTRACT

Aim: To compare heavy metal concentrations in locally consumed vegetables and food crops grown in oil and non-oil-producing communities in Rivers State.
Study Design: Descriptive cross-sectional study.
Place and Duration of Study: Kegbara Dere and Omerelu communities in Gokana and Ikwerre local government areas, Rivers State, Nigeria between November 2021 and January 2022.
Methodology: Heavy metal concentrations (lead (Pb), cadmium (Cd) mercury (Hg), and arsenic (Ars) of vegetables, food crops, and sea animals selected from the local markets and rivers of the two communities were determined. Data entry and analysis were done using IBM Statistical Package for Social Sciences (SPSS)version 21. T-test was used to compare the mean differences in heavy metal concentrations of vegetables and food crops between the two communities.

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Results: Mean concentrations of Lead (0.70 vs 0.01) Cadmium (0.09 vs 0.00) and Arsenic (0.18 vs0.00) respectively of vegetables grown in the oil-producing community were higher than that of the non-oil-producing community. The difference was not statistically significant (*P*>0.05). Mean concentrations of Lead (1.48 vs 0.00) Cadmium (0.28 vs 0.00), and Arsenic (0.41 vs 0.00) of the food crops in the oil-producing community were higher than that of the non-oil-producing community. However, only the difference in the lead concentrations was significant (*P*<0.05) The concentrations of Pb, Cd, and Ars in sea creatures collected from the surface waters of the oil-producing community were above WHO-recommended limits.

Conclusion: Food grown in oil-polluted environments has higher heavy metal concentrations compared to non-polluted environments and therefore highlights the need for continued and increased efforts towards complete remediation of the polluted regions of the Niger Delta.

Keywords: Heavy metal; oil-producing; non-oil-producing; food crops; vegetables; Nigeria.

1. INTRODUCTION

Environmental degradation is an enormous public health problem affecting different regions of the world [1]. Low and middle-income countries are disproportionally affected impacting individuals, families, and communities [2]. Heavy metals are one of the components of crude oil which can contaminate the environment with adverse direct health effects [3]. Environmental exposure to heavy metals is characteristically chronic and often occurs in low doses but potentially has a deleterious impact on the ecosystem [4]. Recent reports from the Organization of the Petroleum Export Countries (OPEC), state that Nigeria, African's largest producer of crude oil ranks tenth as the country with the world's largest crude oil reserves and the thirteenth as the largest producer of crude oil globally [5]. The Niger Delta is the depot of Nigeria's crude oil and about 90% of the nation's revenue come from oil proceeds [6,7]. However, certain parts of the nation's Niger Delta region is inundated with environmental degradation, from significant pollution from crude oil spills, mainly arising from anthropogenic activities [8-10]. Heavy metals from crude oil spills frequently contaminate the soil and because of its ability to persist, in the environment, on permeating the soil, they can bioaccumulate in food plants [11-14].

Certain heavy metals such as lead, mercury, cadmium, and arsenic have been identified as metals of public health importance [15]. These elements occur in nature but in little amounts. However, when with prolonged, low dose exposure, there is known that certain harmful effects can impact man's health [2]. These adverse effects range from congenital anomalies, blood, heart, and brain disorders, including cancers [16]. Common pathways for human exposure to heavy metals include ingestion, dermal and inhalational routes [16]. This can occur from contaminated soil affecting agricultural produce, consumption of fish and other aquatic animals harvested from polluted waters and drinking contaminated water [3]. Due to the paucity of existing literature, this study aimed at comparing the heavy metal concentrations of food samples in oil and non-oil-producing communities in Rivers State [17,18].

2. MATERIALS AND METHODS

2.1 Study Area

The study was carried out in Nweekol-KegbaDere, an oil-producing/impacted community, and Omerelu, an upland, non-oil-producing community in Gokana and Ikwerre local government areas of Rivers State.

2.2 Study Design

This was a descriptive cross-sectional study.

2.3 Sample Collection of Commonly Consumed Food (Vegetables, Food Crops, Aquatic Biotas)

Fresh samples each of locally grown and commonly consumed vegetables and food crops such as fluted pumpkin (*Telferia occidetalis*), Okazi (*Gnetum africanum*), and Okra (*Abelmoschus esculentus*), tomato (*Solanum lycopersicum*) yam (*Dioscorea alata*), coco yam (*Colocasia esculenta*), Plantain (*Musa paradisiaca*), Cassava (*Manihot esculenta*), palm fruit (*Elaeis guineensis*) aquatic biotas (*Tilapia genesis*, Trypanotomus fish carton, *Desmocarius trpriosp*) were selected from different parts of the local markets and creeks in Kegbara Dere and Omerelu communities. The crops were properly labelled carefully wrapped up in black polythene bags and transported to the laboratory within an hour. This was done in order to prevent exposure to light because of the volatility of arsenic when exposed to sunlight for heavy metal analysis [19].

2.4 Sample Preparation and Pretreatment of Commonly Consumed Food

After the sample collection and transportation to the laboratory, the food samples were removed from the bags and the edible parts of the samples were used while the damaged and bad parts were discarded. They were adequately washed to remove dust that had become adsorbent on the edible parts. In order to remove moisture and also to avoid the effect of sunlight on the food samples, they were air-dried at room temperature in a clean, shaded area of the laboratory. Subsequently, they were cut into small parts and completely dried in an oven at 70-80°C. Afterwards, they were ground into fine, homogenous powder using a mortar and pestle made of porcelain and weighed on a chemical balance. The ground powder produced was preserved in an air tight pouch at room temperature before digestion and analysis of the heavy metals [18].

2.5 Determination of Heavy Metal Concentration of Commonly Consumed Food

The determination of heavy metals concentration of the food samples was described by Orisakwe and his colleagues 20]. Four (4 ml) of nitric acid and 1 ml of hydrogen perchloric acid (4:1) was added to the ground mixture and allowed to rest for about 30 minutes. After which it was made up to a final volume of 25mls of distilled deionized water. The hot plate was set at 105-110^{0}C/45 min. Thereafter, the mixture was transferred to the hot plate until the digestion was complete. Complete digestion occurred when the components of the solution is clear, with a pale yellow colour or the solution is reduced to a third of its original volume. After digestion, the mixture was allowed to cool for about 30 minutes. The mixture was then filtered with Whatman filter paper of 0.2 ml through the funnel into a graduated measuring cylinder. Thereafter the digestion vessel was rinsed into the cylinder, making it to mark in order to remove all possibility of bias. Subsequently a sample was taken and stored in a polyethene container for further analysis using the atomic absorption spectrometry (AAS) for heavy metal content [20].

2.6 Data Analysis

The data analysis of this study was done using Statistical Package for Social Sciences (SPSS version 21). The comparison of the heavy metal concentrations of the commonly consumed food crops between the two communities was done using *T* test. For this study, the guideline values for heavy metal concentrations in the vegetables and food crops were lead 2.0mg/kg, cadmium 0.20mg/kg, mercury0.3mg/kg and arsenic 0.10mg/kg (WHO Edition, 2015) Any values for the heavy metal studied that were higher than the guideline values were considered elevated [21].

3. RESULTS AND DISCUSSION

Table 1 shows the nephrotoxic heavy metal concentrations found in the commonly consumed foods in the studied oil-producing community. The lead concentrations in the cocoyam (*Colocasia esculenta*) and plantain (*Musa paradisiaca*) exceeded the WHO maximum permissible limits. Also, the Cadmium levels in the okro (*Abelmoschus esculentus*) and plantain (*Musa paradisiaca*) sampled were elevated compared to the WHO recommended limits. The mercury levels in all the food crops were within normal limits. The Arsenic levels in the leafy vegetables, cassava, yam, and plantain were all elevated above the recommended limits.

Table 2 shows the nephrotoxic heavy metal concentrations of commonly consumed aquatic biotas from the creeks in the oil-producing community. The lead, cadmium and arsenic concentrations of the fresh water fish (*Tilapia genesis)* were all above the WHO permissible limits. Similarly, other aquatic foods (Periwinkle *Trypanotomus fish carton* and Shrimps *Desmocarius trpriosp)* extracted from the brackish water had elevated lead, cadmium and arsenic concentrations compared to the permissible limits set by WHO. However, the mercury concentrations of these aquatic foods were below the WHO permissible limits.

Table 3 shows the lead, cadmium, mercury and arsenic concentrations of all the commonly consumed food crops were within the WHO permissible limits.

Table 1. Heavy metal concentration of commonly consumed foods in the oil-producing community

Samples	Heavy metal Concentration (mg/kg or ppm)			
	Lead (Pb)	**Cadmium (Cd)**	**Mercury (Hg)**	**Arsenic (As)**
Fluted pumpkin (*Telferia occidetalis*),	0.4169	0.0243	<0.001	0.7226
Okazi (*Gnetum africanum*)	1.9672	0.0869	<0.001	<0.001
Okro (*Abelmoschus esculentus*)	0.0216	0.2489	0.0010	0.0119
Tomatoes (*Solanum lycopersicum*)	0.4134	<0.001	<0.001	<0.001
Cocoyam (*Colocasia esculenta*)	2.6948	0.1446	0.0014	0.0734
Cassava (*Manihot esculenta*)	0.2967	0.0104	<0.001	0.1241
Yam (*Dioscorea alata*)	1.9427	0.0138	0.0013	0.1328
Cassava (*Manihot utilissima*)	0.1296	0.0138	<0.001	0.0280
Plantain (*Musa paradisiaca*)	2.3184	1.2174	0.0011	1.6932
WHO max permissible limit (2015 edition)	2.0	0.20	0.3	0.10

<0.001 : below detecting limit

Table 2. Heavy metal concentration of commonly consumed aquatic biotas from some creeks (the oil-producing community)

Samples	Heavy metal Concentration (mg/l)			
	Lead (Pb)	**Cadmium (Cd)**	**Mercury (Hg)**	**Arsenic (As)**
Fish (fresh water) Tilapia genesis	2.9167	0.3278	0.0032	1.5232
Periwinkle (Brackish water) Trypanotomus fish carton	3.1478	1.4287	0.0044	2.3491
Shrimps (Brackish water) Desmocarius trpriosp	1.4962	0.1692	<0.001	0.4186
WHO max permissible limit (2015 edition)	0.05	0.005	0.01	0.05

<0.001 : below detecting limit

Table 3. Heavy metal concentration of Commonly consumed foods in the non- oil-producing community

Samples	Heavy metal Concentration (mg/kg)			
	Lead (Pb)	**Cadmium (Cd)**	**Mercury (Hg)**	**Arsenic (As)**
Fluted pumpkin (*Telferia occidetalis*)	0.0104	<0.001	<0.001	<0.001
Okazi (*Gnetum africanum*)	0.0112	<0.001	<0.001	<0.001
Okro (*Abelmoschus esculentus*)	0.0031	<0.001	0.0010	<0.001
Palm fruit (*Elaeis guineensis*)	0.0114	<0.001	<0.001	<0.001
Cocoyam (*Colocasia esculenta*)	0.0046	0.0013	<0.001	<0.001
Cassava (*Manihot esculenta*)	0.0018	0.0020	<0.001	0.0013
Yam (*Dioscorea alata*)	0.0026	<0.001	<0.001	<0.001
Cassava (*Manihot utilissima*)	0.0061	0.0010	<0.001	0.028
Plantain (*Musa paradisiaca*)	0.0015	0.0012	<0.001	<0.001
WHO max permissible limit (2012 edition)	2.0	0.20	0.3	0.10

<0.001 : below detecting limit

Table 4 shows that the mean heavy metal concentrations of lead, cadmium and arsenic of the leafy vegetables in the oil-producing community were higher than the values observed from the non-oil producing community However, the difference in their mean concentrations was not statistically significant. In addition the mean concentration of Arsenic in the sampled leafy vegetables extracted from the oil producing community was above the WHO permissible limits.

Table 4. Mean for heavy metals concentration in vegetables for oil and Non-oil producing communities

Heavy metals	Oil producing community Mean ± SD	Non-oil producing community Mean ± SD	Mean difference (95% CI)	T	*P*-value
Lead	0.704 ± 0.861	0.009 ± 0.003	0.695(-0.358, 1.750)	1.615	.16
Cadmium	0.090 ± 0.111	0.000 ± 0.000	0.090 (-0.046, 0.227)	1.615	.16
Mercury	0.000 ± 0.000	0.000 ± 0.000	0.000 (0.000, 0.000)	0.000	.000
Arsenic	0.183 ± 0.359	0.000 ± 0.000	0.183 (-0.255, 0.623)	1.024	.35

*SD – standard deviation CI – confidence interval *Statistically significant*

Table 5 shows that the mean lead concentrations of the commonly consumed food crops extracted from the oil-producing community was higher than the values observed from the non-oil producing community. The difference observed in the mean concentrations was significant.

The mean cadmium concentration observed in the oil-producing community was higher than that in the non-oil producing community. However, the difference observed in the mean concentrations was not significant. However, the mean cadmium concentrations of the food crops commonly grown in the oil producing community was higher than the WHO permissible limits. Also, the mean concentration of Arsenic in the sampled food crops extracted from the oil producing community were higher than that of the non-oil community. Nevertheless, it was not statistically significant. In addition, the mean concentrations of Arsenic in the food crops sampled from the oil producing community was above the WHO permissible limits.

Ingestion is one of the major pathways for heavy metal exposure in the environment. Crops grown on soils contaminated with crude oil tend to have higher or elevated heavy metal content and this has an implication for human health and has become increasingly important in the concept of one health [22]. The One Health High Level Expert Panel (OHHLEP) developed an operational definition of One Health as an integrated, unifying approach that aims to sustainably balance and optimize the health of people, animals and ecosystems. The concept identifies that the health and ecosystems of man, animals, plants and the broader environment are closely linked and inter-dependent [22]. Environmental exposure to heavy metals can cause adverse effects on human life, animals and plants. The findings from the current study showed that the mean concentrations of Pb, Cd, and Arsenic were higher in the vegetables grown in the oil-producing community compared to the non-oil-producing community. However, these differences were not statistically significant. ($p>0.05$) Individual food crops from the index study revealed varying concentrations of the heavy metals. For instance, the lead concentrations in the cocoyam and plantain crops exceeded the WHO maximum permissible limits. Also, the Cadmium levels in the okro and plantain sampled were elevated compared to the WHO recommended limits. The mercury levels in all the food crops were within normal limits. The Arsenic levels in the leafy vegetables, cassava, yam, and plantain were all elevated above the recommended limits. In the non-oil producing community, all food crops have heavy metal concentrations within WHO recommended limits. Additionally, comparing the mean concentrations of the food crops studied in the oil and non-oil producing communities, It was observed that the mean concentrations of Pb, Cd and Arsenic were higher in the food crops (such as cassava, yam, potatoes, plantain etc) grown in the oil-producing community compared to the non-oil producing community. However only the difference in the Pb concentration was statistically significant ($p<0.05$) The concentrations of Pb, Cd, and arsenic in the sea foods harvested from the village waters of the oil producing community were all elevated and above their WHO recommended limits.

The concentrations observed in the different food crops may be explained by the fact that the primary determinants of plant bioaccumulation of HMs in soil include the absorption mechanism, the physical and chemical characteristics of the soil, the chemical properties of the HMs, the physiological features of the plants, and other environmental variables. These spatial characteristics of bioaccumulation of various HMs in the soil which inadvertently manifests in the crops depend on the certain important soil characteristics such as soil pH, organic matter content of the soil, and soil heavy metal concentration. These factors have been shown to exert significant effects on the soil-crop systems [23].

Table 5. Mean for heavy metals concentration in food crops for oil and non-oil producing communities

Heavy metals	Oil producing community Mean ± SD	Non-oil producing community Mean ± SD	Mean difference (95% CI)	T	*P*-value
Lead	1.476 ± 1.184	0.003 ± 0.001	1.473 (0.251, 2.695)	2.780	.02*
Cadmium	0.280 ± 0.527	0.000 ± 0.000	0.279 (-0.264, 0.822)	1.184	.27
Mercury	0.000 ± 0.000	0.000 ± 0.000	0.000 (-0.000, 0.0014)	1.504	.17
Arsenic	0.410 ± 0.718	0.006 ± 0.012	0.403 (-0.337, 1.144)	1.257	.2

*SD – standard deviation CI – confidence interval *Statistically significant*

Comparable with the findings of the index study, Nwaichi et al. [24] assessed the heavy metal content of locally consumed vegetables and other agricultural produce in oil polluted farmlands of Gokana in Ogoni land and a non-polluted community in Abia State which served as a control site [24]. The authors reported that the lead concentrations of the crops grown in the test site were above the permissible WHO limits. This finding could be attributed to the oil spillage in the community allowing heavy metals to regularly seep into deeper soil surfaces after years. Their persistence in soils frequently results in improved assimilation and bioaccumulation by plants and animals which thrive on them for sustenance, ultimately may result in adverse reactions at different points of the food chain. Also in a similar study conducted by Nkpaa et al. [25] on heavy metal determination of certain species of fishes and crustaceans found in the crude oil polluted waters of Ogoniland. It was observed that all the heavy metal concentrations of the test samples were elevated and exceeded the USEPA and WHO allowable limits. Several researchers have argued in favour of using fish and invertebrates as bioindicators of water quality [26,27]. This is due to the fact that they provide evidence of bioconcentrations that are more stable than that observed with water analysis, which only shows transient conditions. This study shows that efforts must be intensified to protect our oil-rich communities from oil pollution and its attendant health risks. In Warri, Delta State, Akintujoye et al. [28] found that fish samples from both an oil-polluted river and an unpolluted river in Ibadan had higher levels of heavy metals [28]. The researchers found that, with the exception of zinc, all heavy metal concentrations found in the fish samples exceeded WHO allowable maximum levels. Additionally, the amounts of lead, cadmium, and zinc in the tissues of the control fish samples were likewise discovered to be significantly lower ($p>0.05$) than those found in fish from the contaminated river [28]. This observation, in consonance with that of the index study and several studies in the Niger Delta further supports the hypothesis that there is a possible link between oil pollution and heavy metal abundance seen in several water bodies in this oil rich region. In the Niger Delta region's Bonny and Finima rivers, Abarshi and colleagues set out to determine the concentration of heavy metals in tissue samples of commonly consumed fish (croaker fish) [29]. The scientists discovered that fish taken from Finima Creek had the highest concentrations of all the metals they had examined. These unusually high levels of heavy metal deposition seen here may be related to the region's regular crude oil spills as well as any nearby industrial activity that could release waste into Finima Creek. The average levels of various harmful heavy metals observed in this study were generally higher than the recommended WHO acceptable limits [29]. It has been determined that the bioaccumulation of heavy metals in the tissues of aquatic organisms serves as a proxy indicator of the availability and abundance of metals in the marine environment. Because of this, biomonitoring of fish tissue for contamination plays a crucial role as an early warning indication of contamination of sediments or associated water quality issues and makes it possible to take the necessary action to safeguard both the environment, including human health. In contrast with the current study, Ubiogoro and Adeyemo examined the concentrations of heavy metals found in certain rivers and creeks in the Delta state oil-producing communities [27]. They stated that the assessed heavy metal concentrations from the fish tissue samples were slightly below the permissible limits established by WHO and FEPA. The authors stated that although the concentration of the investigated metals in the fish from these rivers was safe [27]. It is crucial to exercise caution and institute a surveillance system for routine monitoring in order to avoid ecological harm to the aquatic life and safeguard the individual consumers from possible toxicities that could arise from exposure to their metals. In support of the index study and previous findings, Adesina and Adelasoye measured the quantities of heavy metals in crops grown in Ogbomoso, Oyo state, on polluted and unpolluted soil [30]. The investigators studied how crude oil pollution altered the amount of heavy metals in the soil and the crops. They noted that all crops grown in polluted soil and polluted site vegetation, had greater concentrations of heavy metals (lead, cadmium, iron, nickel, zinc, and copper) [30]. Subsequent investigation and periodic monitoring are therefore essential in order to foster and maintain environmental sustainability. Comparatively, Odiyi et al. [31] in Akure, Ondo state conducted an experimental study by analysing the impact of crude oil pollution and the presence of heavy metals in a commonly consumed crop (maize) [31]. They reported that there was a significant increase in the heavy metals concentration of the crop as the amount of crude oil pollution increased [31]. The authors stated that this finding raises safety concerns for the residents who routinely consume this staple food in these communities. Additionally, in a nation like Nigeria where maize production is quite common, frequent occurrences of crude oil pollution can result in a large reduction in the yield of this crucial crop, resulting in heightened food insecurity in the country.

Similar studies in Tanzania and the Persian Gulf have reported increase in estimated daily intake for the metals above the provisional tolerable daily intake (PTDI) for all sampled specie of fishes [32,33]. The authors opined that petrochemical effluents at the pond located east of the study area were responsible for the elevated heavy metal concentration in the fish samples. This calls for prompt public health action of ensuring that the ecosystems are environmentally sustainable. In comparison with the current study and the previous findings is a study by Kortei et al. [34] who set out to investigate the heavy metal concentration of certain species of fishes from Rivers basins in Ghana [34]. Kortei and colleagues observed substantial levels of heavy metals in the fish samples. However only mercury exceeded the recommended WHO limits. The authors, however opined that these rivers were sites for artisanal gold mining leading to contamination of the water bodies. Corroborating with the index study, Hashim et al. [35] reported varying concentrations of heavy metals (cadmium, lead) in tissues of fish species harvested from a river in Malaysia [35]. The authors observed that the heavy metal concentrations were elevated above the permissible limits set by WHO in these test samples. This further emphasizes the need for bioremediation of the waters that breed these sea creatures which serve as food and in some cases, local delicacies for residents in and around these communities.

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4. CONCLUSION

The local health authority should conduct regular assessments of locally consumed food crops and bodies and environmental waters in order to determine their heavy metal concentrations. Subsequently, prompt interventions should be instituted when recommended limits are exceeded in order to reduce the health risks associated with exposure to the heavy metals.

ETHICAL APPROVAL

Ethical approval was sought from the Ethics Committee of the University of Port Harcourt before the study commenced. Community entry into the study communities was done and permission to conduct the study was sought and obtained from the Chief and Heads of the communities.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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